ACTA TECHNICA

ACADEMIAE SCIENTIARUM HUNGARICAE

ADIUVANTIBUS

L. GILLEMOT, GY. HEVESI, K. P. KOVÁCS, I. RÁZSÓ, K. SZÉCHY, G. TARJÁN

REDIGIT

A. GELEJI

TOMUS XVIII FASCICULI 1—2

AKADÉMIAI KIADÓ BUDAPEST

1957

ACTA TECHN. HUNG.

ACTA TECHNICA

A MAGYAR TUDOMÁNYOS AKADÉMIA MŰSZAKI TUDOMÁNYOK OSZTÁLYÁNAK KÖZLEMÉNYEI

SZERKESZTŐSÉG ÉS KIADÓHIVATAL: BUDAPEST V. ALKOTMÁNY UTCA 21

Az Acta Technica német, angol, francia és orosz nyelven közöl értekezéseket a műszaki tudományok köréből.

Az Acta Technica változó terjedelmű füzetekben jelenik meg. Több füzet alkot egy kötetet. Évenként 2—3 kötet jelenik meg.

A közlésre szánt kéziratok, géppel írva, a következő címre küldendők :

Acta Technica, Budapest 62, Postafiók 440.

Ugyanerre a címre küldendő minden szerkesztőségi és kiadóhivatali levelezés.

Az Acta Technica előfizetési ára kötetenként belföldre 80, külföldre 110 Ft. Megrendelhető a belföld számára az Akadémiai Kiadónál (Budapest V. Alkotmány utca 21. Bankszámla 05-915-111-44), a külföld számára pedig a „Kultura" Könyv- és Hírlap Külkereskedelmi Vállalatnál (Budapest VI. Népköztársaság útja 21. Bankszámla: 43-790-057-181), vagy külföldi képviseleteinél és bizományosainál.

Die Acta Technica veröffentlichen Abhandlungen aus dem Bereiche der technischen Wissenschaften in deutscher, englischer, französischer und russischer Sprache.

Die Acta Technica erscheinen in Heften wechselnden Umfanges. Mehrere Hefte bilden einen Band.

Die zur Veröffentlichung bestimmten Manuskripte sind an folgende Adresse zu senden :

Acta Technica, Budapest 62, Postafiók 440.

An die gleiche Anschrift ist auch jede für die Schriftleitung und den Verlag bestimmte Korrespondenz zu richten.

Abonnementspreis pro Band: 110 Forint. Bestellbar bei dem Buch- und Zeitungs-Aussenhandels-Unternehmen »Kultura« (Budapest VI. Népköztársaság útja 21. Bankkonto Nr: 43-790-057-181) oder bei seinen Auslandsvertretungen und Kommissionären.

ACTA TECHNICA

Tomus XVIII

INDEX

ACTA TECHNICA

ACADEMIAE SCIENTIARUM HUNGARICAE

ADIUVANTIBUS

L. GILLEMOT, GY. HEVESI, K. P. KOVÁCS, I. RÁZSÓ, K. SZÉCHY, G. TARJÁN

REDIGIT

A. GELEJI

TOMUS XVIII

AKADÉMIAI KIADÓ BUDAPEST

1957

ACTA TECHN. HUNG.

THE DETERMINATION OF THE STRENGTH OF THE INTERATOMIC BOND AND THE LATTICE DISTORTION IN THE CASE OF SOME Al- OR Ti-CONTAINING COMPOUNDS OF HIGH MELTING POINT AND THEIR SOLID SOLUTIONS*

J. S. UMANSKIJ
MEMBER OF THE ACADEMY OF SCIENCES OF THE USSR

and

S. M. NIKOLAEVA
DOCTOR OF THE TECHNICAL SCIENCES

[Manuscript received October 10, 1955]

The strength of the interatomic bond in crystals is one of the most important factors, determining the resistance of metals and alloys to deformation and fracture, especially at high temperatures.

The resistance of solid solutions to plastic deformation depends at the same time largely upon the static distortion of the crystal lattice, originated as a result of the formation of these phases. The lattice distortion renders always more difficult the plastic deformation, on account of the rise in the hardness of the material.

The effect of the lattice distortion predominates in the majority of the alloys and the hardness of solid solutions — based on pure metals as well, as based on metallic compounds — is therefore almost without exceptions higher than that of the basic phase. To this fact it was already called attention by Kurnakow [1].

It is to be expected, however, that in all cases, when the formation of the solid solution gives rise to a profound reduction in the strength of the interatomic bond, this effect masks the influence of the lattice distortion and the hardness of the alloy will be correspondingly lower. This characteristic is to be expected in the case of the solid solutions of the very stable metallic compounds. In the work described an attempt is made to prove this assumption.

The strength of the interatomic bond may be described, as it is known, by the characteristic temperature, because the strength of the interatomic bond is directly related with the square of the characteristic temperature, as given by

$$f = m\,\Theta^2 \tag{1}$$

where : m — is the mass of the atom.

The determination of the characteristic temperature of brittle materials may be best effected by measuring the variations in the X-ray interferences, as

* Delivered at the International Congress of Light Metals, Budapest, September 28—30, 1955, arranged by the Hungarian Academy of Siences. — The text appeared in Hungarian in the Kohászati Lapok, **88** (1955), 530—533.

in these cases the measurement of the modulus of elasticity is connected with great experimental difficulties.

The purpose of the experiments herein described was :

1. the determination of the characteristic temperature of the metallic compounds, type NiAl (i. e. CoAl and NiAl) and TiC — compounds, which are very stable, brittle and have a high melting point — as well as solid solutions, based on the same compounds ;

2. comparison between the static and dynamic lattice distortion in solid solutions of substitutional type (for instance solutions of Co or Ni in CoAl, resp., NiAl) and in solid solutions of defective type (for instance solution of Al in CoAl or NiAl, resp., TiC, not saturated with C).

The alloys Co—Al, Ni—Al and Ti—C were chosen, besides of their great practical value, as bonding agents and basic phases of the high temperature alloys, because it was hoped, that in the case of these alloys it could be shown the variation of the bonding forces and the amount of the static lattice distortion with alteration in the type of the solid solution, by varying the concentration of the components, as well as the effect of both factors on the hardness of these compounds.

Two alloys of type Co—Al (containing 50, resp. 55 atomic per cent Co), three alloys of type Ni—Al (containing 45,5, 50, resp. 60 atomic per cent Ni) and two alloys of type Ti—C (30, resp., 50 atomic per cent C) were selected for investigation.

The alloys type Co—Al and Ni—Al were produced by sintering in a vacuum furnace type TVV-2, in vacuo, resp., under protecting inert atmosphere of argon.

The TiC of stoichiometric composition was produced by carburizing metallic titanium in vacuo.

The unsaturated Ti—C alloy was produced by chemical separation from cast titanium ingots, melted in graphite crucibles, under protective atmosphere of argon.

The characteristic temperatures of the above alloys were determined by the measurement of the relative intensities of X-ray interferences, at several temperatures. This method was already succesfully adopted to this purpose lately by G. V. Kurdumow, V. I. Iweronowa and their co-workers [2 and 3]. The X-ray micrographs were taken at three different temperatures : 110, 295 and 473° K, using Mo-radiation.

The specimens for the X-ray investigation were prepared by crushing the sintered briquettes in metallic mortars. The powders were thereafter annealed in vacuo, in sealed fused silica tubes, at a temperature of 750—900°C for 1 hour, to remove the residual stresses of P- and S- order, actually controlling the attenuation of the same stresses.

Each specimen was investigated at different temperatures, by taking 3 to 8 X-ray micrographs.

Each X-ray micrograph was evaluated visually, using a MF-4 type microphotometer.

The evaluation is based on the comparison of the relative intensities of the $(200)_a$ and $(510)_a$ lines in the micrographs of the Co—Al and Ni—Al alloys, resp., those of the $(400)_a$ and $(842)_a$ lines in the case of the Ti—C alloys.

The characteristic temperature is given by

$$\Psi(\Theta_1 T_1, T_2) = \frac{1}{\Theta}\left[\frac{\Phi\left(\frac{\Theta}{T_1}\right)}{\Theta/T_1} - \frac{\Phi\left(\frac{\Theta}{T_2}\right)}{\Theta/T_2}\right] = B \cdot \ln\frac{\gamma_1}{\gamma_2}, \qquad (2)$$

where :

$$B = \frac{m \cdot a^2 \cdot k}{3 \cdot h^2 (\Sigma l_2^2 - l_1^2)},$$

$\Phi\left(\frac{\Theta}{T}\right)$ — is the Debye-function,

γ_1 and γ_2 — are the relative intensities of one of the same pair of $(h_1 k_1 l_1)$ and $(h_2 k_2 l_2)$ lines at two different temperatures, T_1, resp., T_2,

m — is the reduced mass of the alloy,

h — is Planck's constant and

k — is Boltzmann's constant.

From these, γ_1 and γ_2 are determined by experiments.

The characteristic temperatures were obtained graphically, by plotting the calculated values of function Ψ (Θ, T_1, T_2).

The characteristic temperatures resulting from these experiments in two different temperature intervals (110—295 °K, resp. 295—473 °K) were conforming each other to a sufficient degree ; the final characteristic temperatures were selected therefore as the arithmetic mean of the Θ values of the two temperature intervals.

The interatomic bonding forces were computed for the alloys investigated as $m \cdot \Theta^2$.

Table 1 contains the characteristic temperatures and the $m \cdot \Theta^2$ values of the investigated alloys.

The mean square deviation of the atoms from their positions in equilibrium at a temperature of 110, 295, resp., 473 °K was computed from the formula

$$\bar{U}_d^2 = \frac{9 \cdot h^2}{4 \cdot \pi^2 \cdot m \cdot k \cdot \Theta}\left[\frac{\Phi\left(\frac{\Theta}{T}\right)}{\Theta/T} + \frac{1}{4}\right]. \qquad (3)$$

The difference $(\overline{U_1^2} - \overline{U_2^2})$, which characterizes the variation of the deviation of

Table 1

Alloy	Θ °K	m · Θ^2 · 10^{18} g · K²
Co — Al — 50	540	17,9
Co — Al — 55	480	14,7
Ni — Al — 45	420	10,5
Ni — Al — 50	500	15,6
Ni — Al — 60	450	13,4
Ti — C — 50	1130	40,7
Ti — C — 30	840	29,6

the atoms from their position in equilibrium, when going from a temperature T_1 to another temperature T_2, is given by

$$\bar{U}_1^2 - \bar{U}_2^2 = \frac{\ln \gamma_1/\gamma_2}{\frac{4}{3} \cdot \pi^2 \left(\frac{\Sigma l_2^2 - \Sigma l_1^2}{a^2} \right)}, \tag{4}$$

without the need for computing the characteristic temperature.

Table 2 shows the root-mean-square values $\sqrt{\bar{U}_d^2}$, computed for the temperatures 110, 295 and 473 °K ; the differences $(\bar{U}_1^2 - \bar{U}_2^2)$, computed for the temperature intervals 110—295 °K resp. 295—473 °K.

Table 2

Alloy	$(\bar{U}^2_{295} - \bar{U}^2_{110})$ Å²	$(\bar{U}^2_{473} - \bar{U}^2_{295})$ Å²	$(\sqrt{\bar{U}_d^2})_{110}$ Å	$(\sqrt{\bar{U}_d^2})_{295}$ Å	$(\sqrt{\bar{U}_d^2})_{473}$ Å	$(\sqrt{\bar{U}_{Szt}^2})$ Å	HV kg/mm²
Co — Al — 50	0,0058	0,0072	0,083	0,112	0,141	—	530
Co — Al — 55	0,0074	0,0089	0,089	0,125	0,155	—	470
Ni — Al — 45	0,0105	0,0118	0,097	0,141	0,176	0,099	400
Ni — Al — 52	0,0071	0,0079	0,085	0,122	0,151	—	520
Ni — Al — 60	0,0085	0,0097	0,091	0,150	0,162	0,077	370
Ti — C — 50	0,0018	0,0025	0,073	0,085	0,098	—	2850
Ti — C — 30	0,0029	0,0043	0,076	0,094	0,112	0,116	1950
Ni — Al — 50	—	—	—	—	—	—	540
Ni — Al — 55	—	—	—	—	—	—	440

The static lattice distortions of solid solutions were determined for the case of the compounds NiAl and TiC.

As a basis for comparison, i. e. alloys without any crystal lattice distortion were chosen the specimens of the compounds NiAl and TiC of stoichiometric composition.

As to exclude the influence of extinction on the intensity of the first lines of specimens of relatively large grain-size, the X-ray micrographs were taken with a reference material (Al).

The computations were made on the basis of comparison of the $(222)_\alpha$ lines of the Ni—Al alloys and the $(422)_\alpha$ line of the reference material, resp. the $(511)_\alpha$ line of TiC and the $(422)_\alpha$ line of the reference material, both for the alloys without or with lattice distortion.

The intensities obtained were corrected, considering the fact, that the intensity-factors for the different alloys investigated, having lattice distortion, were different from those of the alloys without lattice distortion.

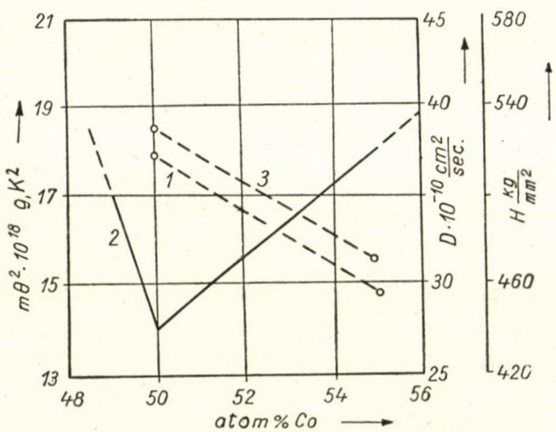


Fig. 1

The values of $\sqrt{\overline{U^2_{Szt}}}$ are also listed in Table 2.

The results of the X-ray investigation were compared with the micro-hardness values of the investigated alloys (see Table 2 ; the microhardness values of the Ti—C alloys with different carbon-content were taken from [4]).

The characteristic temperature of alloy Co—Al-50 — containing 50 atomic per cent Co — is higher, than that of an alloy, containing 55 atomic per cent Co : 540 resp. 480 °K. The characteristic temperature of an alloy Ni—Al, not differing much from the stoichiometric composition and containing 52 atomic per cent Ni, is higher, than that of both alloys in the Ni—Al system, which are near to the phase-boundaries of the single β-phase portion of the binary diagram : an alloy with the greatest Ni-content (60 atomic per cent Ni) and an alloy with the greatest Al-content (54,5 atomic per cent Al). The characteristic temperatures are in the given order as 500, 450 and 420 °K. The characteristic temperature of alloy Ti—C-50, containing 49 atomic per cent C is considerably higher than that of alloy Ti—C-30, containing about 32 atomic per cent C ; the values are 1130, resp., 840 °K.

The data obtained for the alteration of the characteristic temperature of solid solutions, as a function of concentration are in good agreement with the results [5], obtained for the coefficient of diffusion of Co in alloys of the system Co—Al (Fig. 1).

The calculated values of the mean square deviation of the atoms at three different temperatures show, that these deviations show a much steeper rise with the temperature for the alloys with a composition near the phase boundary, than for those near to the stoichiometric composition.

The calculated values of the static lattice distortion of the solid solutions of the compounds Ni—Al show, that the value for an alloy with an excess Al-content is greater, than that for an alloy with an excess Ni-content (0,099 Å, resp., 0,077 Å). Our results seem to conform with the assumption, that the lattice distortion in solid solutions of the defective type is much greater, than that of the substitutional solid solutions, on account of the vacancies of the defectuous structure.

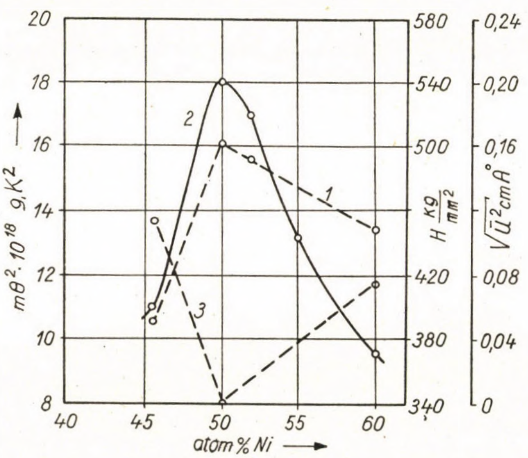


Fig. 2

The static lattice distortion of the unsaturated Ti—C alloy is very considerable (0,116 Å).

When plotting the microhardness against the composition of the Ni—Al alloys, one can find a maximum, corresponding to the alloy with 50 atomic per cent Ni (HV equals 540 kg/mm^2). The microhardness values of the other two alloys, having an excess Ni-content (60 atomic per cent Ni) or an excess Al-content (54,5 atomic per cent Al) are smaller, than that of the stoichiometric composition : 370, resp., 400 kg/mm^2. The microhardness value of the Co—Al alloy, containing 50 atomic per cent Co is greater, than that of the Co—Al alloy with an excess Co-content of 55 atomic per cent (530, resp., 470 kg/mm^2).

The microhardness value of the Ti—C alloys varies linearly with the C-content, as already shown by investigations of A. E. Kowalskij and T. G. Makarenko [4] and reaches its greatest value at the stoichiometric, i. e. ideal, TiC composition.

On the basis of the above results, one may deduct the following conclusions :

1. The solution of either nickel (or cobalt), or aluminium in the metallic compounds NiAl or CoAl results in decrease of the characteristic temperature (and as the consequence of it, in the reduction of the interatomic bonding forces), the increase of the static lattice distortion and the reduction of the microhardness of the alloys. These effects are more pronounced in the case of defective solid solutions, than in the case of the substitutional solid solutions (Fig. 1 and 2).

2. The interatomic bonding forces of the crystal lattice of TiC, containing about 50 atomic per cent C are very considerable. If the alloy is not saturated in respect to the C-content, this results in the decrease of the characteristic temperature (and as the consequence of it, in the reduction of interatomic bonding forces), the increase of the static lattice distortion and the reducrion of the microhardness of the alloys.

3. When comparing the trend in the *variation of the static lattice distortion and* the values of the *microhardness*, we find, that the chemical distortions *do not alter considerably* — at least in the case of the alloys herein investigated *the resistance to plastic deformation*, due to the fact, that the effect of the chemical distortions is to a great extent masked by the influence of the interatomic bonding forces.

4. When comparing the *microhardness* values of the alloys with an excess Al- or Ni-content, with the corresponding *static distortion values*, we may conclude, that the crystal lattice distortion of the defective solid solutions exerts a much greater effect on the microhardness value of the alloy, than the distortions resulting from the simple substitution of atoms in the crystal lattice of substitutional solid solutions.

REFERENCES

1. *Н. С. Курнаков:* Введение в физико-химический анализ, (An introduction to Physical-Chemical Analysis) ОНТИ, 1936 г.

2. *В. И. Иверонова, З. И. Кузьмина, С. И. Футергендлер, Е. И. Детлаф:* Известия АН СССР, серия физическая, (Bull. of the Ac. Sci. of USSR, Ser. Phys.) 15, 44, 1951.

3. *В. А. Ильина, В. К. Крицкая, Г. А. Курдюмов:* Проблемы металловедения и физики металлов. Второй сборник трудов. (Some problems of the metallography and physics of metals. Second compilation) Металлургиздат, 1951 г., стр. 222.

4. *А. Е. Ковальский* и *Т. Г. Макаренко:* Сборник «Микротвердость», (Symposium on "Microhardness") изд. АН СССР. Москва, 1951 г., стр. 187.

5. F. C. Nix, F. E. Jaumot: Physical Review, 83 (1951), 1275.

SUMMARY

The authors attempted the determination of the characteristic temperature of the very stable metallic compounds CoAl, NiAl and TiC, having a high melting point, as well as that of their solid solutions ; the comparison between the static and dynamic lattice distortion of substitutional and defective solid solutions. The characteristic temperatures of the above alloys were determined by the method of messuring the relative intensities of X-ray interferences at 110, 295 and 473 °K. The lattice distortion was determined by X-ray micrographs. The microhardness of the alloys was determined too.

The authors came to the following conclusions :

a) when comparing the trend in the variation of the static lattice distortion and the values of microhardness we find, that the chemical distortions do not alter considerably the resistance of the investigated alloys to plastic deformation, because this effect is to a great excent masked by the influence of the interatomic bonding force.

b) when comparing the microhardness values of the alloys with the static distortion values we find, that the lattice distortion of the defective solid solutions exerts a much greater effect on the microhardness of the alloy, than the distortions resulting from the simple substitution of atoms in a substitutional solid solution.

BESTIMMUNG DER BINDUNGSFESTIGKEIT ZWISCHEN DEN ATOMEN UND DER GITTERVERZERRUNG BEI EINIGEN Al- UND Ti-HALTIGEN METALLISCHEN VERBINDUNGEN MIT HOHEM SCHMELZPUNKT SOWIE IN DEREN FESTEN LÖSUNGEN

J. S. UMANSKI Mitglied der Akademie, und S. M. NIKOLAJEWA Doktor der techn. Wiss.

ZUSAMMENFASSUNG

Die Verfasser versuchen, die charakteristische Temperatur der sehr harten und einen hohen Schmelzpunkt aufweisenden metallischen CoAl-, NiAl- und TiC-Verbindungen und ihrer festen Lösungen zu bestimmen, indem sie diese mit der statischen und dynamischen Verzerrung des Kristallgitters der einfachen festen Substitituonslösungen sowie der festen Substitutionslösungen mit unbesetzten Kristallstellen vergleichen. Zur Bestimmung der charakteristischen Temperatur messen sie die relative Intensität der Röntgenstrahleninterferenz bei 110, 295 und 473° K. Die Verzerrung des Kristallgitters wird auf Grund von Röntgenaufnahmen ermittelt. Ausserdem untersuchen sie auch die Mikrohärte dieser Legierungen.

Auf Grund ihrer Untersuchungsergebnisse gelangen die Verfasser zu folgenden Feststellungen :

a) Beim Vergleich zwischen der statischen Gitterverzerrungen und dem Charakter der Veränderung der Mikrohärte ist zu sehen, dass die chemische Verzerrung in den untersuchten Legierungen nicht in gesteigertem Ausmass den Widerstand gegen die bildsame Formänderung erhöht, da diese Wirkung von der Wirkung der Bindung zwischen den Atomen stark überschattet wird.

b) Beim Vergleich zwischen der Mikrohärte der Legierungen und den statischen Gitterverzerrungen ist ersichtlich, dass die Gitterverzerrung der festen Substitutionslösungen mit unbesetzten Gitterstellen eine grössere Wirkung auf die Mikrohärte der Legierung ausübt als jene Verzerrung des Kristallgitters der einfachen festen Substitutionslösungen, die infolge des Atomaustausches entsteht.

DÉTERMINATION DE LA FERMETÉ DES LIENS INTERATOMIQUES ET DE LA DÉFORMATION DU RÉSEAU DANS QUELQUES COMPOSÉS D'ALUMINIUM ET DE TITANE ET LEURS SOLUTIONS SOLIDES

J. S. UMANSKI membre de l'Académie, et S. M. NIKOLAYEVA, docteur des sc. techn.

L'étude se propose de déterminer la température caractéristique des composés métalliques de CoAl, NiAl et TiC très durs et d'un point de fusion élevé, et de leurs solutions solides, en comparaison avec la déformation statique et dynamique du réseau cristallin des solutions solides de substitution simple ou d'une substitution avec des points de réseau non saturés. Pour la détermination de la température caractéristique, la méthode de mesure de l'intensité relative de l'interférence de rayons *x* a été appliquée avec mesurage à 110, 295 et 473 °K. La déformation du réseau cristallin à été déterminée à la base de radiogrammes. La micro-dureté des alliages a aussi été déterminée.

Les recherches ont abouti aux constatations suivantes :

a) La comparaison entre la variation des déformations statiques du réseau et la micro-dureté, démontre que dans les alliages étudiés, la déformation chimique n'augmente pas, dans une grande mesure, la résistance à la déformation plastique, cet effet étant fortement couvert par l'influence des liens interatomiques.

b) La comparaison entre la micro-dureté des alliages et les déformations statiques du réseau démontre que la déformaticn du réseau de solutions solides aux points de réseau non saturés a une plus grande influence sur la micro-dureté, que n'en a la déformation du réseau cristallin des solutions de substitution simple causée par l'échange d'atomes.

ОПРЕДЕЛЕНИЕ ПРОЧНОСТИ МЕЖАТОМНОЙ СВЯЗИ И ИСКАЖЕНИЙ РЕШЕТКИ В НЕКОТОРЫХ ТУГОПЛАВКИХ СОЕДИНЕНИЯХ ЛЕГКИХ МЕТАЛЛОВ И ТВЕРДЫХ РАСТВОРАХ НА ИХ ОСНОВЕ

Академик Я. С. УМАНСКИЙ и д-р техн. наук С. М. НИКОЛАЕВА

РЕЗЮМЕ

Авторы ставили своей целью определение характеристической температуры высокопрочных хрупких тугоплавких металлических соединений CoAl, FiAl и TiC и твердых растворов на их основе, а также сравнительная оценка величин статических и динамических искажений в кристаллической решетке этих твердых растворов, образующихся по типу замещения и по типу вычитания. Для определения характеристических температур применялся метод измерения относительных интенсивностей рентгеновских интерференций при разных температурах : 110, 295 и 473 °K. Величина искажений в кристаллических решетках определялась на базе рентгенографического исследования. Определили также микротвердость изученных фаз.

Авторы сделали следующие выводы на основании полученных результатов :

а) Из сопоставления характера изменения статических искажений и величин микротвердости можно заключить, что химические искажения в случае исследуемых сплавов не могут сильно увеличить сопротивление пластической деформации, поскольку влияние химических искажений резко перекрывается влиянием межатомных связей.

б) Из уравнения величин микротвердости сплавов с величиной статических искажений можно заключить, что искажения кристаллической решетки в твердом растворе вычитания, оказывают большее влияние на величину микротвердости сплава, чем искажения, обусловленные замещением атомов в кристаллической решетке твердого раствора замещения.

NOMOGRAPHIC SOLUTION OF WEIGHT AND ATOMIC (MOL) RATIOS IN MULTICOMPONENT SYSTEMS

F. BÁRTFAI and A. BALOGH
HARD METALS INDUSTRY ENTERPRISE, BUDAPEST

[Manuscript received May 3, 1956]

Several papers have dealt with the nomographic solution of weight and atomic (mol) ratios [1, 2, 3]. One of the co-authors of this paper [4] first presented a solution for trinary systems ; later he elaborated the same method for binary systems, too [5].

Some difficulty was caused in the method to be presented in this paper thereby that the scales had to be drawn in advance for a given system.

The solution presented in this paper is a general one (suitable for n-component systems), and its nomogram scale does not depend on the (n-component system) chosen.

The theoretical explanation is presented first for a trinary system.

Notations used : X_i $(i = 1, 2, 3)$ = weight% ; a_i $(i = 1,2,3)$ atomic (mol) weight and ξ $(i = 1, 2, 3)$ atomic (mol)%.

We may write for instance :

$$\xi_3 = \frac{\dfrac{x_3}{a_3}}{\dfrac{x_1}{a_1} + \dfrac{x_2}{a_2} + \dfrac{x_3}{a_3}} = \frac{1}{\dfrac{\dfrac{x_1}{a_1} + \dfrac{x_2}{a_2}}{\dfrac{x_3}{a_3}} + 1} .$$

From this follows by minor transformation

$$\frac{\dfrac{x_1}{a_1} + \dfrac{x_2}{a_2}}{\dfrac{x_3}{a_3}} = \left(\frac{1}{\xi_3} - 1\right) = f(\xi_3) \qquad (1)$$

If atomic (mol) per cents are known, we may write :

$$x_3 = \frac{a_3\,\xi_3}{a_1\,\xi_1 + a_2\,\xi_2 + a_3\,\xi_3} = \frac{1}{\dfrac{a_1\,\xi_1 + a_2\,\xi_2}{a_3\,\xi_3} + 1}$$

whence

$$\frac{a_1 \xi_1 + a_2 \xi_2}{a_3 \xi_3} = \left(\frac{1}{x_3} - 1\right) = f(x_3) \tag{2}$$

This is essentially the relation satisfying equation (1).

For the solution of the alignment chart (nomogram) some straight lines are required, namely

$$y—x = 0, \quad y—x—b = 0, \quad y + 1 = 0 \quad \text{and} \quad x + y—5\sqrt{2} = 0.$$

These are drawn in Fig. 1 separately to facilitate the illustration of the functioning of the chart by referring to it later.

From Fig. 2 the solution of equation (1) can now be read off. That is to say

$$O\,A^{I} = x_1 \qquad A\,B = 1/a_1$$
$$O\,A^{II} = x_2 \qquad A\,C = 1/a_2$$
$$O\,A^{III} = x_3 \qquad A\,D = 1/a_3$$
$$O\,A = 1$$

On the basis of similar triangles, however

$$A^{I}\;B^{I} = x_1/a_1$$
$$A^{II}\;C^{I} = x_2/a_2$$
$$\text{and} \quad A^{III}\,D^{I} = x_3/a_3$$

$A^{I}B^{I} = O\,B^{II} = B^{IV}\,B^{III}$ after projection on the angle bisector, from this follows that the equation of the line passing through points $B^{IV}\,c^{III}$

$$y - x - \frac{x_I}{a_I} = 0 \tag{3}$$

(namely the general equation of the line is $y = mx + b$, considering that our straight line is parallel to the angle bisector, $y = mx + b$ thus $m = 1$, and $b = OB^{IV} = A^{I}\,B^{I} = x_1/a_1$.) Since $A^{II}\,C^{I} = OC^{II}\,\frac{x_2}{a_2}$, these values of x substituted into equation (3) and this solved for y, we have :

$$y = c^{II}\,c^{III} = x + \frac{x_1}{a_1} = \frac{x_2}{a_2} + \frac{x_3}{a_3} \tag{4}$$

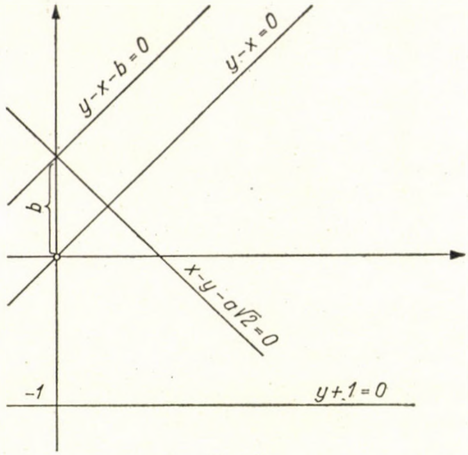


Fig. 1

Further $\frac{x_3}{a_3} = A^{III} D^{I} = OD^{II}$ and since $c^{II} c^{III} = D^{II} D^{IV}$ from this follows that

$$\operatorname{tg}(C^{IV} O D^{II}) = \frac{c^{IV} D^{II}}{OD^{II}} = \frac{c^{II} c^{III}}{OD^{II}} = \frac{\frac{x_1}{a_1} + \frac{x_2}{a_2}}{x_3/a_3} ,$$

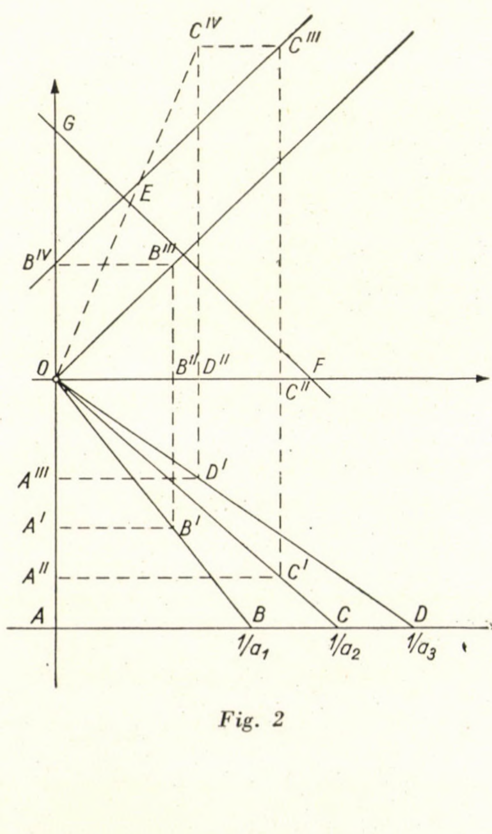


Fig. 2

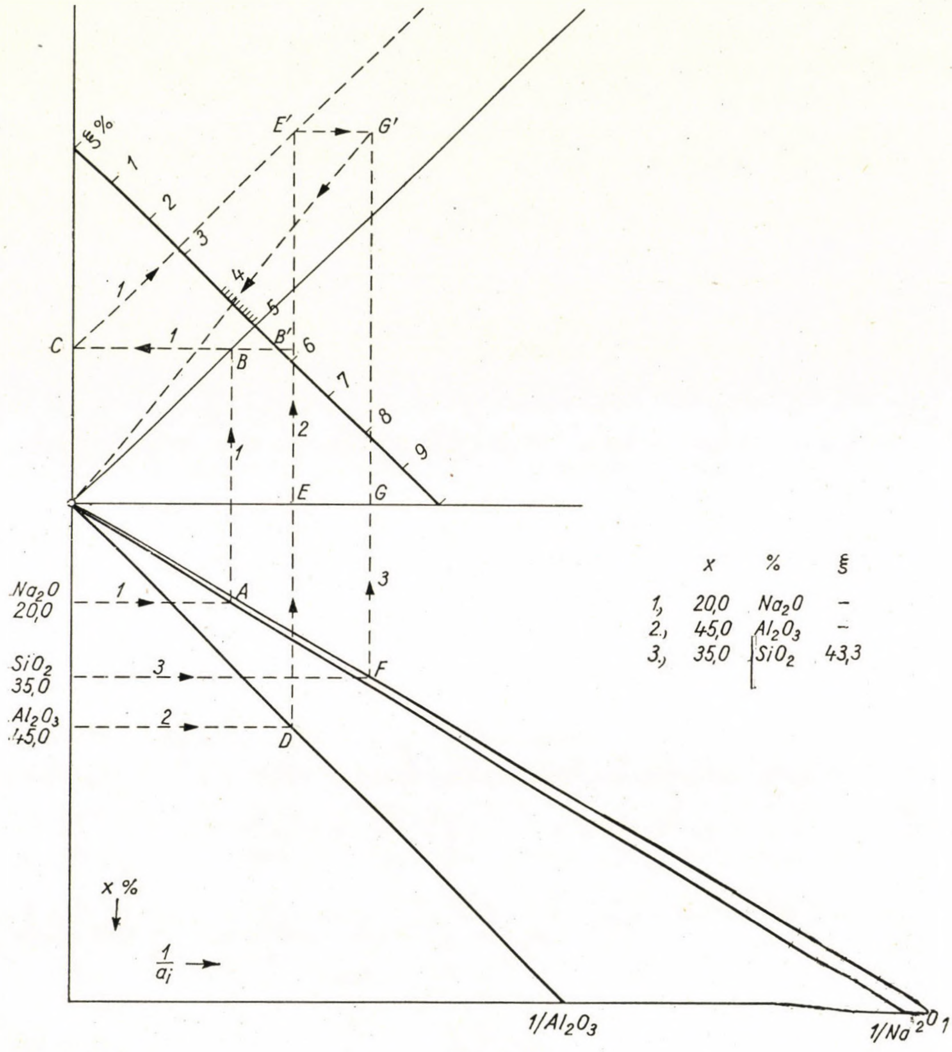


Fig. 3

Therewith the left side of equation (1) has been established as a tg function. The set of values of the tg function are identical to that of $f(\xi_3)$. Therefore the values of the independent variable ξ_3 can be written in advance. In Fig. 2 this has been solved by using the portion $G\ F$ between the axes of straight line $x + y - a = 0$, perpendicular to the angle bisector, as scale ξ_3. Since the same scale will be applied in the entire nomogram the value of "a" has been taken for $5\sqrt{2}$.

Examples:

a) Let the trinary system be 20% Na_2O, 45% Al_2O_3 and 35% SiO_2. The mol % of SiO_2 is sought. The solution can be read off from Fig. 3.

b) As an example for equation (2) the following composition is chosen: 23,9% Na_2O, 32,8% Al_2O_3 and 43,3% SiO_2. The weight % of SiO_2 is sought.

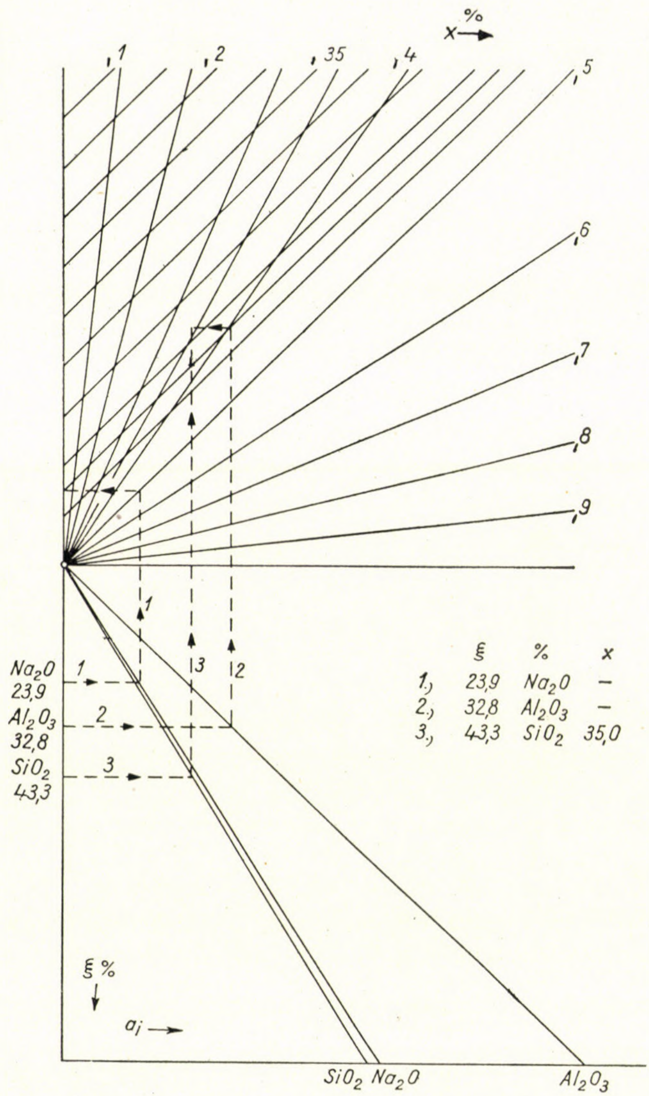


Fig. 4

The solution can be read off from Fig. 4. A divergence from the previous example subsists not only in values laid off on line $y + 1 = 0$ (a_i and not $1/a_i$!!!) but also in that instead of the line $x + y = 5\sqrt{2} = 0$ a system of a bunch of rays has been applied for reading off x_3.

Supplement and generalization

The solution of equations (1) and (2) has been attained by the so-called double chart. Since the values of equations (1) and (2) do not change if on their left sides numerators and denominators are multiplied by the same number, therefore the scale laid off on line $y + 1 = 0$ is arbitrary.

In Fig. 3 the factor of scale ξ can be varied with the choice of "a" (in the fig. $a = 5\sqrt{2}$). For instance taking $a = 10\sqrt{2}$ the scale will be double of that shown in the figure.

In the solution of Fig. 3 scales have to be laid off only on lines $y + 1 = 0$, $-y$ and $x + y - 5\sqrt{2} = 0$ and, for instance, the scale factor may be chosen equal for all three.

The advantage of the solution is that all scales are linear.

The procedure can be applied to any binary, trinary or n-component system (elements, oxides, compounds). (To any n-class combination :) Namely equation 1 can be written in the following general form :

$$\frac{\sum_{i=1}^{n-1} \frac{x_i}{a_i}}{\frac{x_n}{a_n}} = \left(\frac{1}{\xi_n} - 1\right)$$

That is, it holds for a binary system of $n = 2$, but, e. g. for alniko, too ($n = 6$).

The authors gratefully acknowledge the helpful criticism of Prof. Dr. B. LÁNYI and of Prof. Dr. J. MIKA relative to this paper.

REFERENCES

1. A. OELANDER : Graphical Method for Converting for Atomic Per Cent into Weight Per Cent. Ind. Eng. Chem. Anal. Edit. 4, (438) (1932).
2. F. E. WITTIG : Über die Umrechnung von Molprozenten in Gewichtsprozente. Z. Metallkunde 41, 395 (1950).
3. H. D. BAEHR : Ein Nomogramm zur Umrechnung von Gewichts- und Molprozenten. Chem. Ing. Technik 676—677 (1953).
4. F. BÁRTFAI : Nomogram of the Weight and Mol (Atomic) Per Cent Ratios of Trinary Systems. (Hungarian), Kohászati Lapok (Journal for Metallurgy), 227—229 (1955).
5. F. BÁRTFAI : Nomogram of the Weight and Mol (Atomic) Per Cent Ratios of Binary Systems, (Hungarian), Kohászati Lapok (Journal for Metallurgy), 173 (1956).

SUMMARY

The known nomographic solution of weight and mol (atomic) per cent ratios of binary systems has been extended by one of the authors to trinary systems, too. The generalization of the solution for n-component systems with linear scales is presented on the basis of simple geometric relationships, such as similitude of triangles, projection on the angle bisector. Nomographically the solution holds for the following type of equation:

$$\frac{1}{a_n x_n} \sum_{i=1}^{n-1} a_i x_i = \left(\frac{1}{\xi_n} - 1 \right)$$

From advantages of the double-member chart are pointed out: scales are linear, precision of reading can be boosted, common scale factor can also be used.

NOMOGRAPHISCHE DARSTELLUNG DES ZUSAMMENHANGES ZWISCHEN GEWICHTS- UND MOLPROZENTEN IN MEHRSTOFF-SYSTEMEN

F. BÁRTFAI und A. BALOGH

ZUSAMMENFASSUNG

Die für den Zusammenhang zwischen Gewichts- und Molprozenten von binären Systemen bekannte nomographische Darstellung wurde durch einen der Verfasser auch auf ternäre Systeme ausgedehnt. In der vorliegenden Arbeit wird die Verallgemeinerung der Lösung auf Systeme mit n Komponenten im linearen Massstab, auf Grund von einfachen geometrischen Beziehungen — Eigenschaften ähnlicher Dreiecke, Projektion an der Winkelhalbierenden — erörtert. Nomographisch hat die Lösung für folgenden Gleichungstyp Gültigkeit:

$$\frac{1}{a_n x_n} \sum_{i=1}^{n-1} a_i x_i = \left(\frac{1}{\xi_n} - 1 \right)$$

Von den Vorteilen der Lösung durch Doppeltafeln sei hervorgehoben: die Skalen sind linear, ihre Ablesungsgenauigkeit kann erhöht werden, und es lassen sich auch Skalen mit dem gleichen Massstab verwenden.

SOLUTION NOMOGRAPHIQUE DES RELATIONS DE POURCENTAGES PONDÉRAUX ET MOLÉCULAIRES EN SYSTÈMES À PLUSIEURS CONSTITUANTS

F. BÁRTFAI et A. BALOGH

RÉSUMÉ

La solution nomographique des relations de pourcentages pondéraux et moléculaires des systèmes binaires a été étendue par l'un des auteurs aux systèmes ternaires. L'étude traite de la généralisation de la solution pour les systèmes à n constituants, aux échelles linéaires, à la base de relations géométriques simples — similitude de triangles, projection sur la bisectrice angulaire. Dans le graphique, la solution est valable pour le type d'équation suivant :

$$\frac{1}{a_n x_n} \sum_{i=1}^{n-1} a_i x_1 = \left(\frac{1}{\xi_n} - 1 \right)$$

Des avantages de la solution au double-graphique mentionnons que les échelles sont linéaires, la précision de la lecture peut être augmentée et des échelles de proportions identiques peuvent être utilisées.

НОМОГРАФИЧЕСКОЕ РЕШЕНИЕ ВЕСОВОЙ И АТОМНОЙ (МОЛЯРНОЙ) ПРОЦЕНТНОЙ ЗАВИСИМОСТИ В СЛУЧАЕ МНОГОКОМПОНЕНТНЫХ СИСТЕМ

Ф. БАРТФАИ и А. БАЛОГ

РЕЗЮМЕ

Номографическое решение, известное для весовой и молярной процентной зависимости двухкомпонентных систем, распространено одним из авторов также на трехкомпонентные системы. Обобщение решения для н-компонентных систем трактуется линейными шкалами, на основе простых геометрических зависимостей — свойств подобных треугольников, зеркальное отображение на биссектрисе. Номографически решение действительно для следующего вида уравнений:

$$\frac{1}{a_n x_n} \sum_{i=1}^{n-1} a_i x_i = \left(\frac{1}{\xi_n} - 1\right)$$

Среди положительных сторон решения следует подчеркнуть: линейность шкал, возможность повышения точности их отсчета; можно использовать также шкалы с общим масштабом.

BEITRÄGE ZUR BERECHNUNG DER ZULÄSSIGEN BODENPRESSUNG UND DER UNTER DEN GRÜNDUNGSKÖRPERN AUFTRETENDEN SPANNUNGEN

L. VARGA
LEHRSTUHL FÜR BODENMECHANIK, TIEF- UND ERDBAU, BAU- UND VERKEHRSTECHNISCHE UNIVERSITÄT, BUDAPEST

[Eingegangen am 11. Mai 1956]

I. Über die zufolge der Vergrösserung der plastischen Bereiche zulässige Bodenpressung

Der Zweck dieser kurzen Studie ist zu beweisen, dass die auf Grund der Vergrösserung der plastischen Bereiche aufgestellten Theorien der zulässigen Bodenpressung auf einem einzigen Grundprinzip beruhen; es gibt nur eine einzige Grundformel und die Formeln der jeweiligen Verfasser unterscheiden sich nur insofern voneinander, dass jeder die eine darin vorkommende Grösse subjektiv bis zu einem gewissen Grad anders bewertet.

Was die sog. FRÖHLICH-, MASSLOW- und JAROPOLSKIJschen Formeln anlangt, so kann obiges — der gleichen Ausgangsbedingen wegen — direkt eingesehen werden, obgleich die allgemein bekannte Form der FRÖHLICHschen Formel die nahe Verwandtschaft mit den beiden anderen bis zu einem gewissen Grad verdeckt. Dazu im Gegensatz hält man die JÁKYsche Formel für eine andere Theorie, was in der von den anderen abweichenden langwierigen Ableitung und der sich unterscheidenden, andersgestalteten Art der Aufstellung begründet ist. Die gewohnte Form deckt auch einen Widerspruch der JÁKYschen Theorie, auf den noch an geeigneter Stelle hingewiesen werden wird.

Es ist bekannt, dass mit der Erhöhung der Bodenbelastung von den Eckpunkten des Gründungskörpers sog. *Bruchzonen ausgehen* (siehe Abb. 1), auf Grund deren Ausbreitung die für den Boden zulässige Spannung festgestellt werden kann. Hier auf die im allgemeinen bekannte Ableitung detailliert einzugehen ist überflüssig, lediglich erinnernd sei sie skizziert.

Stellt man die Spannungen mit Hilfe des MOHRschen Kreises dar, so können daraus die Bedingungen der plastischen Deformation durch die Gleichung

$$\sin\varphi = \frac{\sigma_1 - \sigma_2}{\sigma_1 + \sigma_2} \tag{1}$$

abgeleitet werden.

φ = der innere Reibungswinkel des Bodens,

$\sigma_{1,2}$ = die am untersuchten Punkt wirkende erste und zweite Hauptspannung (Abb. 2).

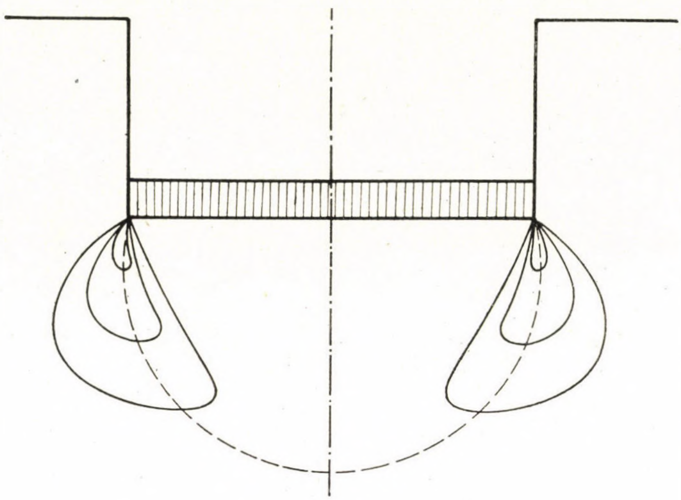


Abb. 1

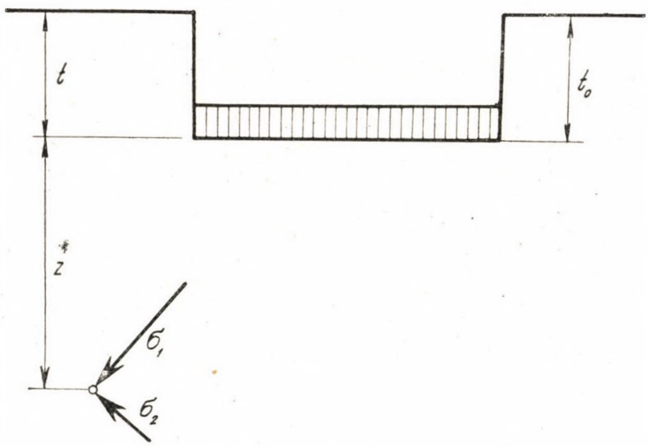


Abb. 2

Wird bei Voraussetzung gleichmässiger Kontaktdruckverteilung der Wert dieser Hauptspannungen aus dem bekannten MICHELLschen Zusammenhang berechnet, wird ferner die Entlastungswirkung der Erdverdrängung berücksichtigt und werden die Spannungen des Eigengewichtes als hydrostatische Lösung aufgefasst, so wird

$$\sigma_1 = \frac{q - t_0 \gamma}{\pi} (2 \varepsilon + \sin 2 \varepsilon) + (z + t) \gamma \tag{2}$$

$$\sigma_2 = \frac{q - t_0 \gamma}{\pi} (2\,\varepsilon - \sin 2\,\varepsilon) + (z + t)\,\gamma\,, \tag{3}$$

wo natürlich

$$t \equiv t_0\,. \tag{4}$$

Die Kohäsion kann so berücksichtigt werden, dass man die Gründungstiefe durch einen fiktiven Wert einsetzt. Dieser Wert* ist :

$$H = t + \frac{c}{\gamma \operatorname{tg} \varphi}\,. \tag{5}$$

Werden die Werte von (2), (3) und (5) in den Zusammenhang (1) eingesetzt, so bekommt man die Gleichung für die Grenzlinien der plastischen Zone

$$Z = \frac{q - t_0 \gamma}{\pi \gamma} \left[\frac{\sin 2\,\varepsilon}{\sin \varphi} - 2\,\varepsilon \right] - t - \frac{c}{\gamma \operatorname{tg} \varphi} \tag{6}$$

d. h. bei gegebener Belastung und gegebenen bodenphysikalischen Kennwerten ist $z = f(\varepsilon)$. Der tiefste Punkt der plastischen Zone ist dort, wo

$$\frac{dz}{d\varepsilon} = \frac{q - t_0 \gamma}{\pi \gamma} \left[\frac{2 \cos 2\,\varepsilon}{\sin \varphi} - 2 \right] = 0 \tag{7}$$

wobei sich $2\,\varepsilon = 90^\circ - \varphi$
ergibt. Die Punkte $Z_{\max}$ liegen also auf einem Kreis, bei dem

$$2\,\varepsilon = 90^\circ - \varphi$$

ist.

Wird das Ergebnis von (7) in den Zusammenhang (6) eingesetzt und geordnet, so bekommt man schliesslich

$$q = \frac{\pi \gamma \left[Z_{\max} + t + \dfrac{c}{\gamma \operatorname{tg} \varphi} \right]}{\operatorname{cotg} \varphi - \dfrac{\pi}{2} + \varphi} + t_0 \gamma. \tag{8}$$

Dieses ist die Grundgleichung, die die Basis *jeder* weiteren Formel ist.

* siehe *Kézdi :* Bodenmechanik I. Seite 526.

Nach FRÖHLICH darf die zulässige Bodenpressung nur so gross sein, dass in keinem Punkt des Bodens plastische Deformation entsteht, d. h. also $Z_{\max} = 0$. Die von ihm angegebene Formel lautet :

$$q = \gamma t \frac{\operatorname{cotg}\varphi + \varphi + \pi/2}{\operatorname{cotg}\varphi + \varphi - \pi/2} + C \operatorname{cotg}\varphi \left[\frac{\operatorname{cotg}\varphi + \varphi - \pi/2}{\operatorname{cotg}\varphi + \varphi - \pi/2} - 1 \right]. \tag{9}$$

Schreibt man im Zähler des ersten Gliedes für den Wert $+ \pi/2 = \pi - \pi/2$ und bringt man sämtliche Glieder auf einen gemeinsamen Nenner, so bekommt obige Formel nach einigen Änderungen folgende Form :

$$q = \frac{\pi\,[t\gamma + C \cdot \operatorname{cotg}\varphi]}{\operatorname{cotg}\varphi + \varphi - \pi/2} + t_0\gamma\,. \tag{10}$$

Übrigens bekommt man dieses Ergebnis direkt aus der Formel (8), wenn man $Z_{\max} = 0$ einsetzt. MASSLOW hält die Pressung für zulässig, bei der sich die Bruchzone noch nicht bis unter den Gründungskörper erstreckt (die Bodenmenge unter dem Fundament befindet sich also noch im Zustand elastischer Formveränderung). Nach ihm soll also der Punkt $Z_{\max}$ senkrecht unter den Kanten des Gründungskörpers liegen. Dieses veranschaulicht die linke Seite der *Abb. 3*. Die Formel lautet also :

$$q = \frac{\pi\,[2\,b\gamma \operatorname{tg}\varphi + t\gamma + C \cdot \operatorname{cotg}\varphi]}{\operatorname{cotg}\varphi + \varphi - \pi/2} + t_0\gamma\,. \tag{11}$$

Nach JAROPOLSKIJ ist es dagegen zulässig, wenn die Bruchzonen unter dem Gründungskörper sich gerade berühren (Abb. 3. rechte Seite). Somit ist

$$q = \frac{\pi\left[2\,b\gamma \dfrac{\operatorname{tg}(45^\circ + \varphi_2)}{2} + t\gamma + C \cdot \operatorname{cotg}\varphi\right]}{\operatorname{cotg}\varphi + \varphi - \pi/2} + t_0\gamma\,. \tag{12}$$

Die grosse Ähnlichkeit der Formeln (10), (11) und (12) ist augenfällig. Interessant ist zu beachten, dass obwohl sich in der Jaropolskijschen Formel nur das eine Glied ändert, es in dem hier skizzierten Fall auf einen doppelten Wert angewachsen ist ; dieser Unterschied hat immerhin eine derartig schnelle Zunahme der Bruchzone zur Folge, dass bei der Anwendung dieser Theorie die grösste Vorsicht geboten ist.

Verfasser bemerkt, dass die sog. SCHELJAPINsche Formel keine neue Voraussetzung sondern nur eine neue Bezeichnung beinhaltet. Nach Einsetzen der entsprechenden Werte kann seine Formel auf die unter (12) angegebene zurückgeführt werden.

JÁKY geht bei der Ableitung seiner Formel ebenfalls von den Formeln (2) und (3) aus, er *vernachlässigt aber die Wirkung der Eigengewichtsspannungen* bzw. die zweiten Glieder der Ausgangsformeln bleiben weg.

Wie bekannt, leitet er folgendes Ergebnis ab :

$$q = \frac{\pi}{2} \cdot \frac{1 - \sin\varphi}{\cos\varphi - \left(\frac{\pi}{2} - \varphi\right)\sin\varphi} \sigma_{ny} + t_0 \gamma . \tag{13}$$

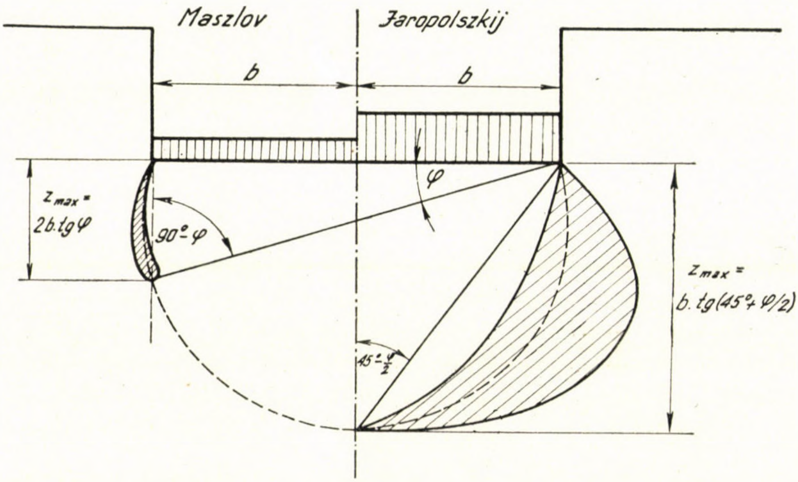


Abb. 3

Man setze hier folgende Elementarzusammenhänge ein :

$$\sigma_{ny} = 2 \cdot c \cdot \text{tg}\,(45° + \varphi/_2)$$

und

$$\text{tg}\,(45° + \varphi/_2) = \frac{\cos\varphi}{1 - \sin\varphi}$$

so ist

$$q = \frac{\pi}{2} \cdot \frac{(1 - \sin\varphi)\, 2 \cdot C \cdot \dfrac{\cos\varphi}{1 - \sin\varphi}}{\cos\varphi - \left(\frac{\pi}{2} - \varphi\right)\sin\varphi} + t_0 \gamma .$$

Werden Zähler und Nenner obigen Bruches durch sin φ geteilt und vereinfacht man, so ergibt sich folgendes Endresultat

$$q = \frac{\pi \cdot C \cdot \text{cotg}\,\varphi}{\text{cotg}\,\varphi + \varphi - \pi/_2} + t_0 \gamma . \tag{14}$$

Man sieht also, die JÁKYsche Formel nimmt die gleiche Form an, wie die anderen. Eigentlich entspricht obiger Ausdruck dem unter (10) angegebenen, jedoch führt Jáky nicht nur stillschweigend die Bedingung $Z_{max} = 0$ ein, sondern wie schon erwähnt, vernachlässigt er auch die Eigengewichtsspannungen, weshalb im Zähler der Formel (14) das Glied $t \cdot \gamma$ fehlt. Dies ist aber ein Widerspruch, weil so einerseits $t = 0$ ist, andererseits jedoch mit der Bedingung $t_0 \neq 0$ gearbeitet wird, während die Gleichheit (4) schon eine selbstverständliche Forderung bedingt.

Damit hat der Verfasser die in der Einleitung aufgestellte Behauptung bewiesen.

Es muss noch erwähnt werden, dass die Jákysche Formel übertrieben vorsichtige Bedingungen stellt, was zu unwirtschaftlichen Messungen führt, besonders dann, wenn man in die Formel (13) den von ihm vorgeschlagenen Wert σ_{ny}^{a} einsetzt, der nur einen Bruchteil der Druckfestigkeit ausmacht. Für die Praxis ist die Formel (11), deren Umfangsbedingungen noch mit realer Bestimmtheit festgestellt sind, am besten zu gebrauchen.

Schliesslich sei noch auf die Parallele verwiesen, die zwischen der Entwicklung der für kohäsionslose Böden abgeleiteten Bruchtheorie und der für bindige Böden abgeleiteten Formveränderungstheorie besteht. Von der nur einen Faktor berücksichtigenden Rankineformel ausgehend über die Prandtlsche Theorie bis zu den die Wirkungen der Breite in Betracht ziehenden neuesten Ergebnissen ist eine ähnliche Entwicklung zu bemerken wie beim Vergleich der Formeln (14), (10) und (11). Es ist deshalb nicht unbegründet, dass die neuesten ungarischen Vorschriften gleicherweise erlauben, die Wirkung der Breite in Betracht zu ziehen. Bei gewissem vorteilhaftem Bodenzustand ist dies unbedingt zulässig, wie das auch die neuesten ungarischen Grundbauvorschriften vorsehen.

ZUSAMMENFASSUNG

Die auf der Ausdehnung der Zone plastischer Deformation beruhenden Theorien können nach den Ergebnissen dieser Studie auf eine gemeinsame Basis zurückgeführt werden [Zusammenhang (8)]. Der im Schrifttum als JÁKYsche Formel bekannte und auf Grund anderer Voraussetzungen abgeleitete Zusammenhang [Formel (13)] ist auch nur eine Variante dieses allgemeinen Zusammenhanges, birgt aber einen inneren Widerspruch in sich. Die sogen. SCHELJAPIN-formel führt keine neuen Bedingungen ein und sie kann nach Abstimmen der entsprechenden Bezeichnungen auf den Zusammenhang (12) zurückgeführt werden.

Der Verfasser verweist darauf, dass in den zur Berechnung der Belastung von Kohäsionsböden dienenden Formeln die Abmessung b, also die Breite des Gründungskörpers eine Rolle spielt. Dieser günstige Effekt wird auch schon von den neuesten ungarischen Vorschriften berücksichtigt.

CONTRIBUTIONS TO THE COMPUTATION OF THE PERMISSIBLE SOIL PRESSURE AND OF STRESSES ARISING UNDER FOUNDATIONS

I. THE THEORIES BASED ON THE EXTENSION OF THE DOMAIN OF PLASTIC DEFORMATION

L. VARGA

SUMMARY

The theories based on the extension of the domain of plastic deformation can be traced back, according to evidence produced in the paper, to a common basis (Relation 8). The formula known in literature under *Jáky*'s name, deduced on the basis of other suppositions, (Formula 13) is also only a variant of this general relationship, but it includes a hidden inner contradiction. The so-called *Shelyapin* formula does not introduce a new supposition, after tuning together the corresponding notations it can be brought back to the relation under 12.

The paper demonstrates that in formulas serving for the calculation of the bearing capacity of solid soils too, the dimension *b*, or the width of the foundation body has been assigned a part. This favourable effect has already been taken account of by the most recent Hung. Code.

CONTRIBUTION AU CALCUL DES PRESSIONS ADMISSIBLES SUR LES SOLS ET DES TENSIONS SE PRODUISANT SOUS LES MASSIFS DE FONDATION

I. LES THEORIES BASÉES SUR L'ÉLARGISSEMENT DE LA ZONE DE LA DÉFORMATION PLASTIQUE

L. VARGA

RESUMÉ

Les différentes théories de déformation — plus exactement les théories basées sur l'élargissement de la zone de la déformation plastique — peuvent être ramenées selon cette étude sur une base commune (formule 8). La relation (13), connue dans la littérature comme formule de *Jáky* et qui repose sur d'autres hypothèses connues, n'est également qu'une variante de cette relation générale, mais elle recèle une contradiction interne. La formule dite de *Scheliapine* n'introduit pas de nouvelles conditions et peut, après établissement des notations correspondantes, être ramenée à la relation (12).

L'auteur signale que dans les formules servant au calcul de la capacité de charge des sols de cohésion, la dimension *b*, c'est à dire la largeur du massif de fondation a également obtenu un rôle. Cette effet favorable a été déja prise en considération par les nouvelles Règles Hongroises.

К РАСЧЕТУ ДОПУСКАЕМЫХ НАГРУЗОК ГРУНТОВ И ВОЗНИКАЮЩИХ ПОД ОСНОВАНИЯМИ НАПРЯЖЕНИЙ

I. О ТЕОРИИ ДЕФОРМАЦИИ

Л. ВАРГА

РЕЗЮМЕ

Различные теории деформации — или точнее: теории, основывающиеся на распространении диапазона пластичных деформаций — согласно результатам работы можно свести к идентичной общей основе (зависимость 8). Также зависимость (формула 13), выведенная на основе других предположений и известная в литературе в качестве формулы Яки, представляет собою только один из вариантов общей зависимости, однако имеет скрытое внутреннее противоречие. Так называемая формула Шельяпина не вводит новое предположение и после согласования соответствующих обозначений может быть сведена к зависимости 12.

Автор указывает, что и в формулах, служащих для вычисления устойчивости под нагрузкой кохезионных грунтов, определенную роль играет размер *в*, т. е. ширина основания. Этот благоприятный предел уже учитывается новейшими нормами, изданными в Советском Союзе.

BEITRÄGE ZUR BERECHNUNG DER ZULÄSSIGEN BODENPRESSUNG UND DER UNTER DEN GRÜNDUNGS-KÖRPERN AUFTRETENDEN SPANNUNGEN

L. VARGA
LEHRSTUHL FÜR BODENMECHANIK, TIEF- UND ERDBAU, BAU- UND VERKEHRSTECHNISCHE UNIVERSITÄT, BUDAPEST

[Eingegangen am 25. Mai 1956]

II. Annäherungsrechnungen zur Spannungsbestimmung unter geschlossenen Gründungskörpern

Wie bekannt, sind für die Berechnung der unter rechtwinkligen Viereckfundamenten entstehenden Spannungen die STEINBRENNER- und NEEWMARKschen Formeln bzw. Nomogramme und Tabellen gebräuchlich. Letztere haben sich deshalb als nötig erwiesen, weil die Endresultate der theoretisch richtigen Ableitungen zu so komplizierten Ausdrücken führten, dass sie für die Zwecke der direkten Berechnung reichlich schwerfällig sind.

Das Ziel vorliegender kurzer Arbeit ist, eine einfachere und für die Errechnungsarbeit praktische Formel vorzuführen, die — eben wegen der im Interesse der Einfachheit notwendigen Vernachlässigung — wohl kein exaktes, aber vom Standpunkt der praktischen Berechnung durchaus befriedigend genaues Resultat gibt.

*

Der in der Abbildung gezeigte rechteckige Gründungskörper überträgt auf den Boden einen gleichmässig verteilten Kontaktdruck p_0 und es sei untersucht, wie grosse Spannung σ_z in einem Punkt P unter dem Eckpunkt entsteht.

Vorerst betrachte man ein Flächenelement und drücke die Wirkung der hier angreifenden Kraft, die als konzentrische Belastung angesehen wird, durch die BOUSSINESQsche Formel aus und nach doppeltem Integrieren erhält man das gesuchte Endresultat.

Die Grösse des Flächenelementes ist

$$dF = dx \cdot dy$$

also ist die Kraft

$$dP = p_0 \, dy \cdot dx$$

die unter ihrer Einwirkung entstehende Vertikalspannung ist

$$d\,\sigma_z = \frac{3\,p_0\,dy \cdot dx}{2\,\pi\,r_y^2} \cos^3 \varrho \tag{1}$$

wo ausser den obigen

ϱ = der Winkel zwischen der Senkrechten des Flächenelementes und dem Radius r_y,

r_y = die Länge des Radiusvektors des betrachteten Punktes.

Ferner:

$$r_y = \frac{r}{\cos \psi}$$

wo r die Länge des Strahles ist, der den betrachteten Punkt P mit dem auf der Abbildung ersichtlichen Punkt A verbindet.

Die Abbildung zeigt, dass

$$y = r \cdot \operatorname{tg} \psi$$

wo

$$\frac{dy}{d\psi} = \frac{r}{\cos^2 \psi} = \frac{r_y}{\cos \psi}$$

d. h.

$$dy = \frac{r_y\,d\psi}{\cos \psi} = \frac{r \cdot d\psi}{\cos^2 \psi}. \tag{2}$$

Ferner:

$$\cos \varrho = \frac{z}{r_y} = \frac{r \cdot \cos \vartheta}{\dfrac{r}{\cos \psi}} = \cos \vartheta \cdot \cos \psi .$$

In ähnlicher Weise:

$$x = r \cdot \operatorname{tg} \vartheta$$

und hieraus

$$dx = \frac{z}{\cos^2 \vartheta}\,d\vartheta = \frac{r}{\cos \vartheta}\,d\vartheta . \tag{3}$$

Werden die daraus gewonnenen Zusammenhänge in die Formel (1) eingesetzt

$$\sigma_z = \frac{3\,p_0}{2\,\pi} \int_0^{\varepsilon} \int_0^{\beta} \frac{r \cdot d\psi}{\cos^2 \psi} \cdot \frac{\cos^2 \psi}{r^2} \cos^3 \psi \, \frac{\cos^3 \vartheta \cdot r \cdot d\vartheta}{\cos \vartheta}$$

und nach Durchführung der möglichen Kürzungen:

$$\sigma_z = \frac{3\,p_0}{2\,\pi} \int_0^{\varepsilon} \int_0^{\beta} \cos^3 \psi \cdot \cos^2 \vartheta \, d\psi \, d\vartheta . \tag{4}$$

Da $\vartheta \neq f(\psi)$, kann die eine Integration ohne weiteres durchgeführt werden:

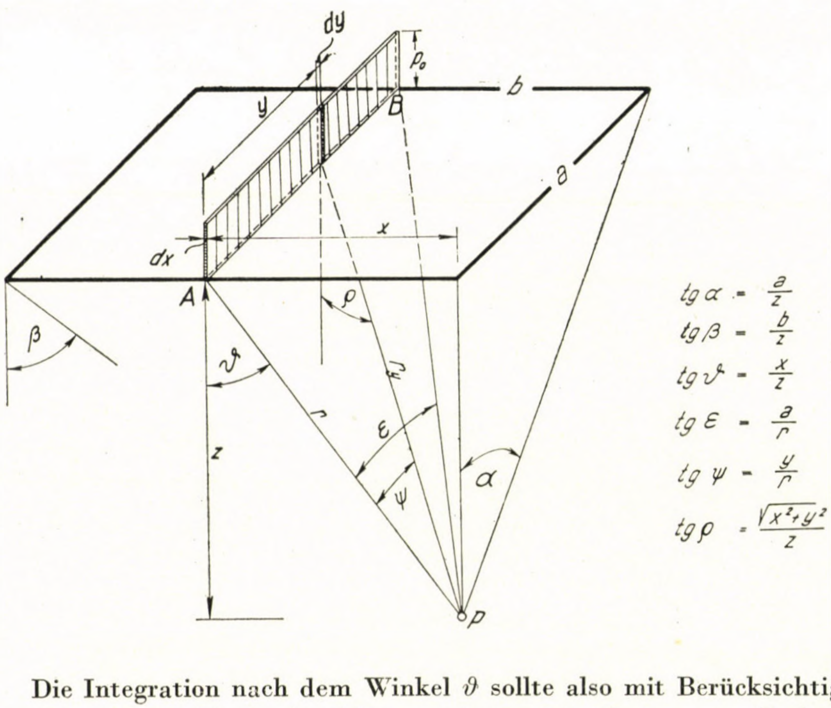
$$\int\limits_{\psi=0}^{\psi=\varepsilon} \cos^3 \psi \, d\psi = \left| \sin \psi - \frac{1}{3} \sin^3 \psi \right|_0^{\varepsilon} = \sin \varepsilon - \frac{1}{3} \sin^3 \varepsilon . \tag{5}$$

Der Winkel ε kann abermals wie folgt ausgedrückt werden:

$$\operatorname{tg} \varepsilon = \frac{a}{r} = \frac{a}{z} \cos \vartheta = \operatorname{tg} \alpha \cdot \cos \vartheta \tag{6}$$

d. h.

$$\varepsilon = f(\vartheta).$$



Die Integration nach dem Winkel ϑ sollte also mit Berücksichtigung des Zusammenhanges (6) durchgeführt werden, wodurch man am Ende der sehr komplizierten und schweren Ableitung die schon bekannte komplizierte Formel bekäme. *Aus Einfachheitsgründen bestimme man*, dass in den Berechnungen

$$\boxed{a \geq b} \tag{7}$$

ist und *annähernd setze man voraus, dass von der Gleichheit* (6) *abweichend*

$$\operatorname{tg} \varepsilon = \operatorname{tg} \alpha . \tag{8}$$

Im ersten Augenblick erscheint die Vernachlässigung gewagt, der Verfasser wird jedoch beweisen, dass der aus ihr entspringende grösste Fehler praktisch vernachlässigt werden kann.

Nach Zugrundelegen der Bedingung (8) erhält die Formel folgende Gestalt:

$$\sigma_z = \frac{p_0}{2\pi}[3 \sin \alpha - \sin^3 \alpha] \int_0^\beta \cos^2 \vartheta \, d\vartheta . \tag{9}$$

wo

$$\int_0^\beta \cos^2 \vartheta \, d\vartheta = \left[\frac{1}{2}\vartheta + \frac{1}{4}\sin 2\vartheta\right]_0^\beta = \frac{2\beta + \sin 2\beta}{4}$$

und wird dies in die Gleichung (9) eingesetzt, so bekommt man folgende Endformel:

$$\sigma_z = \boxed{p_0 \frac{[3 \sin \alpha - \sin^3 \alpha]\,[2\beta + \sin 2\beta]}{8\pi}} \tag{10}$$

wo

$$\alpha = \operatorname{arctg} \frac{a}{z} \tag{11}$$

und

$$\beta = \operatorname{arctg} \frac{b}{z} . \tag{12}$$

Man prüfe, welche Umfangsbedingungen die Formel (10) restlos erfüllt:

① $z \to 0$ d. h. $\alpha = \beta \to 90°$

dann

$$\frac{\sigma_z}{p_0} = \frac{[3-1]\,[\pi + 0]}{8\pi} = 0{,}25 \tag{13}$$

② $z \to \infty$ d. h. $\alpha = \beta \to 0°$

dann

$$\frac{\sigma_z}{p_0} = \frac{(0-0)\,(0+0)}{8\pi} = 0 \tag{14}$$

③ $a \to \infty$ und $b \neq 0$, $b \neq \infty$

dann $\alpha \to 90°$

$$\frac{\sigma_z}{p_0} = \frac{(3-1)\,(2\beta + \sin 2\beta)}{8\pi} . \tag{15}$$

Da die Formel für einen Eckpunkt gültig ist, muss obiges Ergebnis doppelt genommen werden, wenn man wünscht, dass der Zusammenhang (15) die Spannung unter der Kante eines unendlich langen Fundamentes (Streifenfundament) bezeichnen soll. Sucht man die Spannung in der Achse des Streifenfundamentes, so muss obiger Wert vierfach genommen werden, also:

$$\frac{\sigma_z}{p_0} = \frac{1}{\pi}\left[2\beta + \sin 2\beta\right]. \tag{16}$$

Man sieht, dass die Werte von (13) und (14) mit den Ergebnissen der diesbezüglichen exakten Theorie gleichwertig sind und die Formel (16) mit dem bekannten MICHELLschen Zusammenhang für die Achse übereinstimmt.

Bemerkt sei, dass die Prüfung der Fälle $b \to \infty$, $a \neq 0$ und $a \neq \infty$ der (7) Ungleichheit wegen nicht durchgeführt werden kann. (Die Vernachlässigung in der Gleichheit (8) wäre dann schon spürbar gross.)

Schliesslich sei ein allgemeiner Fall untersucht. Es ist leicht einzusehen, dass der in der Vernachlässigung wurzelnde Fehler dann am grössten ist, wenn $a = b$, wenn also von einem quadratischen Fundament die Rede ist und wenn der zu betrachtende Punkt $z \approx a = b$ tief liegt. Zum Vergleich sind in der nachstehenden Tabelle sowohl die *genauen* STEINBRENNER*schen Werte wie auch die aus der Formel* (10) *berechneten Annäherungswerte zu finden.*

z/b	σ_z/p_0			
	STEINBRENNER		Formel (10)	
	a : b = 1	a : b = 3	a : b = 1	a : b = 3
0,25	0,2473	0,2484	0,2485	0,2485
0,5	0,2325	0,2397	0,2359	0,2395
0,75	0,2060	0,2254	0,2110	0,2235
1,0	0,1752	0,2034	0,1807	0,2040
1,5	0,1210	0,1638	0,1241	0,1640
2	0,0840	0,1316	0,0861	0,1325
3	0,0447	0,0860	0,0455	0,0876
4	0,0270	0,0604	0,0275	0,0608
6	0,0127	0,0323	0,0128	0,0326
8	0,0073	0,0195	0,0073	0,0198
10	0,0048	0,0129	0,0048	0,0132

Man sieht, dass die grösste Abweichung wirklich im Fall $a : b = 1$ und $z \sim a$ erscheint und dass auch die grösste Differenz nicht mehr als 0,005 beträgt. *Bei einem anderen Verhältnis a/b oder im Falle anderer Tiefe ist die Abweichung*

noch geringer. (Bemerkt sei, der Verfasser hat die in obiger Tabelle für die Formel (10) genannten Werte mit dem Rechenschieber errechnet und so kann auch die Genauigkeit der praktischen Berechnung erkannt werden.) Dagegen sind die vergleichenden Werte nicht aus dem Diagramm gelesen, sondern sie sind ebenfalls Rechnungsprodukte. Bei Benutzung von Diagrammen ist eine Genauigkeit von vier Dezimalstellen auch nicht zu erwarten.

Das bisher gesagte zusammengefasst kann festgestellt werden, dass die Annäherungsformel (10) *für jeden in der Praxis vorkommenden Fall Werte von befriedigender Genauigkeit* bietet. In einer einzigen Relation ergibt sich eine Abweichung von 5/1000 Grössenordnung, die aber unwesentlich ist, wenn man sie mit den grundlegenden Ausgangsvernachlässigungen der Theorien oder z. B. mit den aus den Unsicherheiten der Berechnungsmethoden von Setzungen sich ergebenden Fehlerquellen vergleicht. Dagegen gelangt man um den Preis der ganz unerheblichen Vernachlässigung zu einer solchen Formel, die für die praktische Rechnung — besonders wienn diese mit dem Rechenschieber geschieht — durchaus genügt und die sich dem Gedächtnis verhältnismässig leicht einfügt. So wird die Anwendung der bekannten schwerfälligen Formeln überflüssig, die auch den Nachteil haben, dass zu ihrem praktischen Gebrauch ein Handbuch oder Lehrbuch mit den unentbehrlichen Nomogrammen unerlässlich ist. Und ausserdem: *muss man die Spannung in Punkten suchen, für die im Nomogramm die a : b- und z/b-Verhältniszahlen nicht zu finden sind, muss man also »nach dem Augenmass« interpolieren, so ist die mit der Formel* (10) *erreichbare Genauigkeit offenbar grösser als die Genauigkeit der Ablesung.*

Schliesslich ist es nicht uninteressant, dass durch die beschriebene Berechnungsmethode auch die Möglichkeit gegeben ist, die Spannung σ_z *in einem beliebigen Punkt* unter einer Kreisscheibe zu berechnen.

Es ist bekannt, dass die Formel der Spannung σ_z nur für Achsenpunkte in geschlossener Form ausgedrückt werden kann. Für Punkte beliebiger Lage, besonders aber für Punkte, die sich unter der Kreisscheibe befinden, können in einigen beschränkten Fällen nur Tabellen verwendet bzw. kann das bekannte Newmarksche Verfahren benutzt werden.

Auf Grund von Verfassers Untersuchungen lassen sich die Ansprüche der Praxis innerhalb einer Fehlergrenze von 0,02 bis 0,03 Grössenordnung noch vollständig befriedigen, wenn man die betrachtete Kreisscheibe *durch ein Quadrat von gleicher Fläche* ersetzt. Eine Seite dieses Quadrates beträgt dann

$$a = r \cdot \sqrt{\pi} = 1{,}77 \cdot r \,. \tag{17}$$

Das vorgeschlagene Verfahren hat den Vorteil, dass auch in solchen Fällen die Spannung bestimmt werden kann, für die die ausgearbeiteten Tabellen keine Werte enthalten und die Interpolation zwischen den zur Verfügung stehenden Werten *zu grösseren Fehlern führen würde.* Die Genauigkeit der so durchgeführten Berech nung erreicht das, was das Newmarksche Verfahren bietet, weil bei letzterem da Ablesen von Teilflächen mit gewissen Unsicherheiten verbunden ist.

SCHRIFTTUM

DR. SZÉCHY Károly: Alapozás I.
(Dr. Karl SZÉCHY: Fundierung I). Közlekedési Kiadó (Verkehrsverlag) 1952.

ZUSAMMENFASSUNG

Bei der Berechnung von Spannungen, die unter Gründungskörpern rechteckiger Form entstehen, ist die Anwendung des STEINBRENNERschen Graphikons gebräuchlich, weil die mathematisch genaue Formel für die Zwecke der direkten Berechnung reichlich schwerfällig ist. Der Verfasser beweist, dass durch Einführung des Zusammenhanges (8) eine viel einfachere und für Rechnungen mit dem Rechenschieber geeignetere Endformel abgeleitet werden kann (Formel 10). Der so begangene Fehler überschreitet nicht den Wert von $\Delta\sigma_z/p = 5/1000$, was die Ansprüche der Praxis vollkommen befriedigt, im Gegenteil, da man beim Graphikon interpolieren müsste, gibt die Berechnung mit der Formel genauere Ergebnisse. Ausserdem wird mit der Anwendung der Formel (10) der Gebrauch des Graphikons ganz überflüssig.

Der Verfasser verweist ferner darauf, dass für Spannungen, die an beliebigen Punkten unter einer Kreisscheibe entstehen, mit guter Annäherung innerhalb von 2—3% Fehlern gerechnet werden kann, wenn man den Kreis durch ein Quadrat von gleicher Fläche ersetzt.

CONTRIBUTIONS TO THE COMPUTATION OF THE PERMISSIBLE SOIL PRESSURE AND OF STRESSES ARISING UNDER FOUNDATIONS

II. APPROXIMATE CALCULATIONS OF STRESSES UNDER ISOLATED FOOTINGS

L. VARGA

SUMMARY

For the calculation of rectangular footings the application of the Steinbrenner formula is routine, because the mathematically precise formula is cumbersome for direct calculation. The paper demonstrates that with the introduction of the approximate relation 8 a much simpler formula, more suitable for slide rule computation can be deduced (Formula 10). The error thus committed does not exceed the value of $\Delta\sigma_z/p_0 = 5/1000$, which fully satisfies practical requirements. Moreover, if interpolation is necessary in the graph, calculation by the formula gives a more accurate result. Besides this, the use of formula 10 makes the application of the graphic entirely superfluous.

The paper demonstrates moreover, that the stress arising at an arbitrary place under a circular slab can be computed with good approximation — a tolerance of 2—3% — if the circle is substituted by a square of equivalent surface.

CONTRIBUTION AU CALCUL DES PRESSIONS ADMISSIBLES SUR LES SOLS ET DES TENSIONS SE PRODUISANT SOUS LES MASSIFS DE FONDATION

II. CALCULS APPROCHANTS DES TENSIONS SE PRODUISANT SOUS DES MASSIFS DE FONDATION CLOS

L. VARGA

RÉSUMÉ

Les tensions qui se produisent sous les massifs de fondation rectangulaires sont généralement calculées à l'aide du graphique de Steinbrenner, la formule exacte au point de vue mathématique étant trop encombrante pour le calcul directe. L'auteur démontre que par l'introduction de la relation (8), on obtient une formule finale beaucoup plus simple et se prétant mieux au calcul par la règle à calcul (formule 10). L'erreur ainsi commise ne dépasse pas la valeur de $\Delta\sigma_z/p = 5/1000$ ce qui satisfait entièrement aux exigences de la pratique, de plus, vu que dans le graphique on devrait recourir à une interpolation, le calcul par la formule fournit des résultats plus exactes. D'ailleurs l'application de la formule (10) élimine la nécéssité de l'utilisation du graphique.

L'auteur indique en outre qu'une tension se produisant dans un point quelconque sous un disque circulaire peut être calculée avec une bonne approximation — une erreur de 2 à 3 % — en remplaçant le cercle par un carré de la même surface.

К РАСЧЕТУ ДОПУСКАЕМЫХ НАГРУЗОК ГРУНТОВ И ВОЗНИКАЮЩИХ ПОД ОСНОВАНИЯМИ НАПРЯЖЕНИЙ

II. ПРИБЛИЖЕННЫЕ РАСЧЕТЫ ДЛЯ ВЫЧИСЛЕНИЯ НАПРЯЖЕНИЯ ПОД ЗАМКНУТЫМИ ОСНОВАНИЯМИ

Л. ВАРГА

РЕЗЮМЕ

Для вычисления напряжений, возникающих под прямоугольными четырехугольными основаниями, обычно используется график Штейнбреннера, так как использование для непосредственных расчетов математически точной формулы является очень затруднительным. Автор показывает, что введением приближенной зависимости 8 можно вывести более простую формулу, пригодную для производства вычислений при помощи счетной линейки (формула 10). Получающаяся при этом погрешность не превышает 5/1000, что полностью удовлетворяет практическим требованиям, более того, в тех случаях, когда необходимо при пользовании графиком производить интерполяцию, вычисления при помощи формулы дают более точные результаты. В случае использования формулы 10 можно полностью избежать пользования графиком.

Кроме того указывается, что напряжение, образующееся в любом месте под кругом, может быть вычислено с хорошим приближением при погрешности порядка 2—3%, если вместо круга вычисление производить для квадрата идентичной площади.

INVESTIGATIONS ON THE SIZING EFFECT BY MEANS OF SIZED COTTON ROVINGS

Prof. M. ZILAHI
D. ENG. SC.
and
I. KELEN
DEPARTMENT OF TEXTILE TECHNOLOGY, TECHNICAL UNIVERSITY, BUDAPEST

[Manuscript received 11st June 1956]

In the technical literature, the testing of sized rovings has only been known since 1952.

In an article discussing "The Evaluation of Textile Sizes" in the September 1952 issue of the Textile Research Journal, King, Weil, Condo and Rutherford stated that the testing of sized yarn gives no adequate information concerning the effect of sizing on loose, untwisted, "slubby" portions of the yarn, and such effect could be better determined by testing sized roving. In the yarn, slubby sections are comparatively rare, and therefore their examination is rather cumbersome. However, as there is a similarity between the slubby parts of the yarn and the roving, the method derives conclusions applicable to the slubs by examining the effect of sizing on the roving.

R. Schutz and S. Marguier report on their experiments with sized rovings in the December 1953 issue of the Bulletin de l'Institut Textile de France.

This paper reports on a new method of testing sized rovings, more sensitive than the ones known so far, and which is therefore more appropriate both for the theoretical and practical examination of the efficacy of sizing. Our examinations also revealed correlations between the extent of size uptake, its character and the abrasion-resistance of the roving.

Purpose of testing sized rovings

At first, the sizing of rovings was merely intended to observe the effect of sizing on the slubby parts of the yarn. Later, however, the method proved fit for the general examination of sizing.

The breaking strength of drafted cotton rovings used for the tests amounts to not more than 6—12 g, and owing to the loose structure, its abrasion-resistance is below the measurable level. Against this, the breaking strength of the sized roving reaches 2—3 kg, and its resistance to abrasion is considerable. Comparing the properties of the sized yarn with those of the sized roving, the following were observed :

Sizing generally increases the breaking strength of the yarn by 10 to 30 percent, while the breaking strength of the roving is increased by several thousand percents by sizing. Obviously, the effect of sizing is more clearly apparent on the roving than on the yarn.

Going one step further, we might state that examination of the size film's properties yielded a picture that was even more characteristic of the size than the one observed on sized rovings. The preparation of the film and the execution of the tests is, however, slow and cumbrous. The thickness of the film cannot be accurately determined. Besides, the method requires laboratory work, which never fully corresponds to actual working conditions. Abrasion resistance tests of the film have not yet been worked out.

Hence, the purpose of our examinations was to observe the size uptake, breaking strength, elongation and abrasion resistance of the sized roving, and to determine under the microscope, the effect of the sizing factors, wherefrom the quality of sizing may be judged.

In our experiments, the following factors were examined with regard to the quality of sizing:

1. The effect of starch concentration.
2. The effect of size temperature (determination of the notion of superficial and useful size uptake).
3. The effect of repeated sizing.

The following statements may be derived from our experiments :

a) A correlation exists between the abrasion resistance of the roving and its size uptake.

b) The increase of abrasion resistance is not proportionate to the size uptake, but depends on its character, according to the two peaks of the size uptake diagram : in this context, we may distinguish between the so-called superficial and useful size uptake.

c) The increase of abrasion resistance is essentially proportionate with the increase of the useful size uptake.

d) Useful size uptake is a function of the size viscosity.

e) An effective method of increasing useful size uptake is the repeated sizing of the roving ; this markedly improves resistance to abrasion.

f) Repeated sizing produces increased size uptake, not only with starch sizes, but also with flour sizes.

Method of sizing and testing rovings

Rovings were sized without changing actual working conditions. Before entering the size box, we twisted the roving to one of the warp threads, conducted it through the box and passed it between the squeeze rolls together with the warp thread.

It passed through the drying chamber with the warp, and on emerging from it dry, it was reeled by hand at the rate at which it was fed into the sizing machine.

Twin-cylinder Sucker, TDC, 11-reel sizing machines were used for the tests. The circumstances were fully corresponding to operating conditions (temperature, size composition, machine speed, etc.). 40—50 m of roving were sized in each batch.

Breaking tests of the untreated rovings were performed on a Schopper pendulum-type yarn tester.

For breaking tests of the sized rovings, a Schopper F. 100 motor-driven tester with diagram recorder was used.

Abrasion-resistance tests were made on an abrader at the Department of Textile Technology of the Budapest Technical University, constructed by Kóczy*. 50 to 100 g pre-loading was applied to each yarn.

Separate test were made with three rovings, each of which had been sized differently, to examine the results, variation and reproducibility of the abrasion test results.

Roving No. 1 : sized with high starch concentration.

Roving No. 2 : sized with low starch concentration.

Roving No. 3 : repeatedly sized with low starch concentration.

Thirty specimens of each roving were subjected to abrasion (in 9 series of test), and the following results were obtained:

	Roving		
	No. 1	No. 2	No. 3
Mean value of wearing tests	81,0	15,6	112,0
Standard deviation	30,3	5,12	33,8
Coefficient of variation	38,0	32,8	30,2
Error of the mean value*	6,7	1,4	7,5
Actual mean value	81,0±6,7	15,6±1,38	112,0±7,5

* with 96,6 per cent statistical probability.

It will be seen from the above test results that their variation amounts to 30—40 percent. In spite of that, taking into account the errors of the mean value, the calculated mean values are well-defined, the abrader results have adequately demonstrated the resistance of the three differently sized rovings.

The diagram of the abrasion is shown in Fig. 1. The curve showing the resistance of the various yarns has been substituted by a characteristic straigth line.

* Kóczy: Az irezés hatását vizsgáló koptató műszer (Academic report, 1952) and Kelen: Az irezés tudományos alapjai (Magyar Textiltechnika, Oct. 1952).

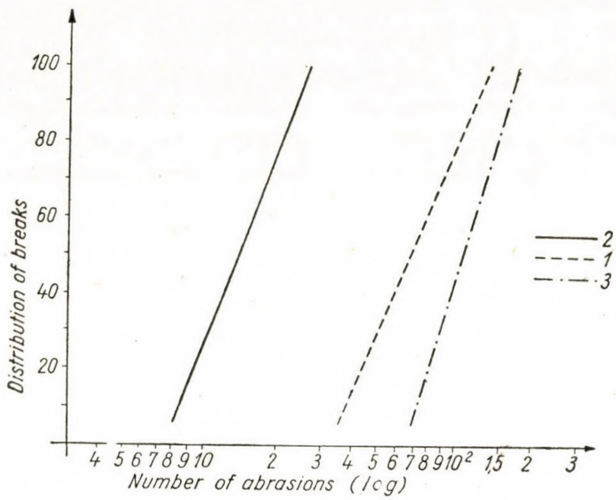


Fig. 1

Test No. 1

The effect of size mixtures of various concentration was examined. Technical specifications of the rovings used are tabled below.

Technical data of the components

	Cotton quality	
	I CA (90 per cent)	O HA (10 per cent)
Fibre count Nm	5300	5300
Fibre breaking strength, g	4,6	4,9
Modal length mm	29,0	28,7
Fibre breaking length, km	24,4	25,2

Technical data of the roving

Roving twist/m	80
Count of roving Nm	4,8—5,0

Sizes used for the tests

Chemicals	Bath No. 9	Bath No. 3	Bath No. 1
Maize starch, kg	37,5	32,0	25,0
Flour sweepings, kg	5,0	—	—
Universol*, kg	2,2	1,6	1,2
Glycerine, kg	0,5	0,5	0,5

* 36—40 p. c. fatty acid
6—10 mg NaOH/g
50—55 p. c. moisture contents

Method of size preparation

Add the starch, flour sweepings and the Universol into 400 lt water of about 25—30 °C temperature. Heat with direct steam while stirring. Boil for 5 minutes, and add the glycerine after the size is cooked. The mixture yields 500 lt of size.

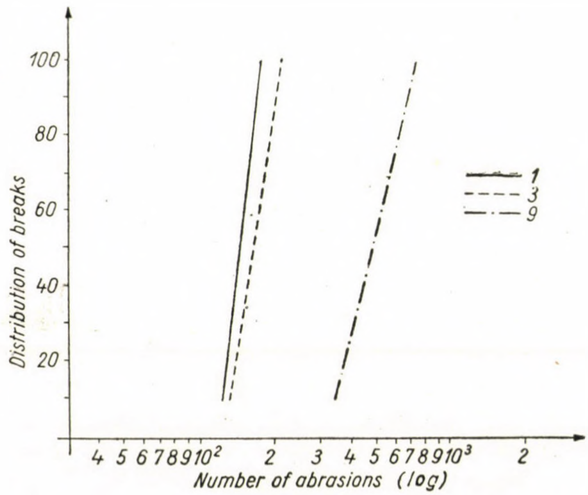


Fig. 2

The size should have a temperature of 85 °C. The sized rovings were tested for abrasion resistance and broken. A basic load of 100 g per roving was used for testing abrasion resistance.

The diagrams of abrasion-resistance tests plotted (Fig. 2) clearly show that the roving sized in bath No. 9 is more resistant than the ones sized in baths 3 and 1. The differences in the breaking strength do not adequately express differences in abrasion resistance.

In Fig. 2, the logarithms of the abrasion numbers were employed. The abrasion curves may, with slight correction, be substituted by characteristic straight lines.

Comparative data

	Breaking strength g	Average of the numbers of abrasions
Unsized roving	12,1	0
Sized in bath No. 3.	2120,0	166,2
Sized in bath No. 9.	2200,0	213,2
Sized in bath No. 1.	2063,0	148,8

The behaviour of slubs in the yarn during weaving — which is of crucial importance for weaving — can be concluded from the breaking length of the sized roving.

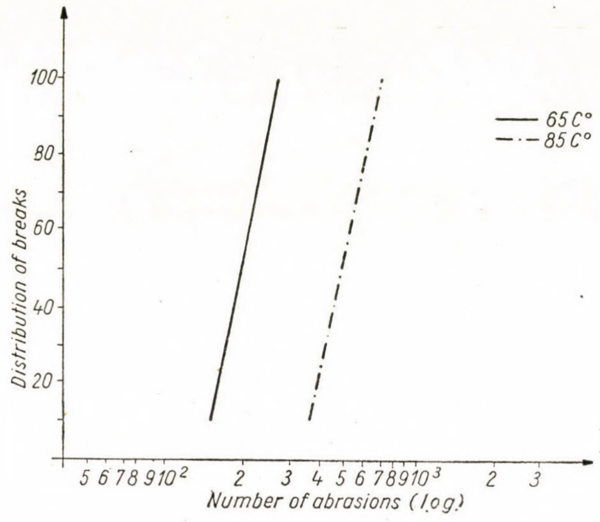


Fig. 3

The breaking strength of cotton warp yarn processed with the usual spinning method is about 11 km; sizing increases it by about 20 percent, bringing the breaking length up to 13,2 km.

From an analysis of the breaking length of sized rovings, the following comparative data have been obtained :

	Roving		
	Count No. Nm	Breaking strength g	Breaking length km
Roving sized in bath No. 3.	4,9	2120	10,4
Roving sized in bath No. 9.	4,8	2200	10,6
Roving sized in bath No. 1.	4,8	2063	9,9

These data show that although the roving is substantially reinforced by sizing, it does not reach the breaking length of the average yarn, though it closely approaches that of an untreated yarn.

Bath No. 9 seemed to have the most propitious effect, both from the point of breaking strength and of abrasion resistance.

The higher efficacy can be attributed only to the higher starch concentration of bath No. 9. Higher concentration entails greater size pickup, which in turn is responsible for the increased abrasion resistance. In the following, we shall, however, demonstrate that the notion of size pickup itself requires elucidation, and that we must discriminate between various kinds of size pickup in the function of the viscosity even where their concentration percentages are equal.

Accordingly, abrasion-resistance also varies under the effect of the various kinds of size pickup.

Examining the adhesive effect of sizes*, the following average values were obtained :

Bath No. 9 $\tau_9 = 13{,}5$ kg/cm².
Bath No. 3 $\tau_3 = 12{,}1$ kg/cm².
Bath No. 1 $\tau_1 = 11{,}6$ kg/cm².

Tests concerning the shearing strength of the adhesion confirmed the above findings.

Test No. 1 proved that — within the limits of the test — the size bath of higher concentration increases the breaking strength and abrasion-resistance, providing the conditions of sizing otherwise unchanged.

Test No. 2

In this experiment, the effect of uniformly prepared sizes was observed in the function of diverse sizing temperatures.

Size composition and cooking specifications were as in test No. 1. The sizing paste was cooled to 65 °C, and the roving was sized once more. The results of the two exposures are compared in Fig. 4. By comparing the resultant data and the diagrams, it will be seen that the roving treated at 85 °C was more resistant to abrasion ; besides, such a comparison will demonstrate the high susceptibility of our test.

Comparative data

	Breaking strength g	Average of the numbers of abrasions	Factor of breaking strength increase
Sized at 85 °C	2200	512,6	182
Sized at 65 °C	1800	209,6	149

During the continued tests, size temperature was gradually raised by steam regulation.

The comparative results of the tests yielded the following data :

* Kelen : Irfilmek vizsgálata. Magyar Textiltechnika. May 1955.

Sizing temperature °C	Breaking strength g	Average of abrasions	Factor of breaking strength increase
64	1795	160,9	148
66	2050	160,0	169
74	1918	204,2	158
86	1904	378,8	157
93	1880	292,6	155
97	1870	245,4	154
99	1872	228,0	154

Abrasion-resistance of the rovings is shown by Figs. 4 and 5. According to Fig. 5, abrasion-resistance increases with the rising temperature, up to 86 °C, whereafter it declines again.

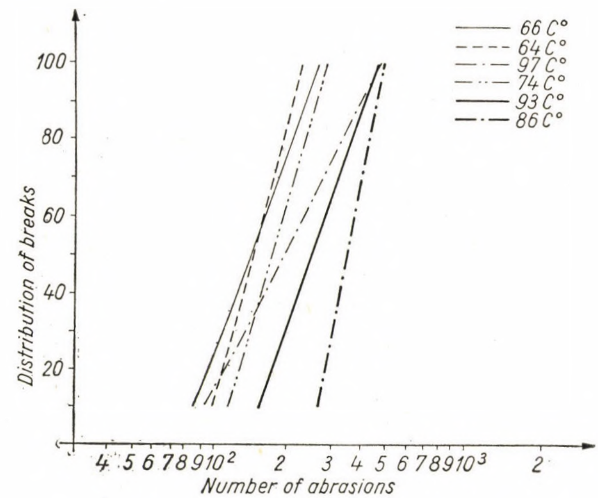


Fig. 4

The curve of the breaking strength first rises to decline afterwards. The increase in abrasion-resistance must be attributed to the formation of a thicker protective film. This film is formed by the fibres and the size mixture, hence its thickness is nearly proportionate with the add-on of size. Abrasion-resistance is only increased by the quantity of starch penetrated between the fibres, whereas the size adhering to the yarn surface readily wears off when exposed to abrasion. The variation of the breaking strength appears to be a function of the size uptake.

If the roving is simply dipped into size without being passed through the squeeze rolls, the size will not penetrate between the fibres of the roving, but will be deposited on the surface. Against this, when the sized roving is passed through the squeeze rolls, the size mixture will penetrate into the roving and some of the fibres will stick together. These fibres will not slip on breaking the roving, but will resist the breaking force. The roving will only break if the roving is subjected to a force of such magnitude that will tear apart the fibres stuck together, and will overcome the friction of the contacting fibres, causing them to slip apart.

The greatest portion of the dry substance of the sizing solution consists of starch. The viscosity of starch sizes is proportional to the temperature, the concentration and the degree of breaking up. In our experiment, the concentration and the degree of breaking up are practically constant, so that viscosity is a function of the temperature alone.

The rovings sized at 64 and 66 °C were immersed into size of high viscosity. The size did not fully penetrate into the roving, on miscroscopic inspection, cavities were observed which were not filled with starch.

The microscopic aspect of yarns sized between 74 and 94 °C showed that by decreasing viscosity, the penetration of size between the individual fibres increases.

The analysis of size uptake yielded the following data :

Sizing temperature °C	*Percentage of size pickup*
58	22,8
65	21,0
71	19,8
78	19,1
85	24,0
91	23,1

Plotting the above data into diagram 5, the curve of the size uptake will be seen first to decline and then to rise again. The curve has two peaks : the first is a result of the viscosity of the size bath (at 58 °C), the second is situated at about 85—90 °C. The character of the two peaks is, however, entirely different. Where the high size uptake is due to high viscosity, a portion of the size is deposited on the surface, while the lower viscosity at about 85 °C permits of the penetration of the starch.

The second peak of the size pick-up curve nearly coincides with the maximum value of the abrasion resistance. This indicates that the size penetrated into the internal layers of the roving, and sticking the fibres together, has a beneficial effect on abrasion resistance, while the size that is not bound by the fibres wears off sooner when exposed to abrasion.

In Fig. 5, size uptake at about 85 °C is expressed by point I ; it shall be called the *useful size uptake.*

On penetrating between the fibres, the size makes them stick together and forms with them a protective layer that resists abrasion. This layer is hard to be abolished, because the starch wears off but slowly between the fibres.

Size uptake at about 60 °C is shown by point II in Fig. 5 ; let us call it ***superficial size uptake.***

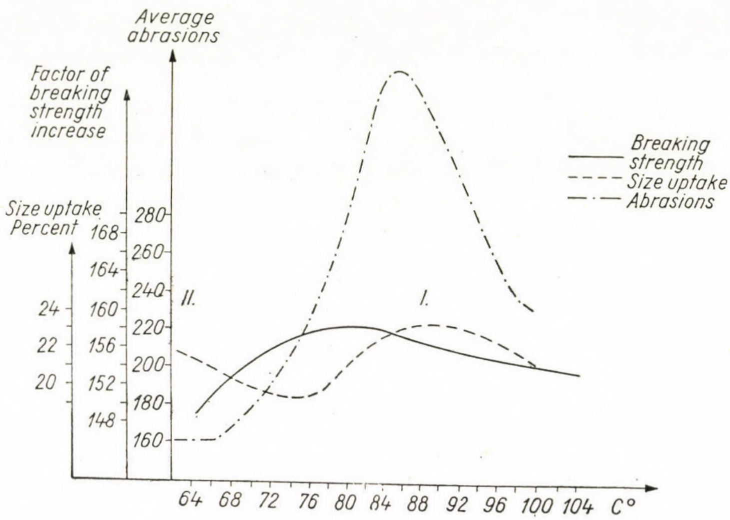


Fig. 5

The superficial size uptake also forms a coat which resists abrasion. This protective coat, however, lacks stability and the starch crumbles off readily. This statement holds good also for the process of yarn sizing, as is proved by the crumbling off of the size in the weave room, in consequence of inadequately broken up starch or cold sizing. The effect of both is the same : an increase of viscosity.

Test No. 3

Repeated sizing of rovings

In our experiment, we endeavoured to produce a more resistive protective coat by repeated sizing. Our purpose was to assure a higher size pickup. Previous tests unanimously evidenced that resistance to abrasion was proportional to the quantity of starch penetrated into the roving.

Microscopic sections of the rovings showed that the starch film was deposited between the outer fibres. Consequently, it could be assumed that the film formed on the first sizing might impede subsequent starch uptake. Still, it seemed probable that size uptake would increase as a result of repeated sizing.

Experimental observation showed that an increase in the size uptake did not invariably set in upon repeated sizing, but was only discerned in a marked degree where the rovings were dried between subsequent sizing processes. Where this was done, the add-on of size was significant, and was accompanied by a marked rise in abrasion-resistance. The latter observation confirmed our experience that resistance of abrasion is proportional to the quantity of the starch penetrated into the yarn.

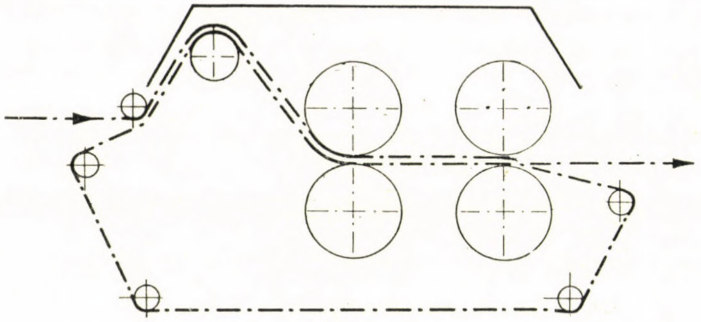


Fig. 6

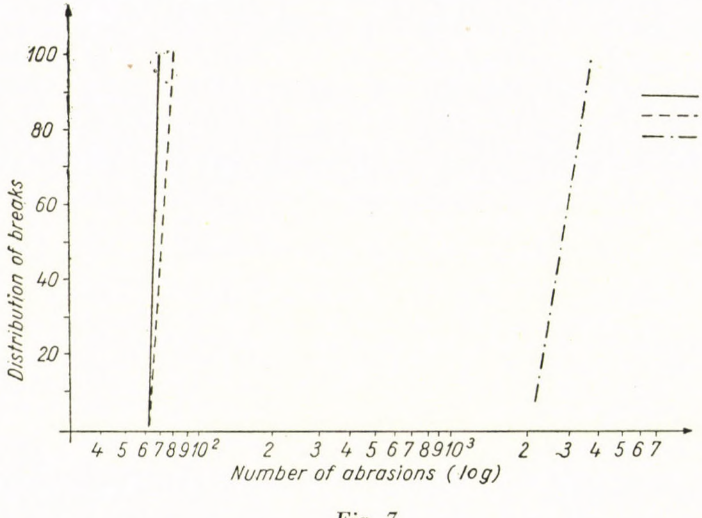


Fig. 7

Roving *a)* was sized as described above (bath No. 9) ; roving *b)* was dipped again into the size box after a first immersion, and was passed on into the drying chamber after a second immersion and squeezing (Fig. 6). Roving *c)* was first sized in exactly the same manner as roving *a)*, except that after drying it was sized once more.

The efficacy of sizing by the three methods is shown in the following table, as well as in diagram 7.

Comparative data

Roving	Breaking strength g	Average number of abrasions	Factor of increase in breaking strength
a)	2085	337,9	172
b)	2056	350,3	170
c)	3085	2549,0	254

Diagram 7 shows the striking rise of the abrasion-resistance of roving *c)* that has been repeatedly sized, whereas the abrasion-resistance of rovings *a)* and *b)* is about equal.

There is also a significant rise in the breaking strength of the re-sized roving.

Through repeated sizing, the breaking length of the roving may be increased to such extent that its value reaches even that of the yarn.

Assuming that the slubby portions of the warp yarn have a character similar to that of the roving, the breaking strength of these portions will presumably be substantially increased by repeated sizing.

The comparison of the behaviour of rovings *b)* and *c)* yields a remarkable result. In both processes, the roving is passed twice through the size box. Roving *b)* is delivered back into the box while still damp, roving *c)* is dried before being immersed again into the vat. Re-sizing was effectual only with the method *c)*, from which we concluded that moisture contents must first be removed from the roving by drying, to permit of the penetration of the fresh size.

Test No. 4

Repeated sizing with various size mixtures

The photomicrograph of sized rovings shows numerous cavities among the fibres of the roving sized once.* The cause of this is inadequate size uptake, as a result of which the starch did not impregnate the roving. Roving *b)* also shows dark, cavernulous fields. Also, it is remarkable that the roving forms no "closed" unity. In analysing the effect of sizing, NEUMAN referred to the compacting effect of sizing on the yarn. RUFF and RAMSTAHLE also used the term "closed", which is an essential point in the subjective study of sizing. Roving *c)* satisfies also that requirement : it seems to be completely saturated with size mixture.

For an example, we refer to photomicrographs Nos 8—11, which confirm that repeated sizing increases the size uptake and abrasion-resistance

* The dark patches indicate starch stained with iodine.

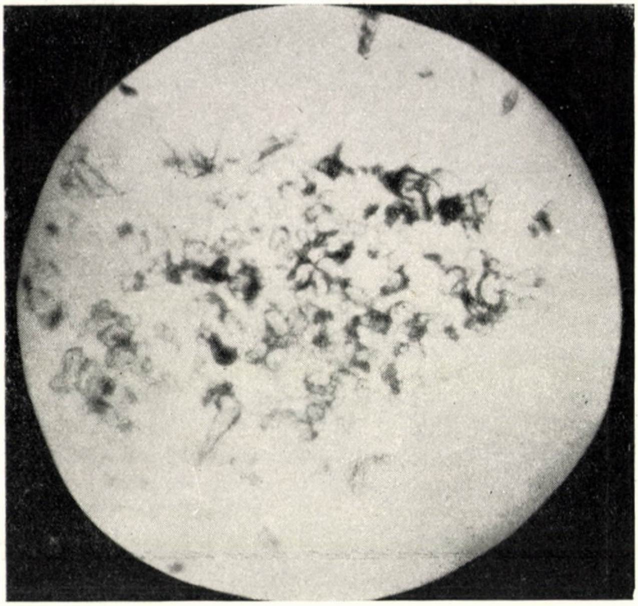


Fig. 8. Sized with broken rice flour

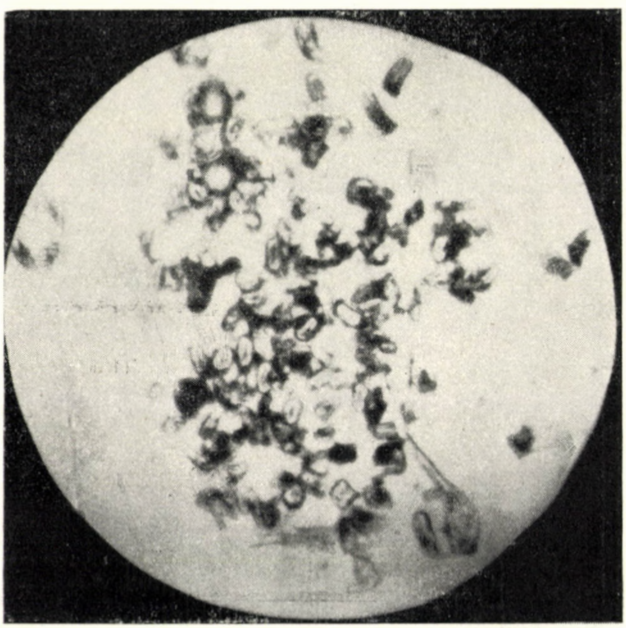


Fig. 9. Sized repeatedly with broken rice flour

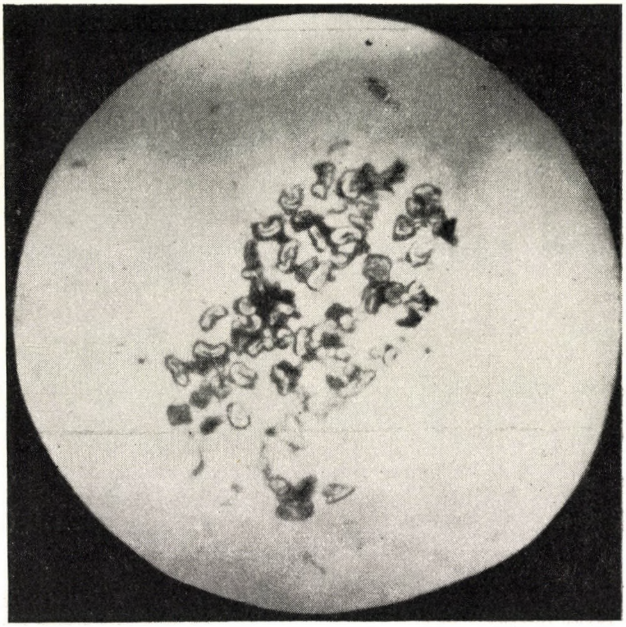


Fig. 10. Sized with maize starch

Fig. 11. Sized repeatedly with maize starch

of the roving even where the size baths have been composed from various ingredients.

Twice sized rovings show invariably a more compact structure.

This experiment proved that repeated sizing entailed an increase in the size uptake irrespective of the kind of basic ingredients used for the size mixture.

REFERENCES

ZILAHI—MEISTER: Magyar Textiltechnika, 3. 1951.
KELEN: Magyar Textiltechnika, 10. 1952.
ALAYRANGUES, CHABERT, MEYBECK: Bull. l'Inst. Text. de France No. 37. 1953.
KESZEGH: Az irezés kémiája. 1953. Post-graduate Engineering Inst. Budapest.
KING, WELL, CONDO, RUTHERFORD: Text. Res. Journal 9. 1952 p. 567.
KRAIS, BLITZ: Leipzig. Monatschrift f. Text. Ind. 38. 1923 p. 207, 10. 1924 p. 290.
SCHUTZ, MARGUIER: Bull. I. T. F. Dec. 1953 p. 81.
KELEN: Pamutfonalak irezése. 1953. Könnyűipari Kiadó.

SUMMARY

Four series of experiments with sized rovings proved that resistance to abrasion was a sensitive index of the efficacy of sizing. In spite of the 30—40 per cent coefficient of variation the average values are well-defined, and yield adequate statistical safety. The statements derived were of a kind that have not been demonstrable as yet by the examination of sized yarns. The conclusions deriving from the experimental results are summarized in the following.

1. The sizing of rovings confirmed that size mixtures prepared with higher starch concentration result in higher size uptake, other sizing circumstances being equal. Appropriate viscosity assures greater resistance to abrasion and generally a higher breaking strength.

2. Examining size uptake in the function of the size temperature, the diagram plotted will show two peaks: the first is due to high viscosity, and the second to the adequately reduced viscosity.

3. The nature of the size uptake observed at the two peaks is thoroughly different. A significant portion of the maximum size uptake due to high viscosity is deposited on the surface of the roving, while part of the easy-flowing size will readily penetrate into the roving. The former size uptake is called "superficial" size uptake, the latter "useful" size uptake.

It has been demonstrated that the rovings' resistance to abrasion and their breaking strength is substantially higher after useful than after superficial size uptake.

4. By raising the temperature, viscosity is further diminished. The size penetrates also in this case into the internal layers of the roving, but when passed through the squeeze rolls, the low viscosity starch is readily removed together with the moisture.

5. The abrasion-resistance of rovings can be substantially increased by repeated sizing. (By repeated sizing, the process of drying the saturated rovings, and thereafter of sizing and drying them again is meant.)

6. Repeated sizing of damp rovings saturated with size does not influence either the rovings' resistance to abrasion or their breaking strength. Before repeated sizing, all unnecessary moisture must be removed from the rovings.

7. The roving's size uptake increases upon repeated sizing. Subsequent sizings will increase the size uptake, which produces a further increase in the resistance to abrasion and in the breaking strength.

8. The effect of repeated sizing consisting in a higher size uptake may be invariably demonstrated with starches made of different basic materials.

UNTERSUCHUNG DES SCHLICHTEFFEKTES AN GESCHLICHTETEN BAUMWOLLVORGARNEN

M. ZILAHI, Doktor der techn. Wiss., und I. KELEN

ZUSAMMENFASSUNG

Vier Versuchsreihen mit geschlichteten Vorgarnen haben bestätigt, dass der Einfluss des Schlichtens auf die Scheuerfestigkeit von Vorgarnen mit grosser Verlässlichkeit nachgewiesen werden kann. Obwohl die Variationskoeffizient 30—40% beträgt, sondern sich die Scheuerungs-Durchschnittswerte voneinander gut ab, und ihre statistische Sicherheit ist entsprechend. Die Verfasser sind zu solchen Feststellungen gelangt, die an geschlichteten Garnen bisher nicht nachgewiesen werden konnten. Die Schlussfolgerungen können aus den Versuchen wie folgt zusammengefasst werden :

1. Das Schlichten von Vorgarnen hat bewiesen, dass bei sonst unveränderten Bedingungen eine mit grösserer Stärkekonzentration zubereitete Schlichtflotte grösserte Aufnahme von Schlichtsubstanz ergibt. Wenn das Schlichten mit entsprechender Viskosität vorgenommen wird, so kommt dies in grösserer Scheuerfestigkeit und im allgemeinen in grösserer Reissfestigkeit zum Ausdruck.

2. Wenn die Schlichtsubstanzaufnahme in der Funktion der Temperatur untersucht wird, zeigen sich im Schaubild zwei Maxima. Das erste Maximum wird von hoher Viskosität, das andere Maximum von entsprechend herabgesetzter Viskosität hervorgerufen.

3. Die beobachteten Schlichteaufnahme bei den zwei Höchstwerten sind von gänzlich verschiedenen Charakter.

Ein bedeutender Teil der zufolge hoher Viskosität entstandenen maximalen Schlichteaufnahme setzt sich an der Oberfläche des Garnes ab. Die dünnflüssige Schlichtflotte ermöglicht ein teilweises Eindringen der Schlichtsubstanz. Die erste Art der Schlichteaufnahme wird »Oberflächenaufnahme«, die zweite »nützliche« Schlichteaufnahme genannt.

Es kann festgestellt werden, dass im Falle der «nützlichen» Schlichteaufnahme, die entstehende Zunahme der Verschleiss- und Zugfestigkeit wesentlich grösser ist, als die entsprechenden Werte bei der »Oberflächenaufnahme« der Schlichtsubstanz.

4. Die Steigerung der Temperatur verringert weiter die Viskosität. Auch in diesem Fall dringt die Schlichtflotte in die inneren Schichten des Vorgarns ein, jedoch wird eine Schlichtflotte mit geringerer Viskosität mit der Überschussfeuchtigkeit zusammen, durch die Quetschwalzen leicht entfernt.

5. Durch wiederholtes Schlichten kann die Scheuerfestigkeit der Vorgarne bedeutend gesteigert werden (unter wiederholtem Schlichten verstehen wir einen Vorgang, bei welchem das Vorgarn nach Sättigung getrocknet und dann nochmals geschlichtet und getrocknet wird).

6. Das wiederholte Schlichten der mit Schlichtsubstanz gesättigten nassen Vorgarne bringt keine Veränderung der Scheuerfestigkeit noch der Reissfestigkeit der Vorgarne. Vor Wiederholung des Schlichtens müssen die Vorgarne von ihrem überflüssigen Wassergehalt befreit werden.

7. Bei wiederholtem Schlichten steigt die Schlichteaufnahme des Vorgarns. Bei weiterer Wiederholung des Schlichtens wird die Schlichtsubstanzaufnahme noch höher, was mit einer weiteren Steigerung der Scheuerfestigkeit und Reissfestigkeit des Vorgarns verbunden ist.

8. Die erhöhte Wirkung der wiederholten Schlichtsubstanzaufnahme kann beim Schlichten mit Stärken von verschiedenem Ursprung in gleicher Weise nachgewiesen werden.

RECHERCHES SUR L'EFFET DE L'ENCOLLAGE DES MÈCHES DE COTON ENCOLLÉES

M. ZILAHI, docteur des sciences techniques et I. KELEN

RÉSUMÉ

Quatre séries d'essais avec des mèches encollées ont confirmé que l'influence de l'encollage sur la résistance au frottement et la résistance dynamometrique des mèches peut être démontré nettement. Malgré une dispersion de 30—40%, les moyennes sont bien séparées, l'une de l'autre, et leur sûreté statistique est suffisante. Les auteurs sont arrivés à des

conclusions lesquelles n'ont pas encore pu être démontrées sur des fils encollés. Les conclusions qui peuvent être déduits des essais ont été groupées comme suit :

1. L'encollage des mèches aussi a démontré que, toutes autres circonstances égales, les colles à plus forte teneur en amidon causent une absorption plus élevée de la colle. En utilisant une viscosité appropriée de la colle, ceci conduit à une résistance plus élevée à l'usure et d'habitude à une résistance dynamometrique plus élevée.

2. En examinant l'absorption de la colle en fonction de sa température, nous trouvons deux maxima sur la courbe représentant le phénomène. Le premier maximum est causé par la viscosité élevée, le deuxième maximum par la viscosité dûment diminuée.

3. Quant au caractère du dépot de la colle, les deux maxima sont d'un caractère totalement différent.

Un pourcentage important de la colle absorbée au premier maximum, dû à la viscosité élevée, se place sur la surface de la mèche. La colle fluide cependant pénètre en partie à l'intérieur de la mèche. Le premier genre du depot est nommé dépot «superficielle», le deuxième genre, «dépot utile».

On constate que la résistance au frottement dynamometrique dûes au dépot «utile» sont beaucoup plus élevées que celles dûes au dépot superficielle.

4. Si l'augmentation de la température continue, la viscosité diminue encore. Dans ce cas aussi, la colle pénètre dans les couches intérieures de la mèche, mais sous l'action des rouleaux de pression la colle fluide est facilement chassée ensemble avec l'humidité.

5. Par un encollage répété, la résistance à l'usure des mèches peut être augmentée considérablement. (Nous appelons collage répété le procédé par lequel les mèches sont séchées aprés saturation, ce qui est suivi par un nouveau encollage et un séchage.)

6. L'encollage répété de mèches humides saturées de colle ne change ni la résistance à l'usure, ni la résistance à la traction des mèches. Avant la répétition de l'encollage il faut libérer les mèches de leur teneur en eau superflue.

7. Au cours du deuxième encollage, l'absorption de colle a augmentée. Par des répétitions suivies de depot de colle augmentera encore, ce qui va ensemble avec une augmentation de la résistance au frottement, et la résistance dynamometrique de la mèche.

8. L'augmentation du dépot de colle dûe aux répétitions du l'encollage peut être démontrée au dépot de l'encollages avec des amidons d'origine différente.

ИССЛЕДОВАНИЕ ШЛИХТОВАНИЯ НА ШЛИХТОВАННОЙ ХЛОПЧАТОБУМАЖНОЙ РОВНИЦЕ

Д-р. техн. наук М. ЗИЛАХИ и И. КЕЛЕН

РЕЗЮМЕ

Четыре серии опытов с шлихтованной ровницей доказали, что влияние шлихтования чувствительно отражается прочностью истирания ровницы. Несмотря на имеющиеся 30—40% отклонения легко отделяются друг от друга средние значения, их статистическая надежность удовлетворительна. Сделаны такие заключения, которые нельзя было установить до сих пор при исследовании шлихтованных ровниц. Выводы, которые можно сделать на основе опытных данных, можно сгруппировать следующим образом.

1. Шлихтование ровницы также подтверждает, что в случае приготовления шлихты с более высокой концентрацией крахмала при неизменных прочих условиях шлихтования получается больший расход шлихты. Выполняя шлихтование при соответствующей вязкости, получается более высокое сопротивление истиранию и обычно более высокое сопротивление разрыву.

2. Исследуя расход шлихты в функции температуры шлихты, на кривой, отображающей происходящие процессы, можно установить два максимума. Первый максимум вызывается высокой вязкостью, а второй максимум — соответствующим образом сниженной вязкостью.

3. Характер расхода шлихты, наблюдаемый в точках указанных двух максимумов, является совершенно отличным для этих максимумов.

Максимум расхода шлихты, наблюдаемый вследствие высокой вязкости, в значительной части распределяется на поверхности ровницы. Жидкотекучая же шлихта делает

возможным частичное проникновение шлихты в ровницу. Предыдущий расход шлихты называется поверхностным расходом шлихты, а последний — полезным расходом шлихты.

Установлено, что сопротивление истиранию и сопротивление разрыву ровницы в случае полезного расхода шлихты значительно превышает эти же показатели, получающиеся при поверхностном расходе шлихты.

4. Дальнейшее повышение температуры дает в результате дальнейшее снижение вязкости. Шлихта и в этом случае проникает во внутренние слои ровницы, но вследствие действия пресс-цилиндров шлихта сниженной вязкости легко удаляется совместно с выпрессованной влагой. Кроме того на место прессования пресс-цилиндрами уносится меньшее количество шлихты сниженной вязкости.

5. Повторным шлихтованием можно добиться значительного увеличения сопротивления истиранию ровницы. (Под повторным шлихтованием подразумевается процесс, при котором ровница подвергается сушке после насыщения, затем вновь шлихтуется и сушится.)

6. Повторное шлихтование влажной ровницы, насыщенной шлихтой, не дает изменения ни в отношении сопротивления истиранию, ни в отношении сопротивления разрыву ровницы. Ровницу перед повторным шлихтованием следует освободить от излишка влаги.

7. В процессе повторного шлихтования расход шлихты в случае ровницы возрастает. В случае дальнейшего повторения шлихтования расход шлихты увеличивается еще больше, что, конечно, связано с дальнейшим ростом сопротивления истиранию и сопротивления разрыву ровницы.

8. Эффект увеличения расхода шлихты при повторном шлихтовании можно показать одинаково для шлихтования с различными по происхождению крахмалами.

ON THE NON-LINEAR ELASTICITY LAW

J. BARTA
D. ENG. SC.
BUILDING RESEARCH INSTITUTE, BUDAPEST

[Manuscript received 10th July, 1956]

Suppositions

The present paper refers to an elastic body the material of which is continuous, homogeneous and isotropic. As to the relation between stress and strain, instead of the linear elasticity law (Hooke's law), a non-linear elasticity law will be supposed. Concerning this law, we suppose the following:

1. The strain components are biunivocal functions of the stress components.

2. The strain components depend only on the stress components, and are independent of the chronological order according to which the stress components vary from zero to their final values.

3. The principal directions of strain coincide with those of stress, and the equations

$$\left.\begin{aligned} \varepsilon_1 &= H(\sigma_1, \sigma_2, \sigma_3), \\ \varepsilon_2 &= H(\sigma_2, \sigma_3, \sigma_1), \\ \varepsilon_3 &= H(\sigma_3, \sigma_1, \sigma_2) \end{aligned}\right\} \qquad \text{(a)}$$

express the relation between the strain components and stress components. $H(\, , \,)$ is the symbol for the function of three variables which characterizes the elastic behaviour of the material.

4. The funtion H is of this kind:

a) It corresponds to the suppositions 1 and 2.

b) It is symmetrical with respect to the second and third variables, that is

$$H(\sigma_1, \sigma_2, \sigma_3) = H(\sigma_1, \sigma_3, \sigma_2). \qquad \text{I}$$

c) The small increasing (decreasing) of any stress produces a lengthening (shortening) in its own direction, and a shortening (lengthening) perpendicularly to its direction.

d) The small increasing (decreasing) of any principal stress produces an increasing (decreasing) of the specific volume.

In the present paper we do not criticize our suppositions. Of course in the case of homogeneous linear function H, our elasticity law is identical with the Hooke's law.

Inferences

We want now to deduce a few inferences from the above suppositions. Firstly, let us consider the strain energy stored in the elastic body, when the principal stresses increase from zero to their final values σ_1, σ_2, σ_3. The intermediate values of the principal stresses will be denoted by σ_1', σ_2', σ_3'. By computing the work done by the stresses acting on the surfaces of an elementary rectangular prism, we obtain that the strain energy per unit volume is*

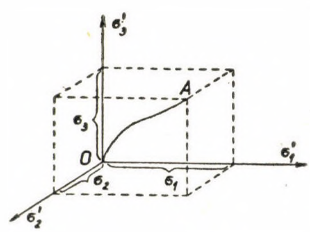


Fig. 1

$$\int_0^A \Big\{ \left[H_1(\sigma_1', \sigma_2', \sigma_3')\,\sigma_1' + H_3(\sigma_2', \sigma_3', \sigma_1')\,\sigma_2' + H_2(\sigma_3', \sigma_1', \sigma_2')\,\sigma_3'\right] d\sigma_1' +$$
$$+ \left[H_2(\sigma_1', \sigma_2', \sigma_3')\,\sigma_1' + H_1(\sigma_2', \sigma_3', \sigma_1')\,\sigma_2' + H_3(\sigma_3', \sigma_1', \sigma_2')\,\sigma_3'\right] d\sigma_2' +$$
$$+ \left[H_3(\sigma_1', \sigma_2', \sigma_3')\,\sigma_1' + H_2(\sigma_2', \sigma_3', \sigma_1')\,\sigma_2' + H_1(\sigma_3', \sigma_1', \sigma_2')\,\sigma_3'\right] d\sigma_3' \Big\}\,.$$

The variation of σ_1', σ_2', σ_3' is shown in Fig. 1. According to supposition 2, the state of strain depends only on the final state of stress. In consequence of this, the final strain energy depends also on the final state of stress only. Hence, the value of the integral must be independent of the path joining the point O with the point A. Thus, if the expressions in square brackets will be denoted by S_1, S_2, S_3, then we have

$$\frac{\partial S_1}{\partial \sigma_2'} = \frac{\partial S_2}{\partial \sigma_1'}\,, \qquad \frac{\partial S_1}{\partial \sigma_3'} = \frac{\partial S_3}{\partial \sigma_1'}\,, \qquad \frac{\partial S_2}{\partial \sigma_3'} = \frac{\partial S_3}{\partial \sigma_2'}\,.$$

* The symbols H_1, H_2, H_3 signify the differential quotients of the function H with respect to the first, second, third variables. Thus, f. ex.

$$H_3(\sigma_2', \sigma_3', \sigma_1') = \frac{\partial}{\partial \sigma_1'} H(\sigma_2', \sigma_3', \sigma_1')\,.$$

After performing the differentiations, we get to the equation

$$\left.\begin{aligned} H_2(\sigma_1, \sigma_2, \sigma_3) &= H_3(\sigma_2, \sigma_3, \sigma_1)\,, \\ H_2(\sigma_2, \sigma_3, \sigma_1) &= H_3(\sigma_3, \sigma_1, \sigma_2)\,, \\ H_2(\sigma_3, \sigma_1, \sigma_2) &= H_3(\sigma_1, \sigma_2, \sigma_3)\,. \end{aligned}\right\} \qquad \mathrm{II}$$

As a consequence of I and II, we obtain

$$\left.\begin{aligned} H_2(\sigma_1, \sigma_2, \sigma_3) &= H_2(\sigma_2, \sigma_1, \sigma_3)\,, \\ &\cdots\cdots\cdots \\ H_3(\sigma_1, \sigma_2, \sigma_3) &= H_3(\sigma_3, \sigma_2, \sigma_1)\,, \\ &\cdots\cdots\cdots \end{aligned}\right\} \qquad \mathrm{III}$$

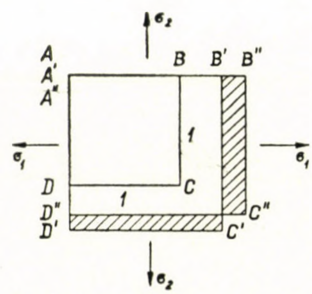


Fig. 2

It follows from supposition 4c that

$$H_1 > 0\,, \qquad H_2 < 0\,, \qquad H_3 < 0\,. \qquad \mathrm{IV}$$

Using supposition 4d, let us consider the volume of the elemental prism, which will be produced by the small variation of σ_1. For simplicity's sake, let the length of edge of the elemental rectangular prism (in unstrained state) be equal to unit. On the Fig. 2, $ABCD$ is the unstrained state, $A'B'C'D'$ is the state produced by the principal stresses σ_1, σ_2, σ_3 and $A''B''C''D''$ is the state produced by the principal stresses $\sigma_1 + d\sigma_1$, σ_2, σ_3. The changes of the lengths

$$\overline{D'C'} = 1 + H(\sigma_1, \sigma_2, \sigma_3)\,, \qquad \overline{B'C'} = 1 + H(\sigma_2, \sigma_3, \sigma_1)\,, \ldots$$

produced by $d\sigma_1$, are

$$H_1(\sigma_1, \sigma_2, \sigma_3)\, d\sigma_1\,, \qquad H_3(\sigma_2, \sigma_3, \sigma_1)\, d\,\sigma_1\,, \ldots$$

Thus, the change of the volume, shaded in Fig. 2, is

$$\{H_1(\sigma_1,\sigma_2,\sigma_3)\,[1+H(\sigma_2,\sigma_3,\sigma_1)]\cdot[1+H(\sigma_3,\sigma_1,\sigma_2)]+$$
$$+H_3(\sigma_2,\sigma_3,\sigma_1)\,[1+H(\sigma_3,\sigma_1,\sigma_2)]\cdot[1+H(\sigma_1,\sigma_2,\sigma_3)]$$
$$+H_2(\sigma_3,\sigma_1,\sigma_2)\,[1+H(\sigma_1,\sigma_2,\sigma_3)]\cdot[1+H(\sigma_2,\sigma_3,\sigma_1)]\}\,d\sigma_1\,.$$

The expression standing here in arched brackets is, by virtue of supposition 4d, positive. Introducing the notations $\overline{D'C'}=s_1$, $\overline{B'C'}=s_2$, ... we have

$$H_1(\sigma_1,\sigma_2,\sigma_3)\,s_2\,s_3+H_3(\sigma_2,\sigma_3,\sigma_1)\,s_3\,s_1+H_2(\sigma_3,\sigma_1\,\sigma_2)\,s_1\,s_2>0\,.$$

It will be supposed that the deformation of the body is small. Therefore $s_1=s_2=s_3=1$ can be written, and so we have

$$H_1(\sigma_1,\sigma_2,\sigma_3)+H_3(\sigma_2,\sigma_3,\sigma_1)+H_2(\sigma_3,\sigma_1,\sigma_2)>0\,. \qquad \text{V}$$

By means of suppositions 4c and 4d, we shall prove now that the increasing (decreasing) of a principal stress produces an increasing (decreasing) of the surface element parallel with it. In the case of positive (negative) $d\sigma_1$, we have $d(s_1,\sigma_2\,s_3)>0\ \ (<0)$, that is $s_1\,s_3\,ds_2+s_2\,d(s_1\,s_3)>0\,(<0)$. But we have $ds_2<0\,(>0)$ and therefore $s_2\,d(s_1\,s_3)>0\ \ (<0)$, that is, $d(s_1\,s_3)>0$. This property of the function H is expressed by the formulas

$$H_1(\sigma_1,\sigma_2,\sigma_3)\,s_3+H_2(\sigma_3,\sigma_1,\sigma_2)\,s_1>0\,,$$
$$H_1(\sigma_1,\sigma_2,\sigma_3)\,s_2+H_3(\sigma_2,\sigma_3,\sigma_1)\,s_1>0\,.$$

Since we have supposed that the deformation of the body is small, we write also here $s_1=s_2=s_3=1$ and in this manner we obtain

$$H_1(\sigma_1,\sigma_2,\sigma_3)+H_2(\sigma_3,\sigma_1,\sigma_2)>0\,,$$
$$H_1(\sigma_1,\sigma_2,\sigma_3)+H_3(\sigma_2,\sigma_3,\sigma_1)>0\,.$$

These two formulas can be deduced also immediately from IV and V.

It can be easily deduced from II, IV and V that the matrix

$$\begin{matrix} H_1(\sigma_1,\sigma_2,\sigma_3) & H_3(\sigma_2,\sigma_3\,\sigma_1) & H_2(\sigma_3,\sigma_1,\sigma_2) \\ H_2(\sigma_1,\sigma_2,\sigma_3) & H_1(\sigma_2,\sigma_3,\sigma_1) & H_3(\sigma_3,\sigma_1,\sigma_2) \\ H_3(\sigma_1,\sigma_2,\sigma_3) & H_2(\sigma_2,\sigma_3,\sigma_1) & H_1(\sigma_3,\sigma_1,\sigma_2) \end{matrix}$$

is symmetrical and positive definite not only for statically possible σ_1, σ_2, σ_3, but also for any σ_1, σ_2, σ_3 (property VI). The deduction can be performed f. ex.

in this manner : the matrix will be considered as a determinant, we add the second and third columns to the first column, and after that we expand the determinant in the terms of the first column.

Of course, our exposition doesn't exclude that the function possesses, in addition to properties I, II, ..., VI, also other properties. Thus, f. ex. the property

$$H(0,0,0) = 0 \qquad \text{VII}$$

is evident.

Applications

1. As an application of property VI, let the proof of the theorem of the minimum complementary strain energy be mentioned. The complementary strain energy is

$$\int\limits_{(V)} \Big\{ H(\sigma_1, \sigma_2, \sigma_3)\,\sigma_1 + H(\sigma_2, \sigma_3, \sigma_1)\,\sigma_2 + H(\sigma_3, \sigma_1, \sigma_2)\,\sigma_3 \\ - \int\limits_0^A \big[(H_1(\sigma_1', \sigma_2', \sigma_3')\,\sigma_1' + H_3(\sigma_2', \sigma_3', \sigma_1')\,\sigma_2' + H_2(\sigma_3', \sigma_1', \sigma_2')\,\sigma_3')\,d\sigma_1' + \\ + (H_2(\sigma_1', \sigma_2', \sigma_3')\,\sigma_1' + H_1(\sigma_2', \sigma_3', \sigma_1')\,\sigma_2' + H_3(\sigma_3', \sigma_1', \sigma_2')\,\sigma_3')\,d\sigma_2' + \\ + (H_3(\sigma_1', \sigma_2', \sigma_3')\,\sigma_1' + H_2(\sigma_2', \sigma_3', \sigma_1')\,\sigma_2' + H_1(\sigma_3', \sigma_1', \sigma_2')\,\sigma_3')\,d\sigma_3' \big] \Big\}\, dV \qquad \text{(b)}$$

where V is the volume. We consider the variations of this expression, produced by $\delta\sigma_1$, $\delta\sigma_2$, $\delta\sigma_3$. The first variation is

$$\int\limits_{(V)} \Big\{ H(\sigma_1, \sigma_2, \sigma_3)\,\delta\sigma_1 + H(\sigma_2, \sigma_3, \sigma_1)\,\delta\sigma_1 + H(\sigma_3, \sigma_1, \sigma_2)\,\delta\sigma_3 \Big\}\, dV\,. \qquad \text{(c)}$$

It may be shown that in consequence of the equilibrium and boundary conditions, the value of (c) is zero. The second variation is

$$\int\limits_{(V)} \Big\{ \big[H_1(\sigma_1, \sigma_2, \sigma_3)\,\delta\sigma_1 + H_3(\sigma_2, \sigma_3, \sigma_1)\,\delta\sigma_2 + H_2(\sigma_3, \sigma_1, \sigma_2)\,\delta\sigma_3\big]\,\delta\sigma_1 \\ + \big[H_2(\sigma_1, \sigma_2, \sigma_3)\,\delta\sigma_1 + H_1(\sigma_2, \sigma_3, \sigma_1)\,\delta\sigma_2 + H_3(\sigma_3, \sigma_1, \sigma_2)\,\delta\sigma_3\big]\,\delta\sigma_2 \\ + \big[H_3(\sigma_1, \sigma_2, \sigma_3)\,\delta\sigma_1 + H_2(\sigma_2, \sigma_3, \sigma_1)\,\delta\sigma_2 + H_1(\sigma_3, \sigma_1, \sigma_2)\,\delta\sigma_3\big]\,\delta\sigma_3 \Big\}\, dV$$

The value of this expression is, in consequence of the property VI, positive. And, what is more, the expression standing here in arched brackets is positive not only for the statically possible $\delta\sigma_1$, $\delta\sigma_2$, $\delta\sigma_3$, but also for any $\delta\sigma_1$, $\delta\sigma_2$, $\delta\sigma_3$ (property VIII). This ascertainment will be employed in the Appendix.

2. Let us consider now the expression (b) by means of which the complementary strain energy was defined. The value of this expression depends on $\sigma_1, \sigma_2, \sigma_3$. We want to prove that the value of expression (b) is positive, not only for statically possible $\sigma_1, \sigma_2, \sigma_3$, but also for any $\sigma_1, \sigma_2, \sigma_3$ (merely for $\sigma_1 = \sigma_2 = \sigma_3 = 0$, the value of expression (b) becomes zero). To carry out the proof, instead of $\sigma_1, \sigma_2, \sigma_3$, the parameter λ will be introduced, by substituting $\sigma_1 = k_1 \lambda$, $\sigma_2 = k_2 \lambda$, $\sigma_3 = k_3 \lambda$, (k_1, k_2, k_3 are constant) into expression (b). After this substitution the value e of expression (b) will depend on λ only. We can easily imagine the graph $e = e(\lambda)$ (Fig. 3). It is, by virtue of property VIII, concave. In consequence of VII, we have $e(0) = 0$. From (c) and VII, we have also $[de/d\lambda]_{\lambda=0} = 0$. From these, the inequality $e > 0$ appears.

3. P. CSONKA in his paper (Acta Technica Academiae Scientiarum Hungaricae, tomus XVIII, in print) has dealt with the case where the strain components $\varepsilon_x, \varepsilon_y, \varepsilon_z$ depend on the normal stresses $\sigma_x, \sigma_y, \sigma_z$, the strain components $\gamma_{xy}, \gamma_{yz}, \gamma_{zx}$ depend only on the shearing stresses $\tau_{xy}, \tau_{yz}, \tau_{zx}$. He points out that in this case the elasticity equations have the form

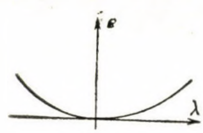


Fig. 3

$$\left.\begin{aligned}
\varepsilon_x &= \frac{1}{2G}\sigma_x + F(\sigma_x + \sigma_y + \sigma_z)\,,\\
\varepsilon_y &= \frac{1}{2G}\sigma_y + F(\sigma_x + \sigma_y + \sigma_z)\,,\\
\varepsilon_z &= \frac{1}{2G}\sigma_z + F(\sigma_x + \sigma_y + \sigma_z)\,,\\
\gamma_{xy} &= \frac{1}{G}\tau_{xy}\,,\\
\gamma_{yz} &= \frac{1}{G}\tau_{yz}\,,\\
\gamma_{zx} &= \frac{1}{G}\tau_{zx}\,,
\end{aligned}\right\} \qquad (d)$$

where G is constant. By applying the above proved properties of the function H, let us discuss the following question: to what restrictions is the function F subjected.

If the coordinate axes, x, y, z are taken in the directions of the principal axes, the equations (d) become

$$\varepsilon_1 = \frac{1}{2G}\sigma_1 + F(\sigma_1 + \sigma_2 + \sigma_3),$$

$$\varepsilon_2 = \frac{1}{2G}\sigma_2 + F(\sigma_1 + \sigma_2 + \sigma_3),$$

$$\varepsilon_3 = \frac{1}{2G}\sigma_3 + F(\sigma_1 + \sigma_2 + \sigma_3),$$

$$0 = 0,$$

$$0 = 0,$$

$$0 = 0.$$

Thus in the case dealt with by P. CSONKA, we have $H(\sigma_1, \sigma_2, \sigma_3) \equiv \frac{1}{2G}\sigma_1 + F(\sigma_1 + \sigma_2 + \sigma_3)$. We see already that this function possesses the properties I, II, III. From property IV

$$\frac{1}{2G} + F' > 0, \quad F' < 0$$

that is

$$-\frac{1}{2G} < F' < 0$$

follows.* From property V

$$\frac{1}{2G} + 3F' > 0$$

that is

$$-\frac{1}{6G} < F'$$

follows. Summarizing the inequalities, we see that the function F must satisfy the inequality

$$-\frac{1}{6G} < F' < 0. \tag{e}$$

APPENDIX

So far our exposition has concerned equations (a) that is the elasticity equations, which are expanded in the *strain components*. Now, let us consider the equations

$$\left.\begin{aligned} \sigma_1 &= h(\varepsilon_1, \varepsilon_2, \varepsilon_3), \\ \sigma_2 &= h(\varepsilon_2, \varepsilon_3, \varepsilon_1), \\ \sigma_3 &= h(\varepsilon_3, \varepsilon_1, \varepsilon_2), \end{aligned}\right| \tag{f}$$

* The symbol F' signifies here the differential quotient. Thus, the differential quotient of the function $F(\alpha)$, with respect to α, is denoted by $F'(\alpha)$.

that is, the equations expanded in the *stress components*. We want to deduce some properties of the function h. For this purpose we shall use only the above proved roperties of the function H, thus we shall not make further suppositions.

From (a), (f) and I

$$h(\varepsilon_1, \varepsilon_2, \varepsilon_3) = h(\varepsilon_1, \varepsilon_3, \varepsilon_2) \qquad \text{IX}$$

follows. By applying the rule for the differentiation of the function of several variables, we obtain from (a)

$$h_1(\varepsilon_1, \varepsilon_2, \varepsilon_3) = \begin{vmatrix} H_1(\sigma_2, \sigma_3, \sigma_1) & H_2(\sigma_2, \sigma_3, \sigma_1) \\ H_3(\sigma_3, \sigma_1, \sigma_2) & H_1(\sigma_3, \sigma_1, \sigma_2) \end{vmatrix} : D \,,$$

$$h_2(\varepsilon_1, \varepsilon_2, \varepsilon_3) = -\begin{vmatrix} H_2(\sigma_1, \sigma_2, \sigma_3) & H_3(\sigma_1, \sigma_2, \sigma_3) \\ H_3(\sigma_3, \sigma_1, \sigma_2) & H_1(\sigma_3, \sigma_1, \sigma_2) \end{vmatrix} : D \,,$$

$$h_3(\varepsilon_2, \varepsilon_3, \varepsilon_1) = -\begin{vmatrix} H_3(\sigma_2, \sigma_3, \sigma_1) & H_2(\sigma_2, \sigma_3, \sigma_1) \\ H_2(\sigma_3, \sigma_1, \sigma_2) & H_1(\sigma_3, \sigma_1, \sigma_2) \end{vmatrix} : D \,,$$

where

$$D = \begin{vmatrix} H_1(\sigma_1, \sigma_2, \sigma_3) & H_2(\sigma_1, \sigma_2, \sigma_3) & H_3(\sigma_1, \sigma_2, \sigma_3) \\ H_3(\sigma_2, \sigma_3, \sigma_1) & H_1(\sigma_2, \sigma_3, \sigma_1) & H_2(\sigma_2, \sigma_3, \sigma_1) \\ H_2(\sigma_3, \sigma_1, \sigma_2) & H_3(\sigma_3, \sigma_1, \sigma_2) & H_1(\sigma_3, \sigma_1, \sigma_2) \end{vmatrix} .$$

From this and from the properties of the function H, it can be seen that

$$\left.\begin{aligned} h_2(\varepsilon_1, \varepsilon_2, \varepsilon_3) &= h_3(\varepsilon_2, \varepsilon_3, \varepsilon_1) \,, \\ h_2(\varepsilon_2, \varepsilon_3, \varepsilon_1) &= h_3(\varepsilon_3, \varepsilon_1, \varepsilon_2) \,, \\ h_2(\varepsilon_3, \varepsilon_1, \varepsilon_2) &= h_3(\varepsilon_1, \varepsilon_2, \varepsilon_3) \,, \end{aligned}\right\} \qquad \text{X}$$

$$\left.\begin{aligned} h_2(\varepsilon_1, \varepsilon_2, \varepsilon_3) &= h_2(\varepsilon_2, \varepsilon_1, \varepsilon_3) \,, \\ &\cdots\cdots\cdots \\ h_3(\varepsilon_1, \varepsilon_2, \varepsilon_3) &= h_3(\varepsilon_3, \varepsilon_2, \varepsilon_1) \,, \\ &\cdots\cdots\cdots \end{aligned}\right\} \qquad \text{XI}$$

$$h_1 > 0 \,, \qquad h_2 > 0 \,, \qquad h_3 > 0 \,. \qquad \text{XII}$$

We have already proved above that the second variation of the complementary strain is positive. If the function h is used, the complementary strain energy will be

$$\int_{(V)} \Big\{ h(\varepsilon_1, \varepsilon_2, \varepsilon_3)\, \varepsilon_1 + h(\varepsilon_2, \varepsilon_3, \varepsilon_1)\, \varepsilon_2 + h(\varepsilon_3, \varepsilon_1, \varepsilon_2)\, \varepsilon_3$$

$$- \int_0^A \left[h(\varepsilon', \varepsilon_2', \varepsilon_3')\, \delta\varepsilon_1' + h(\varepsilon_2', \varepsilon_3', \varepsilon_1')\, \delta\varepsilon_2' + h(\varepsilon_3', \varepsilon_1', \varepsilon_2')\, \delta\varepsilon_3' \right] \Big\} dV \,.$$

The second variation of this is

$$\int_{(V)} \Big\{ \big[h_1(\varepsilon_1, \varepsilon_2, \varepsilon_3)\,\delta\varepsilon_1 + h_3(\varepsilon_2, \varepsilon_3, \varepsilon_1)\,\delta\varepsilon_2 + h_2(\varepsilon_3, \varepsilon_1, \varepsilon_2)\,\delta\varepsilon_3\big]\,\delta\varepsilon_1 + \big[h_2(\varepsilon_1, \varepsilon_2, \varepsilon_3)\,\delta\varepsilon_1 + h_1(\varepsilon_2, \varepsilon_3, \varepsilon_1)\,\delta\varepsilon_2 + h_3(\varepsilon_3, \varepsilon_1, \varepsilon_2)\,\delta\varepsilon_3\big]\,\delta\varepsilon_2 + \big[h_3(\varepsilon_1, \varepsilon_2, \varepsilon_3)\,\delta\varepsilon_1 + h_2(\varepsilon_2, \varepsilon_3, \varepsilon_1)\,\delta\varepsilon_2 + h_1(\varepsilon_3, \varepsilon_1, \varepsilon_2)\,\delta\varepsilon_3\big]\,\delta\varepsilon_3 \Big\}\, dV\,.$$

The expression standing here in arched brackets is positive for any $\delta\varepsilon_1$, $\delta\varepsilon_2$, $\delta\varepsilon_3$. To justify this statement, it is sufficient to mention on the one hand ascertainment VIII, on the other hand the fact that by virtue of (a) and (f) to any system $\delta\varepsilon_1$, $\delta\varepsilon_2$, $\delta\varepsilon_3$ belongs a certain system $\delta\sigma_1$, $\delta\sigma_2$, $\delta\sigma_3$. From the statement and from X it follows that the matrix

$$\begin{matrix} h_1(\varepsilon_1, \varepsilon_2, \varepsilon_3) & h_3(\varepsilon_2, \varepsilon_3, \varepsilon_1) & h_2(\varepsilon_3, \varepsilon_1, \varepsilon_2) \\ h_2(\varepsilon_1, \varepsilon_2, \varepsilon_3) & h_1(\varepsilon_2, \varepsilon_3, \varepsilon_1) & h_3(\varepsilon_3, \varepsilon_1, \varepsilon_2) \\ h_3(\varepsilon_1, \varepsilon_2, \varepsilon_3) & h_2(\varepsilon_2, \varepsilon_3, \varepsilon_1) & h_1(\varepsilon_3, \varepsilon_1, \varepsilon_2) \end{matrix}$$

is symmetrical and positive definite not only for geometrically possible ε_1, ε_2, ε_3, but also for any ε_1, ε_2, ε_3 (property XIII). Finally, we mention that the property

$$h(0,0,0) = 0 \qquad \text{XIV}$$

is evident.

SUMMARY

The elasticity law of an elastic material, which does not obey the Hooke's law, will be written in the form $\varepsilon_1 = H(\sigma_1, \sigma_2, \sigma_3)$, $\varepsilon_2 = H(\sigma_2, \sigma_3, \sigma_1)$, $\varepsilon_3 = H(\sigma_3, \sigma_1, \sigma_2)$, that is $\sigma_1 = h(\varepsilon_1, \varepsilon_2, \varepsilon_3)$, $\sigma_2 = h(\varepsilon_2, \varepsilon_3, \varepsilon_1)$, $\sigma_3 = h(\varepsilon_3, \varepsilon_1, \varepsilon_2)$. Starting from plausible suppositions, the author deduces some properties of the functions H and h. Properties VI and XIII express the following: both the matrix

$$\begin{matrix} \partial\varepsilon_1/\partial\sigma_1 & \partial\varepsilon_2/\delta\sigma_1 & \partial\varepsilon_3/\partial\sigma_1 \\ \partial\varepsilon_1/\partial\sigma_2 & \partial\varepsilon_2/\partial\sigma_2 & \partial\varepsilon_3/\partial\sigma_2 \\ \partial\varepsilon_1/\partial\sigma_3 & \partial\varepsilon_2/\partial\sigma_3 & \partial\varepsilon_3/\partial\sigma_3 \end{matrix}$$

and the matrix

$$\begin{matrix} \partial\sigma_1/\partial\varepsilon_1 & \partial\sigma_2/\partial\varepsilon_1 & \partial\sigma_3/\partial\varepsilon_1 \\ \partial\sigma_1/\partial\varepsilon_2 & \partial\sigma_2/\partial\varepsilon_2 & \partial\sigma_3/\partial\varepsilon_2 \\ \partial\sigma_1/\partial\varepsilon_3 & \partial\sigma_2/\partial\varepsilon_3 & \partial\sigma_3/\partial\varepsilon_3 \end{matrix}$$

are symmetrical and positive definite.

ÜBER DAS NICHT-LINEARE ELASTIZITÄTSGESETZ

J. BARTA
Doktor der technischen Wissenschaften

ZUSAMMENFASSUNG

Das Elastizitätsgesetz des Stoffes, der dem Hookeschen Gesetze nicht gehorcht, schreibt sich in der Form $\varepsilon_1 = H(\sigma_1, \sigma_2, \sigma_3)$, $\varepsilon_2 = H(\sigma_2, \sigma_3, \sigma_1)$, $\varepsilon_3 = H(\sigma_3, \sigma_1, \sigma_2)$, d. h. $\sigma_1 = h(\varepsilon_1, \varepsilon_2, \varepsilon_3)$, $\sigma_2 = h(\varepsilon_2, \varepsilon_3, \varepsilon_1)$, $\sigma_3 = h(\sigma_3, \sigma_1, \sigma_2)$. Ausgehend von plausiblen Voraussetzungen, leitet der Verfasser einige Eigenschaften der Funktionen H und h her. Diese Eigenschaften sind mit Nummern I, II, . . . , XIV bezeichnet. Die Eigenschaften VI und XIII sagen folgendes aus: sowohl die Matrix

$$\begin{matrix} \partial\varepsilon_1/\partial\sigma_1 & \partial\varepsilon_2/\partial\sigma_1 & \partial\varepsilon_3/\partial\sigma_1 \\ \partial\varepsilon_1/\partial\sigma_2 & \partial\varepsilon_2/\partial\sigma_2 & \partial\varepsilon_3/\partial\sigma_2 \\ \partial\varepsilon_1/\partial\sigma_3 & \partial\varepsilon_2/\partial\sigma_3 & \partial\varepsilon_3/\partial\sigma_3 \end{matrix}$$

als auch die Matrix

$$\begin{matrix} \partial\sigma_1/\partial\varepsilon_1 & \partial\sigma_2/\partial\varepsilon_1 & \partial\sigma_3/\partial\varepsilon_1 \\ \partial\sigma_1/\partial\varepsilon_2 & \partial\sigma_2/\partial\varepsilon_2 & \partial\sigma_3/\partial\varepsilon_2 \\ \partial\sigma_1/\partial\varepsilon_3 & \partial\sigma_2/\partial\varepsilon_3 & \partial\sigma_3/\partial\varepsilon_3 \end{matrix}$$

ist symmetrisch und positiv definit.

SUR LA LOI NON-LINÉAIRE DE L'ÉLASTICITÉ

J. BARTA
Docteur des sc. techn.

RÉSUMÉ

La loi d'élasticité des matériaux qui n'obéissent pas à la loi de Hooke, sera écrite sous la forme $\varepsilon_1 = H(\sigma_1, \sigma_2, \sigma_3)$, $\varepsilon_2 = H(\sigma_2, \sigma_3, \sigma_1)$, $\varepsilon_3 = H(\sigma_3, \sigma_1, \sigma_2)$, c'est-à-dire $\sigma_1 = h(\varepsilon_1, \varepsilon_2, \varepsilon_3)$, $\sigma_2 = h(\varepsilon_2, \varepsilon_3, \varepsilon_1)$, $\sigma_3 = h(\varepsilon_3, \varepsilon_1, \varepsilon_2)$. En partant de suppositions plausibles, l'auteur déduit quelques propriétés des fonctions H et h. Les propriétés déduites sont numérotées par I, II, . . ., XIV. Les propriétés VI et XIII disent : la matrice

$$\begin{matrix} \partial\varepsilon_1/\partial\sigma_1 & \partial\varepsilon_2/\partial\sigma_1 & \partial\varepsilon_3/\partial\sigma_1 \\ \partial\varepsilon_1/\partial\sigma_2 & \partial\varepsilon_2/\partial\sigma_2 & \partial\varepsilon_3/\partial\sigma_2 \\ \partial\varepsilon_1/\partial\sigma_3 & \partial\varepsilon_2/\partial\sigma_3 & \partial\varepsilon_3/\partial\sigma_3 \end{matrix}$$

comme la matrice

$$\begin{matrix} \partial\sigma_1/\partial\varepsilon_1 & \partial\sigma_2/\partial\varepsilon_1 & \partial\sigma_3/\partial\varepsilon_1 \\ \partial\sigma_1/\partial\varepsilon_2 & \partial\sigma_2/\partial\varepsilon_2 & \partial\sigma_3/\partial\varepsilon_2 \\ \partial\sigma_1/\partial\varepsilon_3 & \partial\sigma_2/\partial\varepsilon_3 & \partial\sigma_3/\partial\varepsilon_3 \end{matrix}$$

est symétrique et définie positive.

О НЕЛИНЕЙНЫХ ЗАКОНАХ ЭЛАСТИЧНОСТИ

Д-р техн. наук Й. БАРТА

РЕЗЮМЕ

Закон эластичности материалов, не удовлетворяющий закон Гука, имеет вид

$$\varepsilon_1 = H(\sigma_1, \sigma_2, \sigma_3), \quad \varepsilon_2 = H(\sigma_2, \sigma_3, \sigma_1), \quad \varepsilon_3 = H(\sigma_3, \sigma_1, \sigma_2),$$

т. е.

$$\sigma_1 = h(\varepsilon_1, \varepsilon_2, \varepsilon_3), \quad \sigma_2 = h(\varepsilon_2, \varepsilon_3, \varepsilon_1), \quad \sigma_3 = h(\sigma_3, \sigma_1, \sigma_2).$$

Исходя из вероятного предположения, автор выводит некоторые свойства функций H и h. Эти свойства обозначаются римскими цифрами I, II, . . ., XIV. Свойства VI и XIII выражают: как матрица

$$\begin{array}{ccc} \partial\varepsilon_1/\partial\sigma_1 & \partial\varepsilon_2/\partial\sigma_1 & \partial\varepsilon_3/\partial\sigma_1 \\ \partial\varepsilon_1/\partial\sigma_2 & \partial\varepsilon_2/\partial\sigma_2 & \partial\varepsilon_3/\partial\sigma_2 \\ \partial\varepsilon_1/\partial\sigma_3 & \partial\varepsilon_2/\partial\sigma_3 & \partial\varepsilon_3/\partial\sigma_3 \end{array}$$

так и матрица

$$\begin{array}{ccc} \partial\sigma_1/\partial\varepsilon_1 & \partial\sigma_2/\partial\varepsilon_1 & \partial\sigma_3/\partial\varepsilon_1 \\ \partial\sigma_1/\partial\varepsilon_2 & \partial\sigma_2/\partial\varepsilon_2 & \partial\sigma_3/\partial\varepsilon_2 \\ \partial\sigma_1/\partial\varepsilon_3 & \partial\sigma_2/\partial\varepsilon_3 & \partial\sigma_3/\partial\varepsilon_3 \end{array}$$

симметрично и положительно дефинитны.

ON THE MINIMUM WEIGHT OF CERTAIN REDUNDANT STRUCTURES

J. BARTA
D. ENG. SC.
BUILDING RESEARCH INSTITUTE, BUDAPEST

[Manuscript received 11st July 1956]

The present paper refers to the designing of a pin-jointed plane or space structure of n bars involving h redundancies. The geometry (network) and loading system (external forces) are given. The required cross-sectional area A_j for the jth bar is prescribed by a function

$$A_j = A_j(F_j), \qquad (j = 1, \ldots, n). \tag{1}$$

F_j is the force in the jth bar. The positive value of F_j denotes a tensile force. The negative value of F_j denotes a compressive force. Let the function (1) have the following properties:

α) It is continuous.

β) It vanishes for $F_j = 0$.

γ) It is positive for $F_j \neq 0$.

δ) It is monotonously increasing, if $|F_j|$ is monotonously increasing.

ε) It is not concave (seen from above), excepting the origin (Fig. 1).

It is obvious that by proper selection of the cross-sectional areas the weight of structure can be made a minimum. The object of the present paper is to prove the following *theorem:* by removing h properly chosen redundant bars from the given network, it is possible to obtain such a statically determinate structure, which yields the least weight of structure.

G. Sved, in his paper [1], dealing with the same theorem, restricts himself to the particular case, where the prescribed function $A_j = A_j(F_j)$ consists of two straight lines (Fig. 2). The proving method of the present paper differs essentially from that of G. Sved.

Explanatory example

The network and the loading forces of a cantilevered pin-jointed structure are given in Fig. 3. The structure consists of eight bars numbered by $j = 1, \ldots, 8$. For all bars, the specific weight

$$\varrho = 0{,}01,$$

the allowable tensile stress

$$\sigma_{tj} = 3 \tag{2}$$

and the allowable compressive stress

$$\sigma_{cj} = \begin{cases} 3 - 0.02 \dfrac{l_j}{i_j} & \text{for} \quad \dfrac{l_j}{i_j} \leq 100\,, \quad (3) \\[2ex] \dfrac{10\,000}{\left(\dfrac{l_j}{i_j}\right)^2} & \text{for} \quad \dfrac{l_j}{i_j} \geq 100 \quad (4) \end{cases}$$

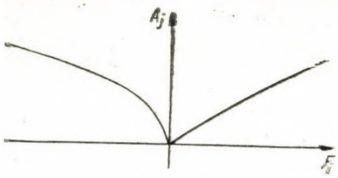


Fig. 1

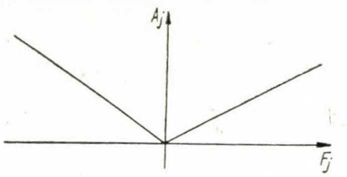


Fig. 2

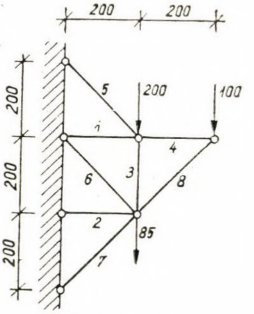


Fig. 3

are prescribed. i_j is the radius of gyration, l_j is the length of the jth bar. $\dfrac{l_j}{i_j}$ is the slenderness ratio. Let the cross-sections be circles. Our task is to design the circular cross-sectional areas so that the weight of structure should be a minimum.

In order to accomplish the task we apply the formulas

$$A_j = \pi r_j^2\,, \qquad i_j = r_j/2 \tag{5}$$

referring to the circle, and the formulas

$$F_j = \begin{cases} A_j \sigma_{tj}\,, & (6) \\ -A_j \sigma_{cj}\,. & (7) \end{cases}$$

By using formulas (2), (3), (4), (5), (6), (7) we easily find the following values :

	r_j	A_j	i_j	l_j	l_j/i_j	σ_{tj}	σ_{cj}	F	
$j = 1, 2, 3, 4$	3,0	28,3	1,5	200	133,3	3	0,563	84,9	— 15,9
	4,0	50,3	2,0	200	100,0	3	1,000	150,9	— 50,3
	5,0	78,5	2,5	200	80,0	3	1,400	235	— 110,0
	6,0	113,1	3,0	200	66,6	3	1,668	339	— 188,5
	7,0	153,9	3,5	200	57,2	3	1,856	461	— 286
	8,0	201	4,0	200	50,0	3	2,00	603	— 402
	9,0	284	4,5	200	44,5	3	2,11	852	— 599
$j = 5, 6, 7, 8$	3,0	28,3	1,5	283	188,8	3	0,281	84,9	— 7,93
	4,0	50,3	2,0	283	141,4	3	0,501	150,9	— 25,2
	5,0	78,5	2,5	283	113,1	3	0,781	235	— 61,3
	6,0	113,1	3,0	283	93,3	3	1,134	339	— 128,3
	7,0	153,9	3,5	283	80,7	3	1,386	462	— 213
	8,0	201	4,0	283	70,7	3	1,586	603	— 320
	9,0	284	4,5	283	62,8	3	1,744	852	— 494

The values A_j and F_j obtained here, are plotted in Fig. 4.

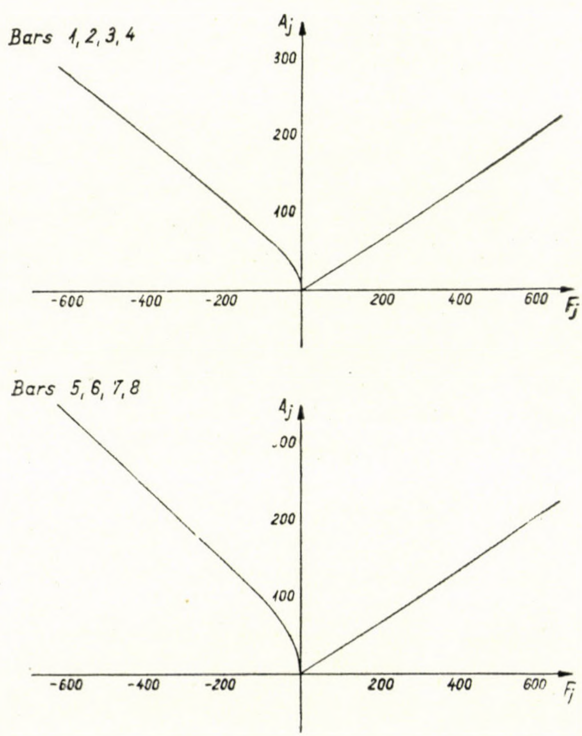


Fig. 4

As we see, these diagrams possess the properties α, β, γ, δ, ε. Consequently, the theorem above formulated holds now. By virtue of the theorem, we may consider, instead of the given statically indeterminate system, the statically determinate systems only. Thus we have to scrutinize all the statically determinate systems (Fig. 5) which arise when two redundant bars are removed from the given network. These systems are numbered from I to XII. A very simple equilibrium consideration yields the forces F_j of each statically determinate system. These values are the following :

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
F_1	—	—	—	−100	100	−185	−385	−100	−100	100	100	−285
F_2	—	185	−385	—	—	—	—	85	−285	285	−485	−100
F_3	−100	−100	−100	—	200	85	285	—	—	−200	−200	185
F_4	100	100	100	100	100	100	100	100	100	100	100	100
F_5	141	141	141	283	—	403	686	283	283	—	—	544
F_6	131	—	403	60	201	—	−141	—	261	—	544	—
F_7	−272	−403	—	−201	−343	−141	—	−261	—	−544	—	—
F_8	−141	−141	−141	−141	−141	−141	−141	−141	−141	−141	−141	−141

The required cross-sectional areas A_j belonging to these values, are to be taken from Fig. 4, and so we find :

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
A_1	—	—	—	74	33	112	194	74	74	33	33	153
A_2	—	62	194	—	—	—	—	28	153	95	235	74
A_3	74	74	74	—	118	28	95	—	—	118	118	62
A_4	33	33	33	33	33	33	33	33	33	33	33	33
A_5	47	47	47	94	—	134	229	94	94	—	—	181
A_6	44	—	134	20	67	—	119	—	87	—	181	—
A_7	180	241	—	147	213	119	—	175	—	306	—	—
A_8	119	119	119	119	119	119	119	119	119	119	119	119

By using the given values ϱ_j and l_j we obtain :

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
$\varrho_1 l_1 A_1$	—	—	—	148	66	224	388	148	148	66	66	306
$\varrho_2 l_2 A_2$	—	124	388	—	—	—	—	56	306	190	270	148
$\varrho_3 l_3 A_3$	148	148	148	—	226	56	190	—	—	226	226	124
$\varrho_4 l_4 A_4$	66	66	66	66	66	66	66	66	66	66	66	66
$\varrho_5 l_5 A_5$	133	133	133	266	—	379	648	266	266	—	—	512
$\varrho_6 l_6 A_6$	124	—	379	57	190	—	337	—	246	—	512	—
$\varrho_7 l_7 A_7$	509	682	—	416	602	337	—	495	—	865	—	—
$\varrho_8 l_8 A_8$	337	337	337	337	337	337	337	337	337	337	337	337
	1317	1490	1451	1290	1487	1399	1966	1368	1369	1750	1477	1493

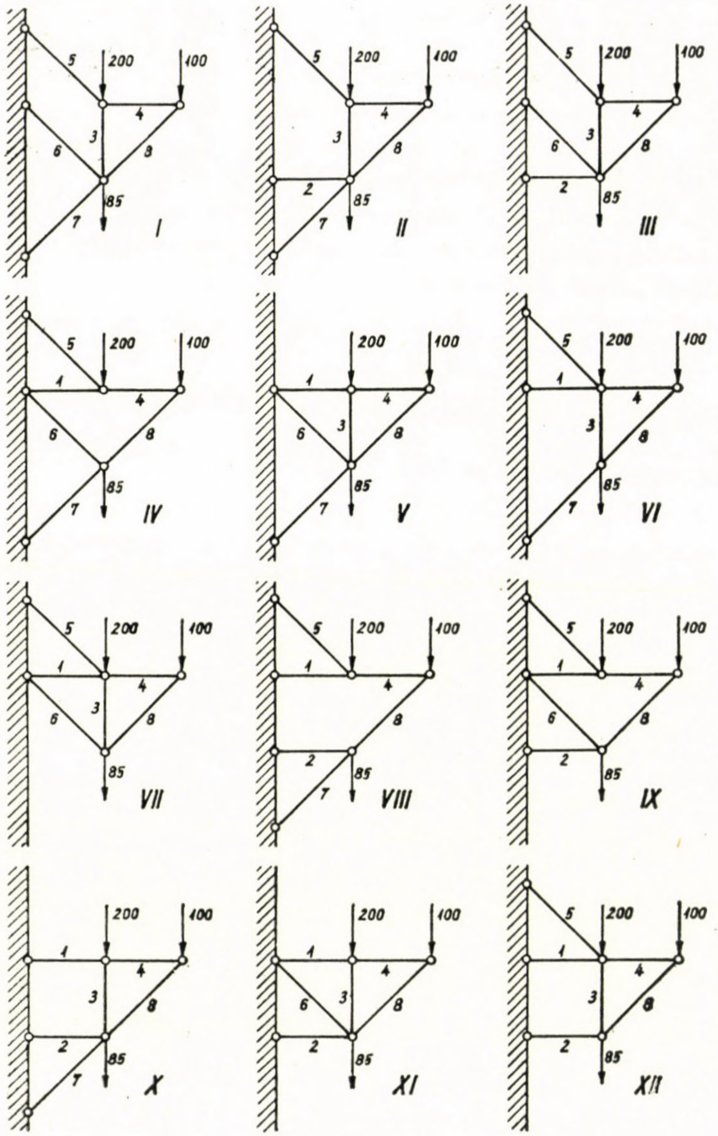


Fig. 5

We see that the statically determinate system IV yields the least sum. From these and from the theorem we conclude that by removing the bars 2 and 3 from the given network, the least weight of structure will be obtained.

The proof of the theorem

Let us imagine that a pin-jointed structure of n bars involving h redundancies is to be designed (in Fig. 3, for instance, we have $n = 8$ and $h = 2$). The network and the loading forces are given. The allowable forces of the bars are prescribed by means of formulas (1). We denote the weight of structure by W.

If the structure is so designed that the loading forces produce the forces $F_1, \ldots, F_n$ in the ba s, then we have the relation

$$W \geqq \varrho_1 l_1 A_1(F_1) + \ldots + \varrho_n l_n A_n(F_n) . \tag{8}$$

$\varrho_1, \ldots, \varrho_n$ are the specific weights of the bars. $l_1, \ldots, l_n$ are the lengths of the bars. The weight of end-connections are disregarded throughout the present paper.

Let the n bars be divided into three groups and numbered in the following manner.* The bars numbered by $1, \ldots, h, h + 1, \ldots, k$ are members the forces of which are statically indeterminate. The bars numbered by

$$1, \ldots, h$$

are the members which will be chosen as redundant members. These bars form the first group. Of course, this choice is more or less arbitrary.** The bars numbered by

$$h + 1, \ldots, k$$

form the second group. The bars numbered by

$$k + 1, \ldots, n$$

are the members the forces of which are statically determinate. These bars form the third group.*** Thus, instead of (8), we write

$$\begin{aligned} W \geqq & \varrho_1 l_1 A_1(F_1) + \ldots + \varrho_h l_h A_h(F_h) \\ & + \varrho_{h+1} l_{h+1} A_{h+1}(F_{h+1}) + \ldots + \varrho_k l_k A_k(F_k) \\ & + \varrho_{k+1} l_{k+1} A_{k+1}(F_{k+1}) + \ldots + \varrho_n l_n A_n(F_n) . \end{aligned} \tag{9}$$

A well-known relation between the values $F_1, \ldots, F_h$ and $F_{h+1}, \ldots, F_k$ is expressed by the linear equations

* This dividing into groups and this numbering serve only for the proving.

** In Fig. 3, for instance, where the numbering system serving for proving, is not applied, twelve such choices are possible, namely 12, 16, 17, 23, 25, 26, 27, 36, 37, 56, 57, 67.

*** In Fig. 3, for instance, the third group consists of two bars, namely 4 and 8.

$$\left.\begin{aligned} F_{h+1} &= c_{(h+1)1} F_1 + \ldots + c_{(h+1)h} F_h + F_{(h+1)0} \\ &\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \\ F_k &= c_{k1} F_1 + \ldots + c_{kh} F_h + F_{k0} \end{aligned}\right\} \tag{10}$$

where the coefficients $c_{(h+1)1}, \ldots, c_{kh}$ and the terms $F_{(h+1)0}, \ldots, F_{k0}$ are constants. These equations are a consequence of the equilibrium condition. From the point of view of the equilibrium, the values $F_1, \ldots, F_h$ can be arbitrarily chosen. But, after that, the values $F_{h+1}, \ldots, F_k$ are to be taken into account according to equations (10). From the point of view of the strain, the values $F_1, \ldots, F_h$ can't be arbitrarily chosen, because they must satisfy the strain condition.* For the time being, we shall neglect the strain condition.

Thus, for the time being, $F_1, \ldots, F_h$ may be freely chosen, and $F_{h+1}, \ldots, F_k$ are to be taken into account according to equations (10). Therefore, the right side of relation (9) can be regarded as a function of $F_1, \ldots, F_h$, and we require that $F_1, \ldots, F_h$ should make the right side of relation (9) a minimum (minimum requirement R).

Let us suppose now that the proportion of the values $F_1, \ldots, F_h$ satisfying the requirement R, are already known. Hence, we may write

$$F_1 = f_1 \lambda, \ldots, F_h = f_h \lambda,$$

where $f_1, \ldots, f_h$ are constants, λ is a parameter. Introducing these into (10) we obtain

$$\begin{aligned} F_{h+1} &= C_{h+1} \lambda + F_{(h+1)0}, \\ &\ldots\ldots\ldots\ldots\ldots\ldots \\ F_k &= C_k \lambda + F_{k0}, \end{aligned}$$

where $C_{h+1}, \ldots, C_k$ are also constants. Consequently, the right side of relation (9) becomes

$$\begin{aligned} &\varrho_1 l_1 A_1 (f_1 \lambda) + \ldots + \varrho_h l_h A_h (f_h \lambda) \\ &+ \varrho_{h+1} l_{h+1} A_{h+1} (C_{h+1} \lambda + F_{(h+1)0}) + \ldots + \varrho_k l_k A_k (C_k \lambda + F_{k0}) \\ &+ \varrho_{k+1} l_{k+1} A_{k+1} (F_{k+1}) + \ldots + \varrho_n l_n A_n (F_n). \end{aligned} \tag{11}$$

We see here that the arguments of the functions $A_1, \ldots, A_n$ depend linearly on λ, or else, they are constants. Let us consider the variation of the value of expression (11). By this consideration, we may obviously disregard the particular case, where the value of expression does not depend on λ. If λ is very great $(+\infty)$ or very small $(-\infty)$, then the value of the expression is very great. It

* For an elastic structure, which obeyes HOOKE's law the theory of elasticity [2] yields the strain condition.

follows thus from the continuity of the functions $A_1, \ldots, A_n$ that for a certain value of λ, the value of expression becomes minimum. In order to find this value of λ, the following procedure may be applied. λ will be continuously increased starting from $-\infty$ and going towards $+\infty$. Meanwhile, the value of expression (11) will vary continuously, and λ will assume all its particular values $\lambda_1, \ldots, \lambda_m$ for which the value of one or more terms of expression (11) vanishes. Let us consider two such values $\lambda_\nu, \lambda_{\nu+1}$ which follow one after the other immediately. When the value of λ varies from λ_ν to $\lambda_{\nu+1}$ then the value of each function A_j in expression (11) varies according to an arc ν, $(\nu + 1)$ shown in Fig. 6.

On the other hand, if the value of the function A_j varied, instead of the arc $\nu\,(\nu + 1)$, according to the chord $\nu\,(\nu + 1)$, then the value of expression (11) as a function of λ will vary linearly, and in this case, in the interval $(\lambda_\nu, \lambda_{\nu+1})$, expression (11) will assume its least value either for λ_ν or for $\lambda_{\nu+1}$. Since the arc

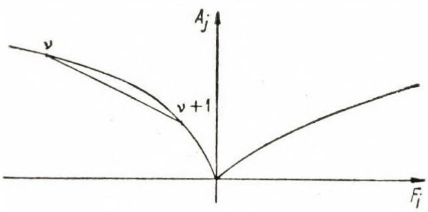


Fig. 6

has greater (or at least not lesser) ordinates than the chord, we see that the value of expression (11) becomes minimum for one of the values $\lambda_1, \ldots, \lambda_m$. Let this be denoted by λ_μ.

If the terms $\varrho_1 l_1 A_1(f_1 \lambda), \ldots, \varrho_h l_h A_h(f_h \lambda)$ are those which vanish for λ_μ, then we have $\lambda_\mu = 0$, that is

$$F_1 = \ldots = F_h = 0$$

and with this, requirement R is already fulfilled.

If one (or more) of the terms $\varrho_{h+1} l_{h+1} A_{h+1} (C_{h+1} \lambda + F_{(h+1)0}) \ldots,$ $\varrho_k l_k A_k (C_k \lambda + F_{k0})$ are those which vanish for λ_μ, then the proof can be continued as follows. Let be, for instance $\varrho_{h+1} l_{h+1} A_{h+1} (C_{h+1} \lambda + F_{(h+1)0})$ that term which vanishes for λ_μ. Now we have $F_{h+1} = 0$. Thus we have found a bar the force of which is zero. The force of this bar will be denoted from now on by F_1, and according to this labelling we number over all the bars. After this we repeat the whole above train of thought, and so we still find another bar, the force of which is zero. Thus, we have already two bars, the forces of which are zero. These forces will be denoted from now on by F_1 and F_2, and according to this labelling, all the bars will be numbered over again, and so on. In this manner we get to

$$F_1 = \ldots = F_h = 0\,.$$

With this, we have demonstrated that the requirement R can always be fulfilled by a properly chosen statically determinate structure.

Up to this point we have neglected the strain condition. To supply this lack it is sufficient to mention that the strain condition is fulfilled by the result

$$F_1 = \ldots = F_h = 0 \tag{12}$$

just obtained. Indeed, if we choose $A_1 = \ldots = A_h = 0$, then a statically determinate structure remains, and the forces $F_{h+1}, \ldots, F_k$ can be computed by formulas (10) and (12). This system satisfies both the equilibrium condition and the strain condition, and — as has been pointed out — makes the weight of structure a minimum.

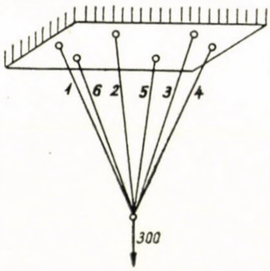


Fig. 7

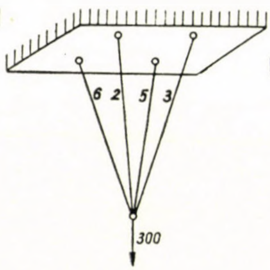


Fig. 8

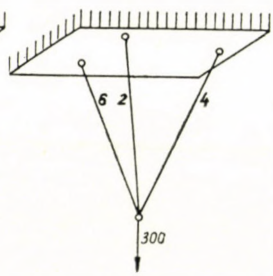


Fig. 9

Remarks

I° — Relation (8) contains both the equality sign and the inequality sign, and therefore the theorem proved in the present paper, doesn't disclaim the possibility of such particular cases where not only a statically determinate structure, but also one or more statically indeterminate structures yield the least weight of structure. The following example (Fig. 7) shows such a case. The redundant structure consists of six bars. The load consists of a given force. The allowable tensile stress is $\sigma_{tj} = 3$. The shape of the given network is a hanging regular pyramid (Fig. 7). It is easy to see that both the statically determinate structure (Fig. 9) and the statically indeterminate structures (Fig. 7 and 8) yield the least weight of structure.

II° — It is interesting to note that the proof carried out in the present paper, doesn't specify the law which expresses the relation between stress and strain. For this reason, the theorem dealt with in the present paper, is valid not only for the case of the Hooke's law, but also for the case of any stress-strain law.

REFERENCES

1. G. Sved : The minimum weight of certain redundant structures. Australian Journal of Applied Science, vol. 5, p. 1, (1954).
2. See f. ex. : Timoshenko—Goodier, Theory of elasticity. — S. Timoshenko : Strength of materials. — Timoshenko-Young : Theory of structures.

SUMMARY

The variation of weight of a pin-jointed structure of n bars involving h redundancies is investigated. The network and a fixed load system are given. For each bar, the required cross-sectional area A_j is prescribed as a well-defined function of the force F_j (Fig. 1). The following theorem will be proved: there is a combination on $n—h$ bars which forms a statically determinate structure and minimizes the weight of structure. In the particular case, where the required cross-sectional area is prescribed according to Fig. 2, the theorem was already discussed by G. Sved.

ÜBER DAS KLEINSTE GEWICHT VON STATISCH UNBESTIMMTEN FACHWERKEN

J. BARTA
Doktor der techn. Wiss.

ZUSAMMENFASSUNG

Der Verfasser untersucht die Gewichtsänderung eines Fachwerks bestehend aus n durch Gelenke verbundenen Stäben mit h Überzähligen. Das Netzwerk und eine ständige Belastung ist vorgegeben. Die notwendige Querschnittsfläche A_j eines jeden Stabes ist als eine Funktion der Kraft F_j festgelegt (Abb. 1). Der folgende Satz wird bewiesen: es gibt eine solche Kombination von $n—h$ Stäben, die ein statisch bestimmtes Fachwerk bildet und dabei das Gewicht des Fachwerks zu einem Minimum macht. Im Spezialfall, wo die notwendige Querschnittsfläche laut Abb. 2 festgelegt ist, wurde der Satz schon von G. Sved behandelt.

SUR LE POIDS MINIMUM DE CERTAINES CONSTRUCTIONS SURABONDANTES

J. BARTA
Docteur des sc. techn.

RÉSUMÉ

L'auteur étudie la variation du poids d'une structure articulée consistant de n barres avec h liaisons surabondantes. Le réseau et une surcharge fixe sont donnés. Pour chacune des barres, l'aire nécessaire A_j de la section est spécifiée comme une fonction bien déterminée de la force F_j (Fig. 1). Le théorème suivant est prouvé: il y a une combinaison de $n-h$ barres qui forme une structure statiquement déterminée et en même temps rend minimum le poids de la structure. Dans le cas spécial où l'aire nécessaire de la section est spécifiée selon Fig. 2, le même théorème fut déjà exposé par G. Sved.

О НАИМЕНЬШЕМ ВЕСЕ ОПРЕДЕЛЕННЫХ КОНСТРУКЦИЙ С НЕОПРЕДЕЛЕННЫМИ ШАРНИРНЫМИ СОЕДИНЕНИЯМИ

Д-р техн. наук Й. БАРТА

РЕЗЮМЕ

Автор исследует изменение веса шарнирной конструкции, состоящей из n стержней, соединенных с h статически неопределимыми шарнирами. Даны схема и одна неподвижная нагрузка. Необходимая площадь сечения A_f каждого стержня дана в функции силы F_j (рис. 1). Доказывается теорема: существует такая комбинация стержней n-h, которая представляет собою статически определенную конструкцию и при этом вес конструкции имеет минимум. В частном случае, когда необходимая площадь сечения определена соглано рис. 2, эта теорема уже была доказана Г. Сведом.

DIE BERECHNUNG DES MITTLEREN VERFORMUNGS-WIDERSTANDES BZW. DES WALZDRUCKES BEIM WARM- UND KALTWALZEN VON QUADRATISCHEN STANGEN- UND BLECHFÖRMIGEN KÖRPERN*

Prof. Dr. A. GELEJI
O. MITGL. D. UNG. AKADEMIE DER WISSENSCHAFTEN, BUDAPEST

[Eingegangen am 17. Januar 1957]

Zur Ermittlung des Walzdruckes und der Walzarbeit ist die Kenntnis des mittleren Verformungswiderstandes unbedingt notwendig. Zur Berechnung des mittleren Verformungswiderstandes wurden von verschiedenen Forschern zahlreiche Formeln und Rechnungsmethoden ausgearbeitet, die wiederum von anderen Autoren überprüft und den Versuchsersergebnissen gegenübergestellt wurden. In letzterer Zeit wurden solche kritische Gegenüberstellungen von Z. Wusatowski und S. Bala [1], sowie von K. H. Lucas und O. Emicke [2] durchgeführt. Diese Forscher haben sich auch mit der Formel von A. Geleji eingehend befasst. Mit Anwendung von neuem und reicherem Versuchsmaterial hat nun der Verfasser die erwähnte Formel, bzw. sein Rechnungsverfahren weiterentwickelt. Die folgenden Ausführungen enthalten die diesbezüglichen neuen Ergebnisse.

Den Ausgangspunkt bildet eine Formel, die vom Verfasser bereits im Jahre 1942 auf Grund theoretischer und experimenteller Überlegungen aufgestellt wurde, u. zw. zur Berechnung des mittleren Verformungswiderstandes beim Walzen von Stücken mit quadratischem Querschnitt, d. h. von Stangen und Blechen [3]:

$$k_m = k_f \left(1 + C \cdot \mu \cdot \frac{l_d}{h} \cdot \sqrt[n]{v} \right) . \tag{1}$$

In dieser Formel bedeuten:

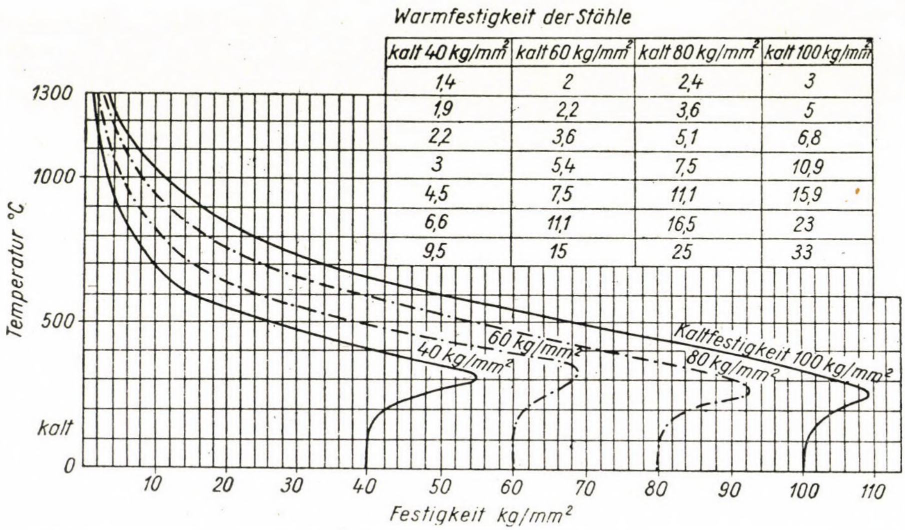
k_f die mittlere Verformungsfestigkeit des gewalzten Werkstoffes im Walzspalt, μ den mittleren Reibungskoeffizienten längs der gedrückten Flächen, l_d die gedrückte Bogenlänge. h wurde bisher der Stärke des aus dem Walzspalt auslaufenden Walzgutes h_2 gleichgesetzt und mit h_1 die Stärke des einlaufenden Walzgutes bezeichnet, es ist aber richtiger wenn h dem Quotienten $\frac{h_1 + h_2}{2}$ gleichgesetzt wird; v bedeutet die Walzgeschwindigkeit. Der Exponent n wird praktisch gleich 4 gesetzt. Der Koeffizient C wurde in erster Annäherung im Mittel mit 5,5 angenommen. Nach genauer Überprüfung erwies es sich, wie wir

* Stark ergänzter Text des am VIII. Berg- und Hüttenmännischen Tag 1956 zu Freiberg/Sa gehaltenen Vortrages.

nachstehend sehen werden, dass der Koeffizient C nicht als Konstante angenommen werden kann, sondern von dem Quotienten $\frac{l_d}{h}$ abhängig ist.

Der Einspannbogen kann beim Warmwalzen mit der einfachen Formel

$$l_{dn} = \sqrt{r \cdot (h_1 - h_2)} = \sqrt{r \cdot \Delta h} \tag{2}$$



kalt 40 kg/mm²	kalt 60 kg/mm²	kalt 80 kg/mm²	kalt 100 kg/mm²
1,4	2	2,4	3
1,9	2,2	3,6	5
2,2	3,6	5,1	6,8
3	5,4	7,5	10,9
4,5	7,5	11,1	15,9
6,6	11,1	16,5	23
9,5	15	25	33

Bild 1

berechnet werden, da hier die Abflachung der Walzen unberücksichtigt bleiben darf. In dieser Formel bezeichnet r den Halbmesser der Walzen. In Formel 1 kann beim Warmwalzen die Verformungsfestigkeit k_f der Warmfestigkeit des Werkstoffes bei Walztemperatur gleichgesetzt werden ; beim Kaltwalzen kann die Verformungsfestigkeit gleich der Fliessgrenze angenommen werden, welch letztere bei praktischen Berechnungen durch die Fliessgrenze $\sigma_{0,2}$ ersetzt werden darf.

Die Warmfestigkeit k_f von unlegierten Kohlenstoffstählen (DIN 1611 u. 1661 mit $C < 0{,}6\%$, Si $< 0{,}5\%$ und Mn $< 0{,}8\%$) muss aus Bild 1 entnommen werden.

In der Literatur pflegt man die Warmfestigkeit von Stählen höheren Kohlen-, Mangan- und Chromgehaltes mit einer Formel von EKELUND zu berechnen :

$$k_f = \left(\frac{1{,}4 + C + Mn + 0{,}3 \cdot Cr}{100} \right) \cdot (1400 - t)\ [\mathrm{kg/mm^2}]\,. \tag{3}$$

In diese Formel sind einzusetzen : die Walztemperatur in °C, der Kohlenstoffgehalt C, der Mangangehalt Mn, und der Chromgehalt Cr in Prozenten.

Zur Berechnung der Warmfestigkeit von unlegierten Kohlenstoffstählen wird oft diese EKELUNDsche Formel verwendet. Das ist aber falsch, da die EKELUNDsche Formel dazu nicht geeignet ist. Diese Formel ergibt nämlich bei unlegierten Kohlenstoffstählen zu hohe Werte. Übrigens gibt jede bekannte Formel für die Warmfestigkeit von Stählen nur Orientierungswerte. Zur genauen Berechnung des Walzdruckes bzw. des Verformungswiderstandes müssen durch Versuche ermittelte Warmfestigkeiten verwendet werden.

Zur Ermittlung des Reibungskoeffizienten beim Warmwalzen von Stählen pflegt man in der Literatur ebenfalls eine EKELUNDsche Formel zu verwenden, wonach die Reibungszahl über 700° C bei Stahlwalzen

$$\mu = 1{,}05 - 0{,}0005 \cdot t, \tag{4}$$

bei Hartgusswalzen

$$\mu = 0{,}8 \cdot (1{,}05 - 0{,}0005 \cdot t) \tag{5}$$

beträgt. In beiden Formeln bedeutet t die Walzguttemperatur.

Der Reibungskoeffizient ist jedoch von der Walzgeschwindigkeit abhängig. Schon die Versuche von W. TAFEL über den Einfluss der Reibungszahl und der Walzgeschwindigkeit auf die Grösse des Greifwinkels haben dahin gedeutet, dass die Reibungszahl beim Walzen mit steigender Walzgeschwindigkeit sich verkleinert [4]. Dieser Umstand ist in diesen Formeln nicht berücksichtigt worden.

Auf Grund sehr vieler Versuchsdaten kann die Reibungszahl bei Warmwalzung durch folgende Formeln angegeben werden :
bei Stahlwalzen

$$\mu = 1{,}05 - 0{,}0005 \cdot t - 0{,}056 \cdot v, \tag{6}$$

bei Hartgusswalzen

$$\mu = 0{,}94 - 0{,}0005 \cdot t - 0{,}056 \cdot v, \tag{7}$$

bei geschliffenen Stahl- oder Hartgusswalzen

$$\mu = 0{,}82 - 0{,}0005 \cdot t - 0{,}056 \cdot v. \tag{8}$$

In diesen Formeln bedeutet v [m/sec] die Walzgeschwindigkeit und t [°C] die Walzguttemperatur. Die Formeln sind unter einer Walzgeschwindigkeit von 5 m/sec und über einer Walztemperatur von 700° C gültig. Nach Beobachtungen des Verfassers ändert sich die Reibungszahl über einer Walzgeschwindigkeit von 5 m/sec kaum [5].

In der Verformungswiderstandsformel von GELEJI wurde der Koeffizient C in erster Annäherung als Konstante und zwar zu 5,5 angenommen. Doch hat der

Verfasser diesen Koeffizienten neuerdings einer gründlichen Untersuchung unterzogen und gefunden, dass der Koeffizient C eine Funktion des Quotienten $\frac{l_d}{h}$ ist. Die Untersuchungen haben folgendes gezeigt: wenn $\frac{l_d}{h}$ grösser ist als 2,5, dann ändert sich der Koeffizient C nur sehr wenig; wenn dagegen $\frac{l_d}{h}$ kleiner ist als 2,5, dann ändert sich C in Funktion von $\frac{l_d}{h}$ sehr stark. Diese Funktion, näm-

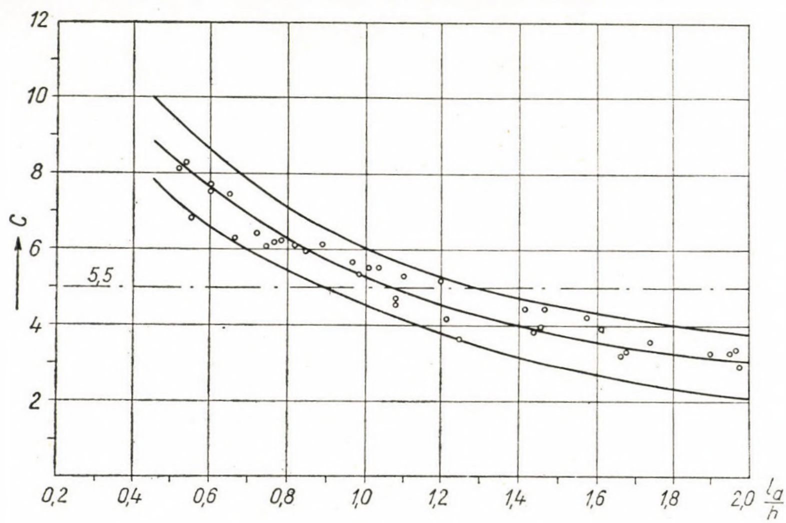


Bild 2

lich $C = f\left(\frac{l_d}{h}\right)$ wurde teilweise aus den Versuchen von O. EMICKE, die im Jahre 1954 durchgeführt worden [2] sind, ermittelt. Die Auswertung dieser Versuchsdaten ergab die Kurve vom Bild 2.

Der zu den höheren $\frac{l_d}{h}$ Werten gehörende Koeffizient C wurde aus verschiedenen Warm- und Kaltwalzversuchen ausgewertet. Durch diese Auswertung ergab sich die im Bild 3 wiedergegebene Kurve der Funktion $C = f\left(\frac{l_d}{h}\right)$.

Der Koeffizient C kann auch rechnerisch ermittelt werden. Wenn nämlich

$$0{,}25 \leq \frac{l_d}{h} \leq 1 \quad \text{ist, dann beträgt} \quad C_{0.25/1} = 5{,}5 + 6\left(1 - \frac{l_d}{h}\right), \qquad (9)$$

wenn

$$1 \leq \frac{l_d}{h} \leq 3 \quad \text{ist, dann beträgt} \quad C_{1/3} = \frac{5{,}5}{\left(\frac{l_d}{h}\right)} + 0{,}075 \left(\frac{l_d}{h} - 1\right) \quad (10)$$

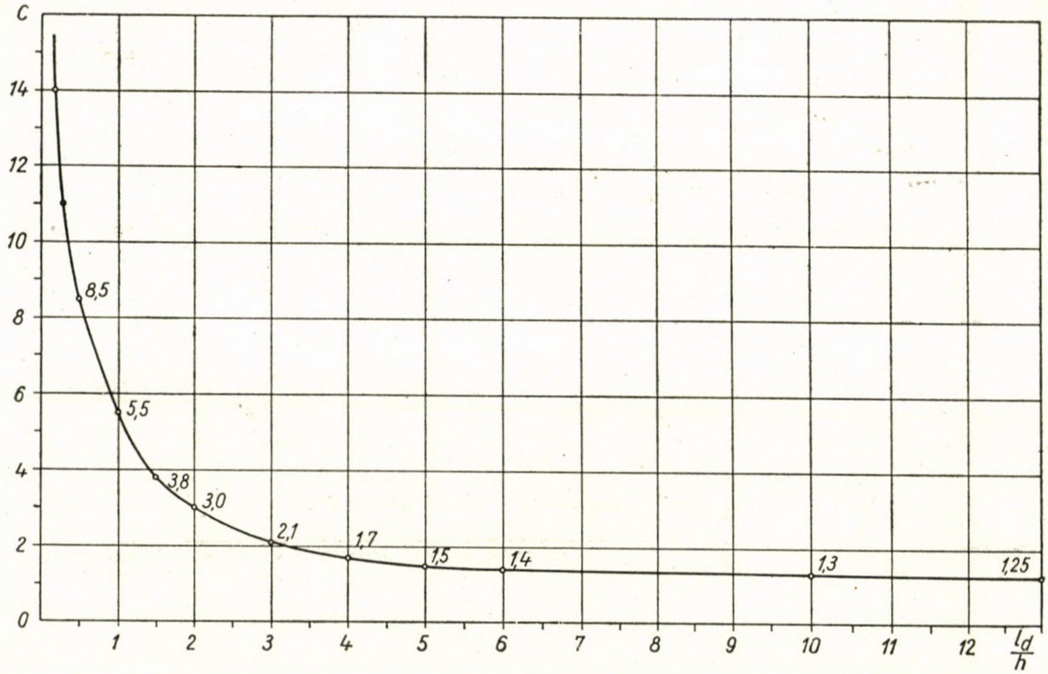


Bild 3

und wenn

$$3 \leq \frac{l_d}{h} \leq 15 \quad \text{ist, dann beträgt} \quad C_{3,15} = 2 - 0{,}082 \left(\frac{l_d}{h} - 3\right). \quad (11)$$

Auf Grund der obigen Ausführungen hat Verfasser den Verformungswiderstand beim Warmwalzen von Grob- und Feinblechen ausgerechnet und den Versuchsdaten gegenübergestellt. Die Versuchsdaten stammen aus den Arbeiten von Z. WUSATOWSKI und S. BALA [1] und von O. EMICKE und K. H. LUCAS. Die Gegenüberstellungen sind in den Tafeln 1, 2, 3, 4, 5 und 6 zu sehen.

Beispiel zur Berechnung des Verformungswiderstandes beim Warmwalzen (Tafel 1).

$D = 532$ mm,	$v = 2{,}3$ m/sec,
$h_1 = 196$ mm,	$\sqrt[4]{v} = 1{,}23$,
$h_2 = 181$ mm,	$t = 1146° C$,
$\Delta h = 15$ mm,	$k_f = 2{,}06$ kg/mm²,
$b_m = 627{,}5$ mm,	$P = 190 \cdot 10^3$ kg (Versuch),

$$l_d = \sqrt{266 \cdot 15} = 63{,}15 \text{ mm},$$

$$\frac{l_d}{h} = \frac{63{,}15}{188{,}5} = 0{,}335; \qquad C = 9{,}58 \text{ (Bild 2)},$$

$$\mu = 1{,}05 - 0{,}0005 \cdot 1146 - 0{,}056 \cdot 2{,}3 = 0{,}357.$$

Der berechnete mittlere Verformungswiderstand (Gl. 1):

$$k_m = 2{,}06 \cdot (1 + 9{,}58 \cdot 0{,}357 \cdot 0{,}335 \cdot 1{,}23) = 4{,}95 \text{ kg/mm}^2.$$

Der berechnete Walzdruck:

$$P = 4{,}95 \cdot 63{,}15 \cdot 627{,}5 = 194 \cdot 10^3 \text{ kg}.$$

Tafel 1

Warmwalzen von Brammen
(Versuche von Wusatowski und Bala)

No.	1	2	3	Bemerkung
h_1 mm	220	212	196	Höhe vor dem Stich [mm]
h_2 mm	212	196	181	Höhe nach dem Stich [mm]
Δh mm	8	16	15	Höhenabnahme [mm]
l_d mm	46,12	65,22	63,15	Gedrückte Länge [mm]
b_m mm	610	622,50	627,50	Breite des Walzstückes [mm]
v m/s	2,37	2,33	2,30	Walzgeschwindigkeit [m/sec]
R mm		265,9		Walzenhalbmesser [mm]
t °C	1150	1148	1146	Walztemperatur [°C]
k_f	2,05	2,05	2,06	Verformungsfestigkeit [kg/mm²]
μ	0,35	0,356	0,357	$\mu = 1{,}05 - 0{,}0005 \cdot t - 0{,}056\ v$
$\sqrt[4]{v}$		1,23		
$\frac{l_d}{h}$	0,22	0,33	0,35	
C	10,60	9,75	9,58	Koeffizient aus dem Diagramm
$k_m R$ berechnet	4,06	4,80	4,95	Verformungswiderstand [kg/mm²] (berechnet)
$k_m V$ Versuch	4,10	4,02	4,80	Verformungswiderstand [kg/mm²] (Versuch)
P_R	115	195	194	Walzdruck (berechnet) [10^3 kg]
P_V	125	162	190	Walzdruck (Versuch) [10^3 kg]
δ %	−8	+19,30	+3,10	

Der mittlere Verformungswiderstand durch Versuch ermittelt:

$$k_m = \frac{P}{l_d \cdot b_m} = \frac{190 \cdot 10^3}{63{,}15 \cdot 627{,}5} = 4{,}80 \text{ kg/mm}^2 .$$

Beim Kaltwalzen von Blechen kann der Verformungswiderstand ebenfalls mit Formel (1) berechnet werden, wobei die Werte des Koeffizienten C aus Bild 3 zu entnehmen sind. Die Berechnung wird aber dadurch komplizierter, dass bei der Ermittlung des Einspannbogens die Formel (2), d. h. die Formel des Nenneinspannbogens: $l_{dn} = \sqrt{r \cdot \Delta h}$ nicht genügt, da hier der durch die Abplattung der Walzen entstandene sog. tatsächliche Einspannbogen $l_{de} = \sqrt{r \cdot \Delta h + \frac{l_u^2}{4}} + \frac{l_\mu}{2}$ in Rechnung gezogen werden muss. Selbstverständlich ist es unumgänglich nötig die genaue Grösse der Reibungszahl und deren Änderung mit sich ändernder Walzgeschwindigkeit zu kennen.

Tafel 2

Warmwalzen von Stahlblechen
(Versuche von Wusatowski und Bala)

No.	1	2	3	4	5	6	Bemerkung
b_m			685				
h_1	18,1	14,1	11,0	8,6	6,7	5,3	
h_2	14,1	11,0	8,6	6,7	5,3	4,1	
Δh	4,0	3,1	2,4	1,9	1,4	1,2	
l_d	37,4	33,0	29,0	25,8	22,1	20,5	
v			1,3188 m/sec				
R			350 mm				
t°	850,0	841,0	830,0	815,0	796,0	772,0	
k_f	5,5	5,6	6,0	6,4	6,5	7,4	
μ	0,322	0,327	0,33	0,341	0,35	0,36	$\mu = 0{,}82 - 0{,}0005 \cdot t - 0{,}056 \cdot v$
$\sqrt[4]{v}$			1,072				
$\frac{l_d}{h}$	2,65	3,0	3,4	3,85	4,2	5,0	
C	2,5	2,45	2,43	2,4	2,3	2,2	Aus dem Diagramm
k_{mR}	18,0	20,0	23,2	27,2	30,5	39,0	Verformungswiderstand (berechnet)
k_{mv}	18,0	23,4	22,4	33,7	37,2	33,5	Verformungswiderstand (Versuch)
δ%	0,0	−14,5	+1,73	−23,8	−18,0	+16,5	Abweichung

Tafel 3

Warmwalzen von Stahlblechen

(Versuche von Wusatowski und Bala)

No.	1	2	3	4	5	6	7	8	9	12	13	16	17	18	19
b_m	750 mm														
h_1	15	11,5	8,8	6,7	5,1	3,9	2,9	4,4	4	5,6	4,7	5,4	4,6	3,9	3,2
h_2	11,5	8,8	6,7	5,1	3,9	2,9	2,2	4	3,6	4,7	3,7	4,6	3,9	3,2	2,8
Δh	3,5	2,7	2,1	1,6	1,2	1	0,7	0,4	0,4	0,9	0,8	0,8	0,7	0,7	0,4
v	1,319 m/sec														
R	350 mm														
t°	860	850	837	821	800	774	748	703	656	820	792	800	773	743	711
k_f	5,4	5,5	6	6,2	6,6	7,4	8,3	9,5	10	6,2	6,7	6,6	7,4	8,3	9,2
μ	0,316	0,321	0,328	0,336	0,346	0,359	0,372	0,395	0,42	0,336	0,35	0,346	0,36	0,374	0,39
$\sqrt[4]{v}$	1,07														
$\frac{l_d}{h}$	3,04	3,5	4,05	4,64	5,3	6,45	5,4	2,7	3,3	3,8	4,3	3,54	4,03	4,9	4,24
C	2,4	2,35	2,3	2,3	2,2	2,1	2,2	2,7	2,4	2,35	2,3	2,35	2,3	2,2	2,25
k_{mR}	18,7	21	25,5	30	35	46	48	36,7	—	26	31,6	26,8	33,7	44	46
k_{mV}	19,85	22,8	25,5	27,9	31,5	34,6	37,7	31	—	27,6	30,8	26,5	31,6	32,4	40,2
δ%	− 5,9	− 7,9	0	+ 7,5	+ 11,2	+ 33	+ 27,4	+ 18,35	—	− 5,8	+ 2,6	+ 1,1	+ 6,7	+ 36	+ 14,4

$\mu = 0,82 - 0,0005 \cdot t - 0,056\ v$

Tafel 4

Warmwalzen von Aluminium

Versuche von *O. Emicke* und *K. H. Lucas*

No.	h_1 mm	h_2 mm	Δh mm	l_d mm	b mm	t °C	k_f kg/mm²	v m/sec	$\frac{l_d}{h}$	C	μ	k_m Versuch	k_m berechnet	P Versuch	P berechnet
1	117	80	37	109,8	280	408	1,5	1,52	1,1	5,0	0,47	5,8	5,8	178	178
2	80	60	20	80,7	620	403	1,5	1,52	1,15	4,58	0,47	5,3	5,5	265	274
3	60	40	20	80,7	1050	400	1,6	1,52	1,6	3,56	0,60	7,1	7,1	603	603
4	40	25	15	69,9	960	400	1,6	1,52	2,13	3,0	0,60	9,1	8,4	612	565
5	25	16	9	54,2	760	396	1,6	1,52	2,53	2,8	0,60	11,5	9,1	475	376

Duo-Walzwerk, durchlaufend, mit Überhebetischen

Walzenabmessungen: D = 650 mm
L = 1500 mm
n = 45/min

Werkstoff: Al 99,5

Walzung mit geringer Petroleumschmierung

Tafel 5

Warmwalzen von Duralumin

Versuche von *O. Emicke* und *K. H. Lucas*

No.	h_1 mm	h_2 mm	Δh mm	l_d mm	b mm	t °C	k_f kg/mm²	v m/sec	$\frac{l_d}{h}$	C	μ	k_m Versuch	k_m berechnet	P Versuch	P berechnet
1	141	130	11	62,1	1075	420	3,7	1,1	0,46	8,9	0,3	8,3	8,4	539	560
2	130	110	20	83,7	1150	403	4,0	1,1	0,70	6,9	0,3	10,0	9,9	922	922
3	110	90	20	83,7	1090	410	4,0	1,1	0,84	6,2	0,3	9,95	9,95	937	937
4	90	70	20	83,7	1060	401	4,0	1,1	1,05	5,5	0,3	10,7	11	981	980
5	70	55	15	72,5	1070	400	4,0	1,1	1,16	4,7	0,3	11,3	10,8	870	840
6	55	40	15	72,5	1080	403	4,0	1,1	1,53	3,7	0,35	12,1	12,1	940	940
7	40	30	10	59,2	1090	390	4,3	1,1	1,70	3,4	0,35	13,1	13,3	835	860
8	30	22	8	52,9	1090	397	4,15	1,1	2,04	3,0	0,35	14,1	13,3	808	765
9	22	15	7	49,5	1090	390	4,3	1,1	2,68	2,3	0,43	16,0	16	860	860
10	15	10	5	41,8	1090	378	4,5	1,1	3,34	1,9	0,51	19,4	19,4	883	883
11	10	8	2	26,5	1090	370	5,0	1,1	2,95	2,0	0,51	21,0	20,4	609	592
12	8	7	1	18,7	1090	335	5,6	1,1	2,50	2,5	0,60	27,8	27	568	550

Duo-Walzmerk, durchlaufend, mit Überhebetischen
Walzenabmessungen: D = 700 mm, d = 480 mm Werkstoff: FWL 3116.
L = 1800 mm, l = 380 mm
Walzenschmierung und Kühlung mit Emulsion

Tafel 6

Warmwalzen von Duralumin

Versuche von *O. Emicke* und *K. H. Lucas*

No.	h_1 mm	h_2 mm	Δh mm	l_d mm	b mm	t °C	k_f kg/mm²	v m/sec	$\frac{l_d}{h}$	C	μ	k_m Versuch	k_m berechnet	P Versuch	P berechnet
1	118,0	115,0	3,0	31,3	545	449	3,2	1,52	0,27	12,5	0,6	12,3	12	210	—
2	115,0	110,0	5,0	40,4	510	452	3,2	1,52	0,36	11,0	0,6	11,4	11,6	235	238
3	110,0	105,2	4,8	39,5	620	445	3,2	1,52	0,37	11,0	0,6	11,6	11,8	285	290
4	105,2	100,0	5,2	41,2	750	445	3,2	1,52	0,40	10,0	0,6	11,6	11,6	360	360
5	100,0	92,0	8,0	51,0	800	437	3,2	1,52	0,53	8,5	0,6	12,1	12,8	495	—
6	92,0	84,0	8,0	51,0	890	442	3,2	1,52	0,58	7,8	0,6	12,2	12,8	555	—
7	84,0	76,2	7,8	50,4	1120	445	3,2	1,52	0,63	7,4	0,6	12,4	13,1	700	—
8	76,2	68,0	8,2	51,7	1170	437	3,2	1,52	0,72	6,7	0,6	12,6	13,3	760	—
9	68,0	60,0	8,0	51,0	1145	434	3,2	1,52	0,80	6,3	0,6	12,9	14,5	750	—
10	60,0	52,0	8,0	51,0	870	426	3,3	1,52	0,91	5,7	0,6	13,4	14,5	595	—
11	52,0	44,2	7,8	50,4	1075	420	3,3	1,52	1,04	5,0	0,6	13,9	14,5	750	—
12	44,2	36,0	8,2	51,7	985	422	3,3	1,52	1,29	4,3	0,6	14,9	15,3	760	—
13	36,0	29,8	6,2	44,9	1100	426	3,3	1,52	1,36	4,1	0,6	16,3	15,3	805	—
14	29,8	25,3	4,5	38,3	920	426	3,3	1,52	1,40	4,0	0,6	17,3	16,9	610	598
15	25,3	21,0	4,3	37,4	920	415	3,7	1,52	1,60	3,6	0,6	18,6	17,8	640	612
16	21,0	17,0	4,0	36,1	920	411	3,8	1,52	1,90	3,2	0,6	20,4	20,6	675	685
17	17,0	13,0	4,0	36,1	920	407	3,9	1,52	2,40	2,7	0,6	22,4	20,8	745	695
18	13,0	10,0	3,0	31,3	920	400	4,0	1,52	2,70	2,3	0,6	24,5	20,4	705	590
19	10,0	7,5	2,5	28,5	920	388	4,5	1,52	3,27	1,9	0,6	26,8	23	700	600

Walzung mit geringer Petroleumschmierung
Walzenabmessungen: D = 650 Werkstoff: FWL 3115
L = 1500

Beim Kaltwalzen von Blechen kann der durch die Abplattung der Walzen vergrösserte Einspannbogen (der gedrückte Bogen, Effektiveinspannbogen) durch die Formeln (12) und (13) bzw. (14) berechnet werden [6]:

$$l_{de} = \sqrt{r \cdot \Delta h + \frac{l_u^2}{4}} + \frac{l_u}{2}\,, \tag{12}$$

wo

$$l_u = \frac{4{,}7 \cdot \left(\frac{r}{E}\right) \cdot k_f \cdot \left(1 + C_n \cdot \mu \cdot \frac{l_{dn}}{h} \cdot \sqrt[4]{v}\right)}{1 - 2{,}35 \cdot k_f \cdot C_n \cdot \left(\frac{r}{E}\right) \cdot \left(\frac{\mu}{h}\right) \cdot \sqrt[4]{v}}\,. \tag{13}$$

Wenn $E = 2{,}1 \cdot 10^{-4}$ kg/mm² in die Formel (10) eingesetzt wird (also beim Stahlwalzen), ergibt sich die Formel (11):

$$l_u = \frac{2{,}22 \cdot 10^{-4} \cdot r \cdot k_f \cdot \left(1 + C_n \cdot \mu \cdot \frac{l_{dn}}{h} \cdot \sqrt[4]{v}\right)}{1 - 1{,}12 \cdot 10^{-4} \cdot k_f \cdot C_n \cdot r \cdot \left(\frac{\mu}{h}\right) \cdot \sqrt[4]{v}}\,. \tag{14}$$

Hier ist $C_n = f\left(\frac{l_{dn}}{h}\right)$ aus der Kurve von Bild 3 zu entnehmen.

Die Verlängerung des gedrückten Bogens bedeutet, dass die Walzen mit dem Halbmesser r längs des gedrückten Bogens so wirken, als ob ihr Radius sich von r auf R vergrössert hätte. Es ist nämlich

$$l_{de} = \sqrt{r \cdot \Delta h + \frac{l_u^2}{4}} + \frac{l_u}{2} = \sqrt{R \cdot \Delta h}\,, \tag{15}$$

und daraus ist der vergrösserte Walzenradius (Bild 4):

$$R = \frac{l_{de}^2}{\Delta h}\,. \tag{16}$$

Wie gesagt, wird beim Kaltwalzen die Verformungsfestigkeit der mittleren Fliessgrenze $\sigma_{0,2}$ des gewalzten Werkstoffes gleichgesetzt. Die mittlere geometrische Verformungsfestigkeit des gewalzten Werkstoffes wird durch die von der Kurve $\sigma_{0,2}$ begrenzte Fläche bestimmt.

Mit der Ermittlung des beim Kaltwalzen auftretenden Reibungskoeffizienten haben sich sehr viele Forscher beschäftigt, die Frage ist jedoch noch heute nicht endgültig abgeschlossen. Der mittlere Reibungskoeffizient beim Walzen kann nur indirekt, aus dem Verformungswiderstand ermittelt werden. Die

Reibungszahlen, die mit den sogenannten direkten Versuchsmethoden ermittelt wurden, sind mit den mittleren Reibungszahlen der Walzung nicht identisch.

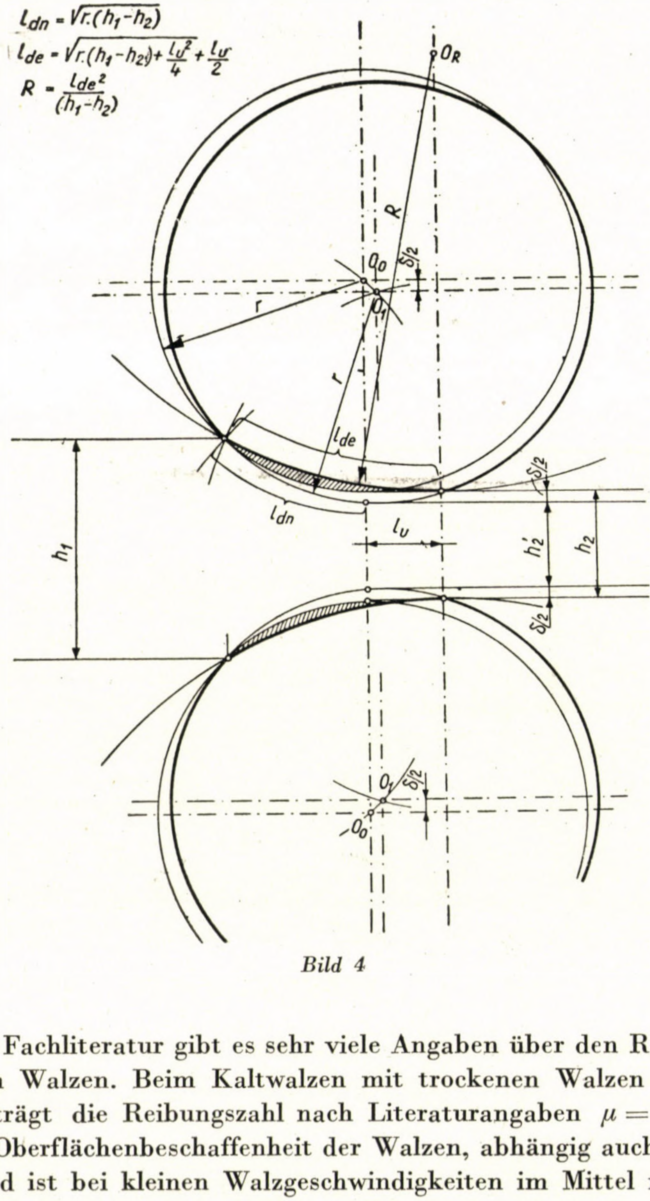


Bild 4

In der Fachliteratur gibt es sehr viele Angaben über den Reibungskoeffizienten beim Walzen. Beim Kaltwalzen mit trockenen Walzen und ölfreiem Walzgut beträgt die Reibungszahl nach Literaturangaben $\mu = 0{,}07$ bis $0{,}15$ je nach der Oberflächenbeschaffenheit der Walzen, abhängig auch von anderen Faktoren und ist bei kleinen Walzgeschwindigkeiten im Mittel mit 0,1 anzunehmen.

Aus den Versuchen von A. Pomp und W. Lueg zur Ermittlung der Reibungszahl beim Stahlbandwalzen ergab sich, dass die Reibungszahl beim Kaltwalzen von dem Werkstoff des gewalzten Stückes, von der Oberflächenbeschaffenheit des Walzgutes und der Walzen, von der Schmierung und von der Walzgeschwindigkeit abhängt [8]. R. B. SIMS und D. F. ARTHUR [9, 10] haben neuerdings den Einfluss der Walzgeschwindigkeit auf den Reibungskoeffizienten bei der Walzung von Stahlband mit Ölschmierung untersucht und erhielten die in Bild 5 wiedergegebene Kurve. Die Reibungszahlen wurden aus den gemessenen Werten von Walzdruck, Formänderungsfestigkeit und Dickenabnahme mit Hilfe der D. B. BLAND—H. FORDschen Walzdruckformel indirekt ermittelt. Die Werte der mittleren Reibungszahl, die sich aus den Versuchen mit Öl als Schmiermittel ergaben, sind in Bild 5 als Funktion der Walzgeschwindigkeit aufgetragen.

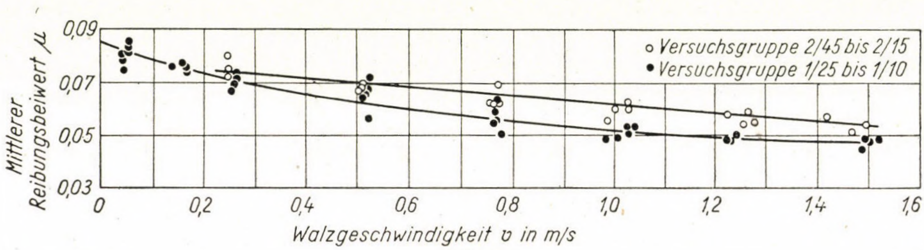


Bild 5

Die Ermittlung des Reibungsbeiwertes geschah auf Grund der FORDschen Versuchsdaten [11]. Die Versuche von H. FORD geben beim Kaltwalzen ein sehr anschauliches Bild von den Veränderungen des Walzdruckes bzw. des Nennverformungswiderstandes in Abhängigkeit von der Walzgeschwindigkeit (Bild 6).*

Die mittlere Reibungszahl wurde aus Formel (1) berechnet, danach ist die Reibungszahl

$$\mu_{me} = \frac{k_{me} - k_f}{k_f \cdot C_e \cdot \dfrac{l_{de}}{h} \cdot \sqrt[4]{v}}, \tag{17}$$

* Der Nennverformungswiderstand ist der auf den Nenneinspannbogen $\left(l_{dn} = \sqrt{r \cdot \Delta h}\right)$ bezogene spezifische Walzdruck:

$$k_{mn} = \frac{P}{b \cdot \sqrt{r \cdot \Delta h}} = \frac{P}{l_{dn} \cdot b}.$$

Der Effektivverformungswiderstand (k_{me}) ist der auf den unter Walzdruck verlängerten Einspannbogen

$$\left(l_{de} = \sqrt{r \cdot \Delta h + \frac{l_u^2}{4}} + \frac{l_u}{2}\right)$$

bezogene Verformungswiderstand:

$$k_{me} = \frac{P}{l_{de} \cdot b}.$$

wo aus der Kurve (Bild 3)

$$C_e = f \cdot \left(\frac{l_{de}}{h}\right) \text{ ist, und wo}$$

$$k_{me} = k_f \cdot \left(1 + C_e \cdot \mu \cdot \frac{l_{de}}{h} \cdot \sqrt[4]{v}\right) \tag{18}$$

den tatsächlichen (effektiven) Verformungswiderstand bedeutet.

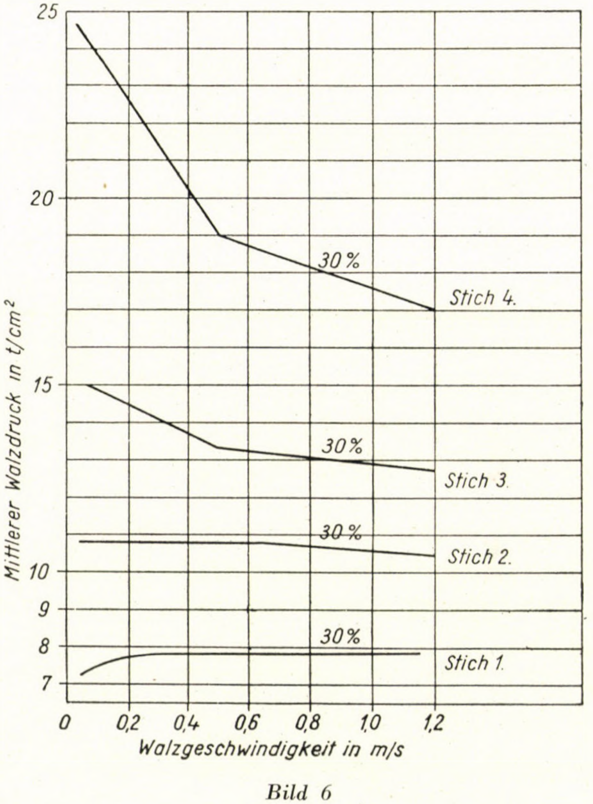


Bild 6

Aus dem Effektivverformungswiderstand ergibt sich der Nennverformungswiderstand als :

$$k_{mn} = k_{me} \cdot \frac{l_{de}}{l_{dn}} \,. \tag{19}$$

Die so ermittelten Reibungszahlen sind in Funktion des Verformungswiderstandes und des Walzdruckes in Bild 7 wiedergegeben.

Die Auswertung der Reibungszahlen nach dem angegebenen Verfahren zeigt, dass die Reibungszahl bei den ersten Stichen mit steigender Walzgeschwindigkeit verhältnismässig wenig fällt. Bei steigender Härte und somit bei

Tafel 7

Kaltwalzen von Stahlbändern

Versuche

	h_1 mm	h_2 mm	Δh mm	$h = \frac{h_1+h_2}{2}$	l_{dn} mm	$\frac{l_{dn}}{h}$	k_{f1} kg/mm²	k_{f2} kg/mm²	k_{fm} kg/mm²	μ	v m/s
2,1 m/min	2,512	1,773	0,739	2,14	9,67	4,50	52,0	66,0	59,0	0,07	0,035
	1,773	1,260	0,513	1,50	8,10	5,40	66,0	69,5	67,75	0,07	0,035
	1,260	0,881	0,379	1,07	6,90	6,40	69,5	71,5	70,5	0,12	0,035
	0,881	0,635	0,246	0,758	5,58	7,37	71,5	72,5	72,0	0,22	0,035
30 m/min	2,518	1,750	0,768	2,134	9,81	4,65	52,0	62,2	59,1	0,048	0,502
	1,750	1,234	0,516	1,492	8,04	5,50	66,2	70,0	68,1	0,066	0,502
	1,234	0,861	0,373	1,047	6,88	6,55	70,0	71,5	70,7	0,066	0,502
	0,861	0,599	0,262	0,730	5,76	7,87	71,5	72,5	72,0	0,08	0,502
70 m/min	2,520	1,757	0,763	2,16	9,87	4,55	52,0	66,0	59,0	0,032	1,193
	1,757	1,239	0,518	1,50	8,10	5,40	66,0	69,5	67,7	0,032	1,193
	1,239	0,861	0,378	1,05	6,90	6,55	69,5	71,5	70,5	0,045	1,193
	0,861	0,607	0,254	0,734	5,65	7,70	71,5	72,5	72,0	0,045	1,193

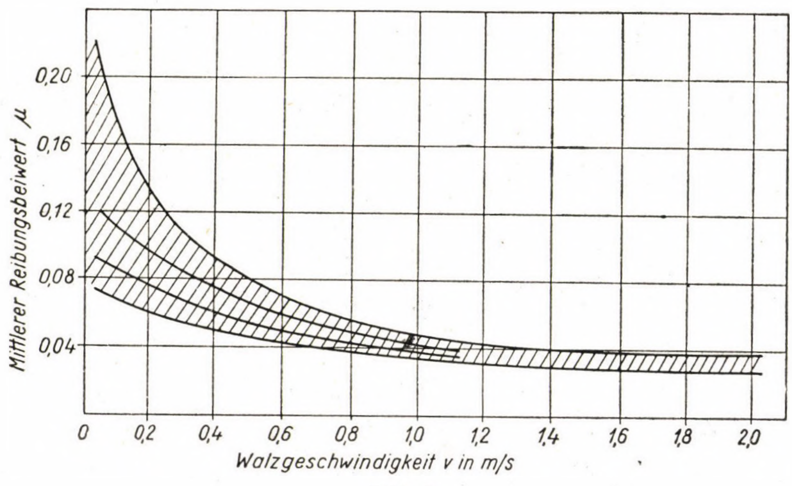


Bild. 7

steigendem Verformungswiderstand fällt die Reibungszahl mit der steigenden Walzgeschwindigkeit anfangs verhältnismässig stark, dann wird aber die Kurve der Reibungszahl immer flacher, und nach Erreichung einer Grenzgeschwindigkeit bleibt sie praktisch konstant. Über dieser Grenzgeschwindigkeit scheint die Reibungszahl auch von der Grösse des Verformungswiderstandes nur wenig abhängig zu sein.

mit Schmierung
von H. Ford

$\sqrt[4]{v}$	c_n	l_u mm	l_{de} mm	$\frac{l_{de}}{h}$	c_e	k_{me} kg/mm²	k_{mn} berechnet	k^*_{mn} Versuch	$\frac{k^*_{mn}-k_{mn}}{k^*_{mn}}$ %	D mm	r mm	$\frac{D}{h}$
0,438	1,45	2,00	10,75	5,0	1,4	72,5	81	70,80	+14	254	127	120
0,438	1,4	2,37	9,34	6,2	1,3	84,4	97,5	106,75	− 8,7	254	127	170
0,438	1,35	2,60	8,64	8,23	1,30	112,0	140	151,90	− 8	254	127	236
0,438	1,3	4,63	8,37	11,0	1,25	168,0	252	251,50	± 0	254	127	335
0,839	1,5	2,17	10,91	5,1	1,45	64,0	70,8	74,90	− 5,5	254	127	120
0,839	1,4	2,86	9,63	6,5	1,3	85,5	102,5	106,60	− 3,85	254	127	170
0,839	1,3	3,17	8,60	8,2	1,3	112,5	140	131,90	+ 6	254	127	236
0,839	1,3	3,94	8,00	11,0	1,2	137,0	190	189,60	± 0	254	127	335
1,045	1,5	2,15	10,95	5,5	1,4	74,0	82	76,20	+ 7,6	254	127	120
1,045	1,4	2,43	9,41	6,27	1,3	86,0	100	103,40	− 3,4	254	127	170
1,045	1,3	2,92	8,56	8,10	1,2	103,0	128	127,00	+ 0,8	254	127	242
1,045	1,3	3,30	7,55	10,3	1,25	116,0	155	169,50	− 8,5	254	127	346

Aus den FORDschen Versuchen kann die Schlussfolgerung gezogen werden, dass bei sehr kleinen Walzgeschwindigkeiten und bei grossen Verformungswiderständen die metallische Reibungszahl der Ruhe zur Geltung kommt, die allmählich in die Reibungszahl der gleitenden Reibung und bei steigender Geschwindigkeit und Ölschmierung in die der Flüssigkeitsreibung übergeht. Nach Überschreitung einer Grenzgeschwindigkeit wird der Wert der Reibungszahl praktisch konstant. Man darf aber auch nicht vergessen, dass sich die Reibungszahl selbst bei Trockenwalzung mit steigender Walzgeschwindigkeit ähnlich verhält, nur ist sie etwas grösser als bei Ölschmierung, dabei scheint der Verformungswiderstand auf die Reibungszahl weniger Einfluss zu haben. Bei niedrigem spezifischem Walzdruck (Verformungswiderstand) kommt selbst bei kleinen Walzgeschwindigkeiten die Wirkung der Schmierung besser zur Geltung, da wahrscheinlich der kleinere spezifische Druck das Öl von der gedrückten Fläche weniger verdrängt als ein grösserer spezifischer Walzdruck. So ist auch die Reibungszahl bei einem kleinen Verformungswiderstand kleiner als bei einem grossen (Bild 7).

Verfasser hat aus einer Stahlbandwalzversuchsreihe von H. FORD den Reibungskoeffizienten ermittelt und mit Hilfe des so gewonnenen Reibungskoeffizienten andere Versuchsreihen von H. FORD [11], J. BILLIGMANN und A. POMP [12] durchgerechnet. Die Ergebnisse dieser Rechnungen und der Vergleich mit den Versuchsergebnissen sind in den Tabellen 4, 5 und 6 zusammengestellt.

Tafel 8

Kaltwalzen von Stahlbändern

Versuche von Billigmann

	h_1 mm	h_2 mm	Δh mm	$h = \frac{h_1+h_2}{2}$	l_{dn} mm	$\frac{l_{dn}}{h}$	k_{f1} kg/mm²	k_{f2} kg/mm²	k_{fm} kg/mm²	μ	v m/s
10 m/min	1,25	0,86	0,39	1,05	5,05	4,8	36	62	49	0,07	0,166
	0,86	0,60	0,26	0,73	4,10	5,6	62	74	68	0,08	0,166
	0,60	0,42	0,18	0,51	3,42	6,85	74	82,4	78	0,09	0,166
	0,42	0,29	0,13	0,355	2,92	8,2	82,4	85,6	83,5	0,10	0,166
	0,29	0,205	0,085	0,247	2,35	9,5	85,6	90	87,8	0,10	0,166
100 m/min	1,25	0,86	0,39	1,05	5,05	4,8	36	62	49	0,03	1,67
	0,86	0,60	0,26	0,73	5,05	5,6	62	74	68	0,03	1,67
	0,60	0,42	0,18	0,51	3,42	6,85	74	82,4	77,8	0,03	1,67
	0,42	0,29	0,13	0,355	2,92	8,2	82,4	85,6	83,5	0,03	1,67
	0,29	0,205	0,085	0,247	2,35	9,5	85,6	90	87,8	0,03	1,67

In Tafel 7 sind eine Reihe von den Stahlbandwalzversuchen von H. FORD aufgearbeitet. Die Ausgangsstärke des geglühten Stahlbandes war 1,25 mm, die Endstärke des ausgewalzten harten Stahlbandes 0,6 mm. Die Auswalzung wurde in vier Stichen ohne Zwischenglühung mit der Walzgeschwindigkeit von 2,1 m/min, 30 m/min und 70 m/min durchgeführt. Die Auswalzung geschah bei Ölschmierung.

In Tafel 8 sind eine Reihe der Stahlbandwalzversuche von J. BILLIGMANN und A. POMP bearbeitet. Die Anfangsstärke des geglühten Stahlbandes war 1,25 mm, die Endstärke 0,2 mm. Die Auswalzung erfolgte in fünf Stichen ohne Zwischenglühung bei einer Walzgeschwindigkeit von 10 m/min bzw. 100 m/min. Die Auswalzung geschah bei Ölschmierung.

In Tafel 9 sind ebenfalls eine Serie der Stahlbandwalzversuche von J. BILLIGMANN und A. POMP bearbeitet. Die Anfangsstärke des geglühten Stahlbandes war 1,25 mm, die Endstärke 0,29 mm. Die Auswalzung wurde mit vier Stichen durchgeführt bei einer Walzgeschwindigkeit von 10, 100 und 300 m/min. Die Auswalzung erfolgte hier ohne Schmierung.

In den Tafeln 10, 11 und 12 sind die Versuchsdaten und die Ergebnisse der Kaltwalzversuche des Verfassers zusammengefasst. Diese Kaltwalzversuche wurden mit Armco-Eisen, mit Ms 72-Messing und mit S 7-Stahlband durchgeführt. In den Tafeln 10, 11 und 12 wurde bei der Berechnung des mittleren Verformungswiderstandes der Reibungskoeffizient mit 0,03 in Rechnung gezogen.

Die Tafeln zeigen folgendes :

Bei Ölschmierung wächst der Reibungskoeffizient mit wachsendem Verformungswiderstand und fällt mit wachsender Walzgeschwindigkeit. Beim

mit Schmierung
und Pomp

$\sqrt[4]{v}$	C_n	l_u mm	l_{d_2} mm	$\frac{l_{d_2}}{h}$	C_e	k_{me} kg/mm²	k_{mn} berechnet	k^*_{mn} Versuch	$\frac{k^*_{mn}-k_{mn}}{k^*_{mn}}$ %	D mm	r mm	$\frac{D}{h}$
0,637	1,50	0,985	5,50	5,25	1,6	66	72	80	− 10	130	65	124
0,637	1,40	1,44	4,92	6,72	1,35	99,5	120	116	+ 3,5	130	65	178
0,637	1,30	1,85	4,46	8,75	1,3	129	168	150	+ 12	130	65	255
0,637	1,30	2,38	4,29	12,1	1,2	160	232	200	+ 16	130	65	365
0,637	1,15	2,40	3,80	15,4	1,1	187	300	310	− 3	130	65	527
1,14	1,50	0,91	5,525	5,25	1,5	62,5	68,5	80	− 16	130	65	124
1,14	1,40	1,29	4,815	6,6	1,4	90	105	100	+ 5	130	65	178
1,14	1,30	1,55	4,31	8,35	1,3	106	134	125	+ 7,2	130	65	255
1,14	1,30	1,72	3,92	11,0	1,2	117	156	156	± 0	130	65	365
1,14	1,15	1,90	3,49	14,2	1,1	134	200	200	± 0	130	65	527

Walzen ohne Schmierung scheint der Reibungskoeffizient von dem Verformungswiderstand unabhängig zu sein, wird aber kleiner mit wachsender Walzgeschwindigkeit.

Bei Schmierung hängt die Reibungszahl auch von dem angewendeten Schmierstoff, sowie von momentanen örtlichen Verhältnissen im Walzspalt ab, die kaum in Rechnung gezogen werden können. Man muss also bei der Ermittlung der Reibungszahl mit einem Unsicherheitsfaktor rechnen.

Die nach der hier angegebenen Rechnungsmethode errechneten Verformungswiderstände weichen beim Kaltwalzen von Stahl von den durch Versuche ermittelten Verformungswiderständen nur in den praktisch erlaubten Grenzen ab.

Beispiel zur Berechnung des mittleren Verformungswiderstandes beim Kaltwalzen (Tafel 7).

Der gewalzte Werkstoff: Armco-Eisen.

Gewalzt wurde auf einem Quartowalzwerk, dessen Arbeitswalzendurchmesser 125 mm und Ballenlänge 285 mm betrug.

Der Abnahmeplan der Bandwalzung:

$$195 \times 0{,}92 \rightarrow 0{,}70 \rightarrow 0{,}55 \rightarrow 0{,}49 \rightarrow 0{,}40 \text{ mm}.$$

Die Walzung wurde bei Zylinderölschmierung durchgeführt.

$h_1 = 0{,}92$ mm, $\qquad k_{f_1} = 23{,}1$ kg/mm²,

$h_2 = 0{,}70$ mm, $\qquad k_{f_2} = 46{,}0$ kg mm²,

$\Delta h = 0{,}22$ mm, $\qquad k_{fk} = 34{,}55$ kg/mm²,

$h = \frac{h_1 + h_2}{2} = 0{,}81$ mm, $\qquad v = 1$ m/sec,

Tafel 9

Kaltwalzen von Stahlbändern

Versuche von Billigmann

	h_1 mm	h_2 mm	Δh mm	$h = \frac{h_1+h_2}{2}$	l_{dn} mm	$\frac{l_{dn}}{h}$	k_{f1} kg/mm²	k_{f2} kg/mm²	k_{fm} kg/mm²	μ	v m/s
10 m/min	1,25	0,86	0,39	1,05	5,05	4,8	36	62	49	0,08	0,167
	0,86	0,60	0,26	0,73	4,10	5,6	62	72	67	0,08	0,167
	0,60	0,42	0,18	0,51	3,42	6,85	72	80	76	0,08	0,167
	0,42	0,29	0,13	0,355	2,92	8,2	80	85	82,5	0,08	0,167
100 m/min	1,25	0,86	0,39	1,05	5,05	4,8	36	60	48	0,05	1,67
	0,86	0,60	0,26	0,73	4,10	5,6	60	70	65	0,05	1,67
	0,60	0,42	0,18	0,51	3,42	6,85	70	78	74	0,05	1,67
	0,42	0,29	0,13	0,355	2,92	8,2	78	84	81	0,05	1,67
300 m/min	1,25	0,86	0,39	1,05	5,05	4,8	36	62	49	0,04	5,0
	0,86	0,60	0,26	0,73	4,10	5,6	62	72	67	0,04	5,0
	0,60	0,42	0,18	0,51	3,42	6,85	72	75	73,5	0,04	5,0
	0,42	0,29	0,13	0,355	2,92	8,2	—	—	—	—	—

$$l_{dn} = \sqrt{62{,}5 \cdot 0{,}22} = 3{,}7 \text{ mm},$$

$$\frac{l_d}{h} = 4{,}58\,; \quad C_n = 1{,}5\,; \quad D = 125 \text{ mm}\,; \quad r = 62{,}5 \text{ mm}.$$

Der Verformungswiderstand wurde mit Formel (1) und der effektive gedrückte Bogen mit Hilfe der Formel (12) berechnet:

$$l_{de} = \sqrt{r \cdot \Delta h + \frac{l_u^2}{4}} + \frac{l_u}{2} \tag{12}$$

wo die unwirksame Bogenlänge aus Formel (11) sich ergibt:

$$l_u = \frac{2{,}22 \cdot 10^{-4} \cdot r \cdot k_f \cdot \left(1 + C_n \cdot \mu \cdot \frac{l_{dn}}{h} \cdot \sqrt[4]{v}\right)}{1 - 1{,}12 \cdot 10^{-4} \cdot k_f \cdot C_n \cdot r \cdot \left(\frac{\mu}{h}\right)\sqrt[4]{v}}\,. \tag{13}$$

Hier ist

$$2{,}22 \cdot 10^{-4} \cdot 62{,}5 \cdot 34{,}55 = 0{,}478\,,$$

$$1 + 1{,}5 \cdot 0{,}03 \cdot 4{,}58 \cdot 1 = 1{,}206\,,$$

$$1 - 1{,}12 \cdot 10^{-4} \cdot 34{,}55 \cdot 1{,}5 \cdot 62{,}5 \cdot \frac{0{,}03}{0{,}81} \cdot 1 = 0{,}987\,,$$

und so ist

$$l_u = \frac{0{,}487 \cdot 1{,}206}{0{,}987} = 0{,}58\,. \tag{12}$$

ohne Schmierung
und Pomp

$\sqrt[4]{v}$	c_n	l_u mm	l_{de} mm	$\frac{l_{de}}{h}$	c_e	k_{me} kg/mm²	k_{mn} berechnet	k^*_{mn} Versuch	$\frac{k^*_{mn}-k_{mn}}{k^*_{mn}}$ %	D mm	r mm	$\frac{D}{h}$
0,637	1,5	1,00	5,55	5,3	1,45	68,5	75	77	— 2,6	130	65	124
0,637	1,4	1,415	4,88	6,7	1,35	97,75	115	104	+ 9,6	130	65	178
0,637	1,3	1,73	4,40	8,65	1,30	119	153	136	+14,0	130	65	255
0,637	1,3	2,07	4,11	11,6	1,20	146	206	198	+ 3,9	130	65	365
1,14	1,5	1,03	5,55	5,3	1,45	69	76	78	— 2,6	130	65	124
1,14	1,4	1,46	4,93	6,72	1,35	98,5	118	110	+ 7,3	130	65	178
1,14	1,3	1,75	4,43	8,7	1,30	122	158	150	+ 5,35	130	65	255
1,14	1,3	2,15	4,15	11,7	1,25	148	218	245	—11,0	130	65	365
1,49	1,5	1,05	5,57	5,3	1,50	72,5	80	77	+ 3,9	130	65	124
1,49	1,4	1,495	4,95	6,8	1,35	104	125	115	+ 8,7	130	65	178
1,49	1,3	1,77	4,425	8,65	1,30	123	159	250	— 3,6	130	65	255
—	—	—	—	—	—	—	—	—	—	130	65	—

Die effektive gedrückte Länge beträgt also nach Formel (12):

$$l_{de} = \sqrt{62,5 \cdot 0,22 + 0,08} + 0,29 = 4 \text{ mm} .$$

An Hand dieser Daten ist

$$\frac{l_{de}}{h} = 4,95 \qquad \text{und aus Bild 2:} \qquad C_e = 1,4 .$$

Der effektive Verformungswiderstand ist also

$$k_{me} = k_f \cdot \left(1 + C_e \cdot \mu \cdot \frac{l_{de}}{h} \cdot \sqrt[4]{v}\right) = 34,55 \cdot (1 + 1,4 \cdot 0,03 \cdot 4,95 \cdot 1) = 41,5 \text{ kg/mm}^2 .$$

Der Nennverformungswiderstand ist laut Formel (19):

$$k_{mn} = k_e \cdot \frac{l_{de}}{l_{dn}} = 41,5 \cdot \frac{4,0}{3,7} = 44,8 \text{ kg/mm}^2 ,$$

Der durch Versuch ermittelte Nennverformungswiderstand beträgt:

$$k_{mn} = \frac{32\,200}{195 \cdot 3,7} = 44,7 \text{ kg/mm}^2 .$$

SCHRIFTTUM

1. Z. Wusatowski i S. Bala: Porównanie metod obliczania nacisku walców w procesie walcowania na gorgco. Prace Institutow Ministerstwa Hutnictwa. Prace IMH 6. (1954). S. 120/132.
2. K. H. Lucas und O. Emicke: Über die Ermittlung der Kennwerte der statischen und dynamischen Belastung von eingerüstigen Grobblechwalzwerken durch Rechnung und Versuch. Metallurgie und Giesserei Technik. 1955. S. 7/12.
3. A. Geleji: Die Berechnung der Kräfte und des Arbeitsbedarfs bei der Formgebung im bildsamen Zustande der Metalle. Akadémiai Kiadó, Budapest, 1955. S. 76/83.
4. W. Tafel: Das Greifen der Walzen. Stahl u. Eisen, 41 (1921). S. 962/963.
5. A. Geleji: Die Berechnung der Kräfte usw. 1955. S. 93/94.
6. A. Geleji: Die Berechnung der Kräfte usw. 1955. S. 88/92.
7. W. Lueg und A. Pomp: Der Einfluss des Walzendurchmessers beim Kaltwalzen von Bandstahl. Mitt. K. W. Inst. f. Eisenfschg. 17. (1935). S. 63/76.
8. W. Lueg und A. Pomp: Der Einfluss des Walzenstoffes, der Walzgeschwindigkeit, der Bandbreite und einer voraufgegangenen Kaltformung beim Kaltwalzen von Bandstahl. Mitt. K. W. Inst. f. Eisenfschg. 56. (1936). S. 235/236.
9. R. B. Sims und D. F. Arthur: Speeddependent Variables in Cold Strip Rolling. J. Iron and Steel Inst. 179/1952. Nr. 3. S. 285/295.
10. A. Lissner: Einfluss der Walzgeschwindigkeit auf Banddickenänderungen beim Kaltwalzen von Bändern. Stahl u. Eisen 73. (1953). S. 670/672.
11. H. Ford: The Effect of Speed of Rolling in the Cold-Rolling Process. J. Iron and Steel Inst. 67. (1947). S. 380/397.
12. J. Billigmann und A. Pomp: Untersuchungen über den Einfluss der Walzgeschwindigkeit auf den Walzdruck, die Festigkeitseigenschaften und die Banddicke beim Kaltwalzen von Bandstahl. Stahl u. Eisen 74. (1954). S. 441/461.

ZUSAMMENFASSUNG

In dieser Abhandlung wird ein Rechnungsverfahren zur Bestimmung des Verformungswiderstandes beim Warm- und Kaltwalzen vorgeführt. Zur Errechnung des Verformungswiderstandes dient die Formel

$$k_m \doteq k_f \cdot \left(1 + C \cdot \mu \cdot \frac{l_d}{h} \cdot \sqrt[4]{v}\right). \tag{1}$$

In dieser Formel ist der Koeffizient C sowohl beim Warmwalzen wie auch beim Kaltwalzen von dem Quotienten $\left(\frac{l_d}{h}\right)$ abhängig. Die Funktion $C = f\left(\frac{l_d}{h}\right)$ ist empirisch ermittelt worden (Bild 2).

Der Koeffizient C kann auch rechnerisch ermittelt werden. Wenn nämlich

$$0{,}25 \leq \frac{l_d}{h} \leq 1 \quad \text{ist, dann beträgt } C_{0,25/1} = 5{,}5 + 6 \cdot \left(1 - \frac{l_d}{h}\right), \tag{9}$$

wenn

$$1 \leq \frac{l_d}{h} \leq 3 \quad \text{ist, dann beträgt } C_{1/3} = \frac{5{,}5}{\left(\frac{l_d}{h}\right)} + 0{,}075 \cdot \left(\frac{l_d}{h} - 1\right), \tag{10}$$

und wenn

$$3 \leq \frac{l_d}{h} \leq 15 \quad \text{ist, dann beträgt } C_{3/15} = 2 - 0{,}082 \cdot \left(\frac{l_d}{h} - 3\right). \tag{11}$$

Beim Kaltwalzen vergrössert sich der gedrückte Einspannbogen durch die Abplattung der Walzen. Diese Abplattung erwirkt eine Vergrösserung des Walzdruckes bzw. des Verfor-

Tafel 10

Kaltwalzen von Armco- Eisenbändern mit Zylinderölschmierung

(Versuche des Verfassers)

	h_1 mm	h_2 mm	Δh mm	h mm	l_{dn} mm	$\frac{l_{dn}}{h}$	k_{f1} kg/mm²	k_{f2} kg/mm²	k_{fm} kg/mm²	μ	v m/sec	$\sqrt[4]{v}$	C_n	l_u mm	l_{de} mm	$\frac{l_{de}}{h}$	C_e	k_{mc} kg/mm²	k_{mn} berechnet kg/mm²	k^*_{mn} Versuch kg/mm²	$\frac{k^*_{mn}-k_{mn}}{k^*_{mn}}$ %	D mm	$\frac{D}{h}$	r mm	P angetriebene Seite	P nicht angetriebene Seite	Σ P 10^3 kg	Bemerkungen
0	0,90	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
1	0,90	0,72	0,18	0,81	3,25	4,02	23,1	46	34,55	0,03	1,0	1,0	1,6	0,58	3,57	4,43	1,5	41,5	45,6	50,5	— 9,7	125	154	62,5	14,0	18,0	32	
2	0,72	0,55	0,17	0,62	3,23	5,22	46	61	53,5	0,03	1,0	1,0	1,5	0,95	3,72	6,0	1,3	66	76	93	— 18,3	125	202	62,5	25,0	33,2	58,2	
3	0,55	0,49	0,06	0,52	1,94	3,72	61	66	63,5	0,03	1,0	1,0	1,75	1,1	2,56	4,94	1,4	76,2	101	121	— 16,5	125	240	62,5	21,6	24,2	45,8	
4	0,49	0,42	0,07	0,455	2,06	3,71	66	71	68,5	0,03	1,0	1,0	1,75	1,195	3,017	6,65	1,3	86,2	126	125	+ 0,08	125	281	62,5	20,0	30,0	50,0	
0	0,92	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	300/125/125/300x x285 Walzgeschwindigkeit 1 m/min
1	0,92	0,70	0,22	0,81	3,7	4,58	23,1	46	34,55	0,03	1,0	1,0	1,5	0,58	4,00	4,95	1,4	41,5	44,8	44,7	0,0	125	154	62,5	16,0	16,2	32,2	
2	0,70	0,56	0,14	0,63	2,96	4,7	46	60	53,0	0,03	1,0	1,0	1,45	0,91	3,455	5,5	1,35	65	76	84,5	— 10,0	125	198	62,5	21,6	27,2	48,8	
3	0,56	0,47	0,09	0,501	2,37	4,73	60	66	63,0	0,03	1,0	1,0	1,45	1,1	2,93	5,35	1,35	78	96,3	88,5	+ 8,8	125	249	62,5	20,5	20,4	40,9	
4	0,47	0,40	0,07	0,435	2,08	4,8	66	73	69,5	0,03	1,0	1,0	1,4	1,2	2,81	6,5	1,3	87	117,3	107	+ 9,0	125	287	62,5	17,8	25,6	43,4	
0	0,90	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
1	0,90	0,72	0,18	0,81	3,2	3,95	23,1	46	34,55	0,03	1,0	1,0	1,65	0,527	3,56	4,4	1,6	38	42,4	33	+ 15,1	125	154	62,5	12,0	8,5	20,5	
2	0,72	0,53	0,19	0,625	3,12	5,0	46	61	53,5	0,03	1,0	1,0	1,5	0,89	3,90	5,92	1,3	63,2	75,2	72,8	+ 3,3	125	200	62,5	21,6	24,9	46,5	
3	0,53	0,47	0,06	0,50	1,95	3,9	61	66	63,5	0,03	1,0	1,0	1,65	1,1	2,55	5,1	1,5	80,5	105,5	103	+ 2,42	125	250	62,5	20,0	19,0	39,0	
4	0,47	0,40	0,07	0,435	—	—	63,5	71	68,5	0,03	1,0	1,0	1,5	1,25	2,805	6,45	1,35	89	119,5	95,8	+ 19,7	125	287	62,5	16,0	22,8	38,8	

Tafel 11

Kaltwalzen von Ms 72-Messingbändern mit geringer Petroleumschmierung

(Versuche des Verfassers)

	h_1 mm	h_2 mm	Δh mm	h mm	l_{dn} mm	$\frac{l_{dn}}{h}$	k_{f1} kg/mm²	k_{f2} kg/mm²	k_{fm} kg/mm²	μ	v m/sec	$\sqrt[4]{v}$	C_n	l_u mm	l_{de} mm	$\frac{l_{de}}{h}$	C_e	k_{me} kg/mm²	k_{mn} berechnet	k^*_{mn} Versuch	$\frac{k^*_{mn}-k_{mn}}{k^*_{mn}}$ %	D mm	$\frac{D}{h}$	r mm	P angetriebene Seite	P nicht angetriebene Seite	Σ P 10^3 kg	Bemerkungen
0	9,70	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	b = 110 mm
1	9,70	5,85	3,85	7,80	24,1	3,1	9	45	27	0,03	0,36	0,77	2,0	1,025	24,5	3,15	1,95	30,9	31,4	29,25	+ 7,4	400	51,2	200	48,0	29,4	77,4	v = 22 m/min
2	5,85	4,15	1,70	5,00	16,0	3,2	45	50	47,5	0,03	0,36	0,77	1,9	1,82	16,91	3,4	1,8	54,2	57,2	52,4	+ 9,15	400	80,0	200	58,8	33,6	92,4	
3	4,15	2,90	1,25	3,52	13,7	3,9	50	52	51	0,03	0,36	0,77	1,7	2,04	14,72	4,18	1,6	58,8	63	51,0	+ 24,5	400	114,0	200	44,6	31,8	76,4	
4	2,90	1,82	1,08	2,36	12,7	5,4	52	58	55	0,03	0,36	0,77	1,4	2,16	13,83	5,88	1,3	64,8	70,5	60,8	+ 16,0	400	170,0	200	52,8	32,2	85,0	
0	9,80	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
1	9,80	6,32	3,48	8,06	22,7	2,83	9	44	26,5	0,03	0,36	0,77	2,15	1,04	23,32	2,9	2,1	31,0	31	27,4	+ 13,2	400	49,5	200	40,4	27,7	68,1	
2	6,32	4,80	1,52	5,56	15,15	2,73	44	48	46	0,03	0,36	0,77	2,25	1,76	16,03	2,88	2,1	52,3	55,3	44,4	+ 24,6	400	72,0	200	44,6	29,0	73,6	
3	4,80	3,30	1,50	4,05	15,0	3,71	48	51	49,5	0,03	0,36	0,77	1,7	1,88	15,54	3,85	1,65	56,8	58,8	53,5	+ 9,9	400	99,0	200	51,6	36,6	88,2	
4	3,30	2,30	1,00	2,80	12,2	4,37	51	56	53,5	0,03	0,36	0,77	1,55	2,08	13,24	4,75	1,45	61,8	67	59,2	+ 13,2	400	142,0	200	48,6	30,8	79,4	
5	2,30	1,85	0,45	2,07	8,2	3,96	56	57	56,5	0,03	0,36	0,77	1,6	2,18	9,29	4,5	1,45	65,0	73,4	70,0	+ 4,85	400	193,0	200	38,2	24,8	63,0	

Tafel 12

Kaltwalzen von S 7-Stahlbändern mit geringer Petroleumschmierung

(Versuche des Verfassers)

	h_1 mm	h_2 mm	Δh mm	h mm	l_{dn} mm	$\frac{l_{dn}}{h}$	k_{f1} kg/mm²	k_{f2} kg/mm²	k_{fm} kg/mm²	μ	v m/sec	$\sqrt[4]{v}$	C_n	l_u mm	l_{de} mm	$\frac{l_{de}}{h}$	C_e	k_{me} kg/mm²	k_{mn} berechnet	k^*_{mn} Versuch	$\frac{k^*_{mn}-k_{mn}}{k^*_{mn}}$ %	D mm	$\frac{D}{h}$	r mm	P angetriebene Seite	P nicht angetriebene Seite	Σ P 10^3 kg	Bemerkungen
0	1,75	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	b = 40 mm
1	1,75	1,55	0,2	1,65	4,5	2,70	58	91,5	74,25	0,03	0,5	0,838	2,3	1,96	5,50	3,37	1,85	84,5	105	120	— 12,5	200	120	100	12,8	8,5	21,3	v = 29,5 m/min
2	1,55	1,35	0,2	1,45	3,9	2,70	91,5	100	95,80	0,03	0,5	0,838	2,3	2,56	5,93	4,1	1,60	111,5	148	141	+ 4,97	200	137	100	14,8	10,3	25,1	v = 0,5 m/min
3	1,35	1,20	0,15	1,275	3,9	3,05	100	100	100,00	0,03	0,5	0,838	2,0	2,70	5,45	4,3	1,60	117,2	162	142	+ 14,2	200	157	100	13,0	9,0	22,0	
0	1,85	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
1	1,85	1,55	0,3	1,70	5,5	3,21	58	93	75,50	0,03	0,5	0,838	1,9	1,96	6,52	3,35	1,7	88,0	104,5	109	—4,14	200	116	100	14,0	10,0	24,0	
2	1,55	1,20	0,35	1,375	5,5	4,00	93	104	98,50	0,03	0,5	0,838	1,65	2,65	6,945	5,08	1,4	115,5	145,5	127	+ 14,6	200	145	100	16,0	11,8	27,8	

mungswiderstandes. Zur Berechnung des vergrösserten Einspannbogens sind die Formeln (14) und (15) angegeben.

Die praktische Anwendbarkeit und Genauigkeit des Rechnungsverfahrens ist aus den beigefügten Tafeln ersichtlich.

Übrigens können aus diesen Tafeln, in denen die Ergebnisse der Kaltwalzversuche zusammengefasst sind, sehr wertvolle Schlüsse über die Grösse und die Veränderung des Reibungskoeffizienten durch Walzdruck und Walzgeschwindigkeit gezogen werden.

COMPUTATION OF THE MEAN DEFORMATION RESISTANCE AND OF THE ROLLING PRESSURE ARISING AT COLD AND HOT ROLLING OF SQUARE RODS AND SHEETS

Prof. A. GELEJI,
Member of the Hungarian Academy of Sciences

SUMMARY

The paper shows a method for computing the deformation resistance at hot and cold rolling. For computing the deformation resistance serves the formula

$$k_m = k_f \cdot \left(1 + C \cdot \mu \cdot \frac{l_d}{h} \cdot \sqrt[4]{v}\right), \qquad (1)$$

where the coefficient C depends at cold rolling as well as at hot rolling from the ratio $\left(\frac{l_d}{h}\right)$. The function $C = f\left(\frac{l_d}{h}\right)$ has been determined empirically (Fig. 2).

At cold rolling the compressed gripping arc is increased by the flattening of the rolls. This flattening causes an increase of the rolling pressure and the deformation resistance. For computing the increased gripping arc serve formulae (11) and (12).

The practical range of usefulness and the precision of the method can be seen from the Tables.

These Tables permit also to draw valuable conclusions on the size and the variation of the coefficient of friction depending on rolling pressure and rolling speed.

CALCUL DE LA RÉSISTANCE À LA DÉFORMATION MOYENNE ET DE LA PRESSION DE LAMINAGE AU LAMINAGE À FROID ET À CHAUD DES TIGES ET DES TOLES CARRÉES

A. GELEJI
Membre de l'Académie Hongroise des Sciences

RÉSUMÉ

Dans ce travail est publiée une méthode de calcul pour déterminer la résistance à la déformation au laminage à froid et à chaud. Pour le calcul de cette résistance sert la formule

$$k_m = k_f \cdot \left(1 + C \cdot \mu \cdot \frac{l_d}{h} \cdot \sqrt[4]{v}\right) \qquad (1)$$

où le coefficient C dépend, au laminage à froid aussi bien qu'au laminage à chaud, du rapport $\left(\frac{l_d}{h}\right)$. La fonction $C = f\left(\frac{l_d}{h}\right)$ a été déterminée empiriquement.

Au laminage à froid l'arc de serrage comprimé est augmenté par l'aplatissement des cylindres. Cet aplatissement cause une augmentation de la pression de laminage et de la résistance à la déformation. Pour le calcul de l'arc de serrage augmenté ont été communiqué les formules (11) et (12).

Les possibilités d'application pratique et la précision de la méthode sont montrés dans les tables ci-jointes.

Ces tables qui résument les résultats des éssais de laminage à froid permettent de tirer des conclusions très précieuses sur la grandeur et les variations du coefficient de frottement par la pression de laminage et la vitesse de laminage.

РАСЧЕТ СРЕДНЕГО СОПРОТИВЛЕНИЯ ДЕФОРМАЦИИ СООТВЕТСТВЕННО ДАВЛЕНИЯ ПРИ ПОКАТКЕ ВО ВРЕМЯ ГОРЯЧЕЙ И ХОЛОДНОЙ ПРОКАТКИ ИЗДЕЛИЙ В ФОРМЕ КВАДРАТНЫХ ПРУТКОВ И ЛИСТОВ

Академик АН Венгрии А. ГЕЛЕЙИ

РЕЗЮМЕ

В данном сообщении приводится расчетная методика определения сопротивления деформации при горячей и холодной прокатке. Для расчета сопротивления деформации служит формула

$$k_m = k_f \cdot \left(1 + C \cdot \mu \cdot \frac{l_d}{h} \cdot \sqrt[4]{v}\right) . \qquad (1)$$

В данной формуле коэффициент C как при горячей, так и при холодной прокатке зависит от частного $\left(\frac{l_d}{h}\right)$. Функция $C = f\left(\frac{l_d}{h}\right)$ установлена эмпирически (см. рис. 2).

При холодной прокатке увеличивается подвергаемая сжатию зажатая дуга вследствие сплющивания валков. Это сплющивание вызывает рост давления при прокатке и, соответственно, сопротивления деформации. Для вычисления увеличившейся зажатой дуги даются формулы (11) и (12).

Практическая применимость и точность расчетной методики видны по приведенным таблицам.

Между прочим, эти таблицы, в которых сведены данные результатов опытов по холодной прокатке, могут служить для установления величины и изменения коэффициента трения от давления при прокатке и скорости прокатки.

REPORTS OF THE HUNGARIAN NATIONAL COMMITTEE OF THE INTERNATIONAL GEODETIC AND GEOPHYSICAL UNION FOR THE 1957 TORONTO CONGRESS OF THE UNION

*

COMPTES-RENDUS DU COMITÉ NATIONAL HONGROIS DE L'UNION INTERNATIONALE GÉODÉSIQUE ET GÉOPHYSIQUE, PRÉSENTÉS AU CONGRÈS DE L'UNION A TORONTO — 1957

*

DIE ANLÄSSLICH DES KONGRESSES DER UNION IN TORONTO 1957 UNTERBREITETEN BERICHTE DES UNGARISCHEN NATIONALAUSSCHUSSES DER INTERNATIONALEN GEODÄTISCHEN UND GEOPHYSISCHEN UNION

*

ДОКЛАДЫ, ПРЕДСТАВЛЕННЫЕ НА КОНГРЕСС В ТОРОНТО В 1957 Г., ВЕНГЕРСКИМ НАЦИОНАЛЬНЫМ КОМИТЕТОМ МЕЖДУНАРОДНОЙ ГЕОДЕТИЧЕСКОЙ И ГЕОФИЗИЧЕСКОЙ ФЕДЕРАЦИИ

LES TRAVAUX GÉODÉSIQUES EN HONGRIE

RAPPORT ÉTABLI À L'OCCASION DE L'ASSEMBLÉE GÉNÉRALE DE L'UNION GÉODÉSIQUE ET GÉOPHISIQUE INTERNATIONALE À TORONTO, 1957.

E. REGŐCZI

DOCTEUR DES SCIENCES TECHNIQUES

Triangulation

Les origines de notre triangulation actuelle remontent à 1853. Des mesures d'un nouveau réseau primordial et secondaire ont été commencées en 1925 et terminées pour 80% jusqu'à 1944, en vue de remplacer le réseau vieilli qui n'avait plus la précision désirée, et présentait de nombreuses lacunes. Les résultats en ont été annulés presque entièrement par suite des événements de la guerre, de sorte qu'en 1948 nous avons procédé au rétablissement d'un nouveau réseau. Ce nouveau réseau comprend un système d'anneau double et deux réseaux complétants.

A) Le schéma du système d'anneau est représenté sur la Fig. 1. Les travaux de mesure commencés en 1949 ont été achevés en quatre ans, soit en 1952. La chaîne du nord encadre la frontière hongroise—tchécoslovaque, par conséquent ses points sont en partie sur territoire hongrois, en partie sur territoire tchécoslovaque.

La longueur totale des chaînes formant le système d'anneau est d'environ 1250 km, celle de l'anneau occidental de 720 km, et celle de l'anneau oriental (y compris la section de chaîne médiane) de 710 km. Le nombre des points dans les chaînes est de 112 ; les points forment 132 triangles, 34 en sont des tours, le reste étant des pyramides d'échafaudage. La longueur moyenne des côtés des triangles est de 30 km.

Les mesures ont été effectuées avec des théodolites Wild T 3, selon la méthode de Schreiber, le poids «p» était 24. Comme signal, on a utilisé le jour un héliotrope, la nuit une ampoule de 6 watts, placée au foyer d'un miroir parabolique de 16 cm. Pour limiter la réfraction latérale, les répétitions ont été mesurées — autant que cela était possible — moitié de jour, moitié de nuit.

La compensation du système d'anneau est terminée. Les résultats des observations ont été réduits, à la base de la hauteur du point envisagé, au niveau de la mer, compte tenu également de la réduction à la ligne géodésique. La réduction provenant de la déviation de la verticale n'a pas été appliquée. On a

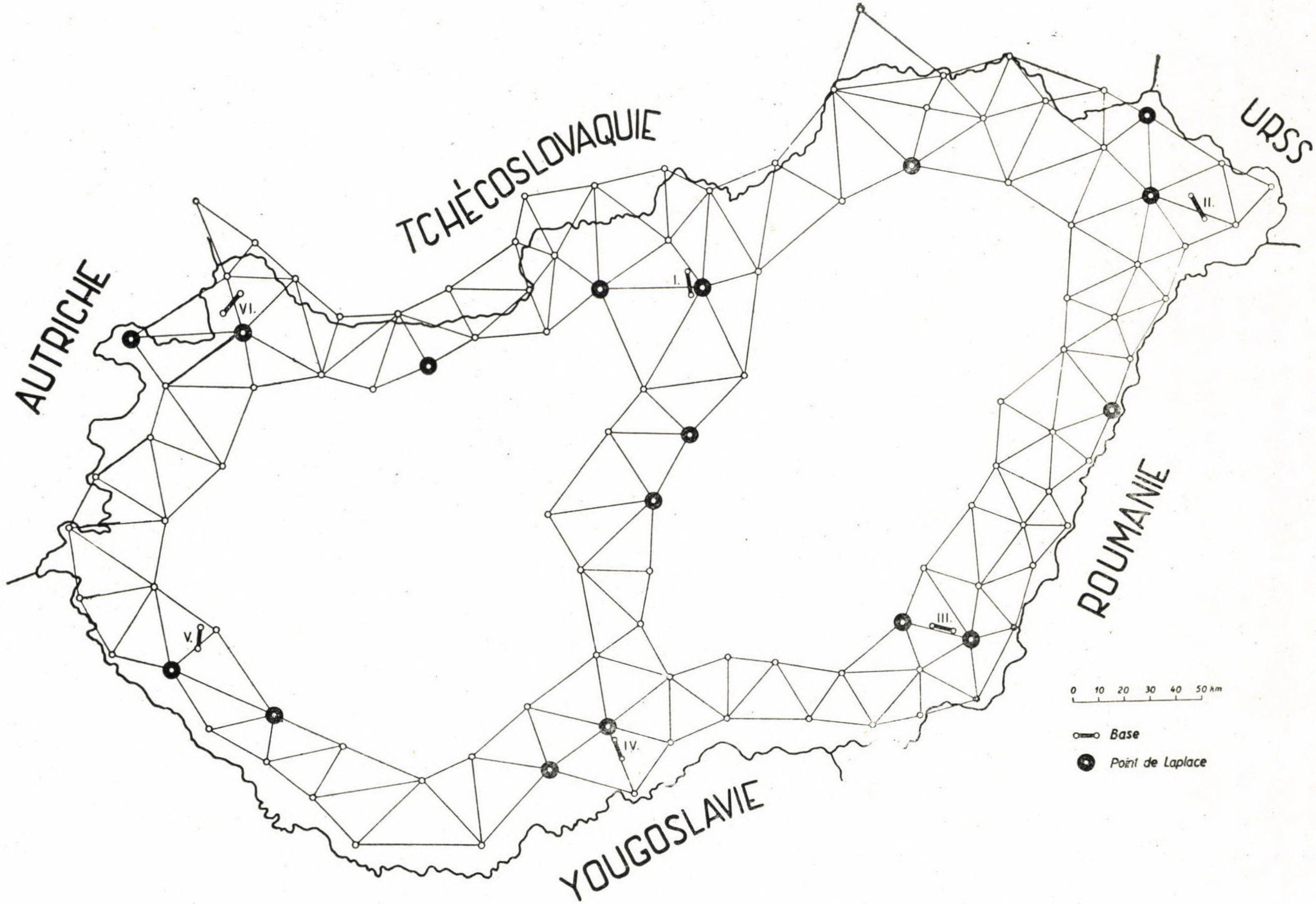


Fig. 1. Triangulation de premier ordre en Hongrie (1949—1952)

effectué la compensation ensemble, sur l'ellipsoïde, selon la méthode de BOLTZ. Nous projetons cependant d'effectuer également la compensation selon la méthode d'EGGERT, et avons même commencé les calculs y relatifs. Dans la compensation, nous considérons les côtés développés des bases comme des résultats de mesure, nous y adjoignons donc des corrections. Les poids des côtés développés ont été déduits de la compensation séparée du réseau développant.

En ce qui concerne la précision du système d'anneau, nous pouvons communiquer les données suivantes (en système sexagésimal) :

Erreur moyenne de direction de la compensation de station	± 0,181″
Erreur moyenne de direction selon Ferrero	± 0,327″
Erreur moyenne de direction après la compensation du réseau	± 0,408″

Notons que les erreurs de fermeture des triangles restent inférieures à 2,0″, leur répartition suit bien la courbe de GAUSS. La somme des erreurs de signe positif est de + 41,935″, celle des erreurs de signe négatif de — 43,968″. La valeur moyenne est donc de — 0,015″, la moyenne des valeurs absolues de 0,651″.

L'erreur de fermeture de l'anneau occidental est linéairement :

en latitude	1,01 m
en longitude	1,18 m
en azimut	1,175″

L'erreur de fermeture de l'anneau oriental est linéairement :

en latitude	2,39 m
en longitude	2,14 m
en azimut	3,51″

C'est-à-dire la valeur relative de l'erreur de fermeture est 1/460 000 dans l'anneau occidental, et 1/220 000 dans l'anneau oriental (1).

B) La mesure du réseau complétent les anneaux a été commencée en 1953. On a utilisé une nouvelle méthode, dont le principe est le suivant : on couvre tout le territoire par un réseau, dont les côtés ont une longueur de 7 km ; on choisit parmi les points du réseau quelques points nommés dominants, formant des triangles d'une longueur de côté de 30—35 km. Les angles des triangles déterminés par les points dominants ne sont pas mesurés directement, mais on les déduit du réseau de petits triangles et en tenant compte des conditions représentées par l'anneau, on compense ce réseau à la base des angles calculés. Après avoir determiné les coordonnés des points dominants, on rattache le réseau des petits triangles entre les points dominants. Pour les détails de cette méthode élaborée par Emil REGŐCZI, voir les ouvrages cités dans notre bibliographie sommaire [2], [3], [4], [5], [6].

Notons encore qu'en vue d'accélérer les travaux et de réaliser une économie de matériaux, les signaux du réseau complétant sont construits en éléments préfabriqués, qui peuvent être, après les observations, démontés et transportés ailleurs.

Les angles horizontaux du réseau complétant sont mesurés avec des théodolites Wild T 3, par la méthode des directions dans 12 séries. A la fin de l'année 1956, l'observation fut terminée sur deux tiers du réseau (dans 1248 triangles).

L'erreur de fermeture des triangles est en général 0,90''

L'erreur moyenne selon Ferrero est 0,44''

Les compensations jusqu'à présent terminées ont justifié cette méthode de développement [7], [8]. Quant aux calculs y relatifs, nous en rendrons compte après leur achèvement.

Bases

Notre nouveau réseau de triangulation a 6 bases. Elles sont situées dans les figures de jonction des chaînes, en général à 172 km l'une de l'autre. Leur longueur varie entre 8,0 et 10,4 km. Aucune n'est brisée. 4 en sont sur région plane, 2 sur région collinée.

Le mode de la stabilisation est visible sur la Figure 2.

Les goujons-repère furent vissés aux pieux en bois de 15 cm de diamètre, enfoncés au sol jusqu'aux deux tiers de leur longueur de 210 cm. On n'a pas employé d'étayages. Le dénivellement des repères voisins était toujours moins de 80 cm.

La mesure a été effectuée sur chaque base entre 1950—52, avec les mêmes fils d'invar d'une longueur de 24 m, fournis par la maison Carpentier. Trois couples d'observateurs participaient à la mesure, chacun des couples avant mesuré avec 2 fils, dans tous les deux sens. Nous nous sommes servis de piquets-tenseurs système Witram, avec un poids tenseur de 10 kg. On a fait les lectures en position assise. Dans chaque position de fils, on effectuait 5 lectures en déplacant les fils, avant les lectures, alternativement en avant ou en arrière. Au lieu de mesurer la température des fils, nous avons mesuré la température de l'air. Par ailleurs, nous avons procédé selon les règles de mesure généralement admises.

On n'a mesuré qu'à temps calme. Si le composant du vent normal à la direction de la base a atteint la valeur de 4m/sec, nous avons interrompu la mesure. Une partie d'une base a été mesurée, à titre d'expérience, sous vent aussi. Ces essais ont confirmé les recherches théoriques de Tárczy-Hornoch, vu qu'entre les résultats de mesure munis de corrections calculées à la base de la vitesse et de la direction du vent, et les résultats obtenus par un temps calme, il ne restait que des erreurs de caractère accidentel [9], [10].

La comparaison des fils avant et après la mesure a été faite sur notre base d'étalonnage de Gödöllő, dont la longueur de 864 m a été déduite en 1940 de la base de référence de Potsdam [11]. Selon nos essais de 1950, la longueur de notre base d'étalonnage n'a pas changé sensiblement durant 10 ans.

Les données des bases sont contenues dans le Tableau I. Les valeurs publiées caractérisant la précision sont calculées selon les formules qui suivent:

L'erreur kilométrique moyenne accidentelle :

$$\mu_{vkm} = \frac{1}{2\,i}\sqrt{(dd)}\sqrt{\frac{1000}{L}}$$

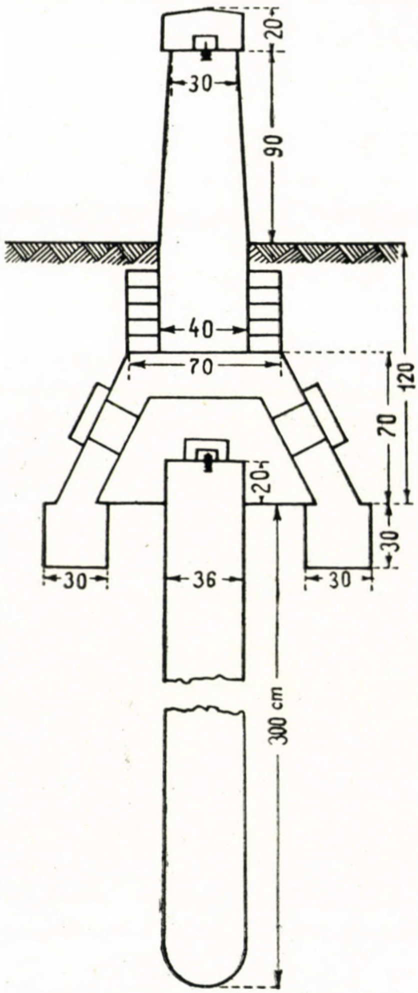


Fig. 2. Stabilisation des bases

où

i = le nombre des fils,

$d = l_0 - l_v$ c'est-à-dire l'écart obtenu par fils entre les résultats d'aller et retour,

L = la longueur de la base.

L'erreur kilométrique moyenne totale :

$$\mu_{tkm} = \frac{1}{\sqrt{i}} \sqrt{\frac{[d_m\, d_m]}{i-1}} \sqrt{\frac{1000}{L}}$$

où

$$d_m = L - \frac{l_0 + l_v}{2}.$$

Tableau I

	Longueur de la base	μ_{vkm} (mm)	μ_{tkm} (mm)	Erreur moyenne totale relative	Longueur du côté développé (km)	Erreur moyenne totale relative du côté développé (mm)
I	8,04	±0,80	±1,14	1/2 485 000	20,10	± 78,92
II	10,39	0,45	1,78	1/1 814 000	29,48	59,14
III	10,18	0,20	1,15	1/2 844 000	28,21	49,64
IV	8,45	0,39	1,10	1/2 650 000	29,58	107,52
V	8,02	0,28	1,75	1/1 616 000	24,85	144,02
VI	9,93	0,30	2,11	1/1 493 000	21,77	28,18

Les réseaux développant les bases ont la figure rombique. L'amplification est entre 1/2,2—1/3,5. Les angles ont été observés avec des théodolites Wild T3, selon la méthode de SCHREIBER ($p = 48$). La moitié des répétitions a été mesurée de jour, l'autre moitié de nuit, en observant toujours sur lumière [12].

RÉFÉRENCES

1. HŐNYI E. : Új elsőrendű háromszögelési láncolatunk szögméréseinek pontossági vizsgálata. (Földméréstani Közlemények 1954.)
2. REGŐCZI, E. : Takarékos felsőrendű háromszögelés. (Földméréstani Közlemények 1951).
3. REGŐCZI, E. : Réseau primordial déduit d'un réseau trigonométrique de troisième ordre. (Acta Technica, Tom IV. fasc. 1—4. Budapest, 1952.)
4. TÁRCZY-HORNOCH, A. : Beszámoló a felsőgeodézia terén folyó vizsgálatokról. — (Magyar Tudományos Akadémia Műszaki Osztályának Közleményei. I. 1. Budapest 1951.)
5. HAZAY, ST. : Über Ausgleichung von Landestriangulierungsnetzen und kontinentalen Triangulierungsnetzen. — (Acta Technica Tom. VI. fasc. 3—4. Budapest 1953.)
6. REGŐCZI, E. : Über das Ausfüllnetz des Kettenrahmens der Triangulation erster Ordnung in Ungarn. (Vermessungstechnik 1954.)
7. HŐNYI, E. : A magyarországi új kitöltő háromszögelési hálózat kísérleti számításai. — (Geodézia és Kartográfia 1955.)
8. HŐNYI, E. : Eljárás kitöltőhálózatunk kiegyenlítésére. — (Geodézia és Kartográfia 1957.)
9. TÁRCZY-HORNOCH, A. et ESZTÓ, P. : On the influence of wind in connection with Jäderin-wires. — (Bulletin Géodésique. 1947. 23—48 p.)
10. TÁRCZY—HORNOCH,, A. és ESZTÓ, P. : A szélnyomás hatása a Jäderin-drótokra. — (Földméréstani Közlemények 1950.)
11. REGŐCZI, E. : A gödöllői országos összehasonlító alapvonal. — (Budapest 1942.)
12. JÁN, L. : A magyar felsőrendű háromszögelés alapvonalai és alapvonalfejlesztő hálózatai. — (Földméréstani Közlemények 1954.)

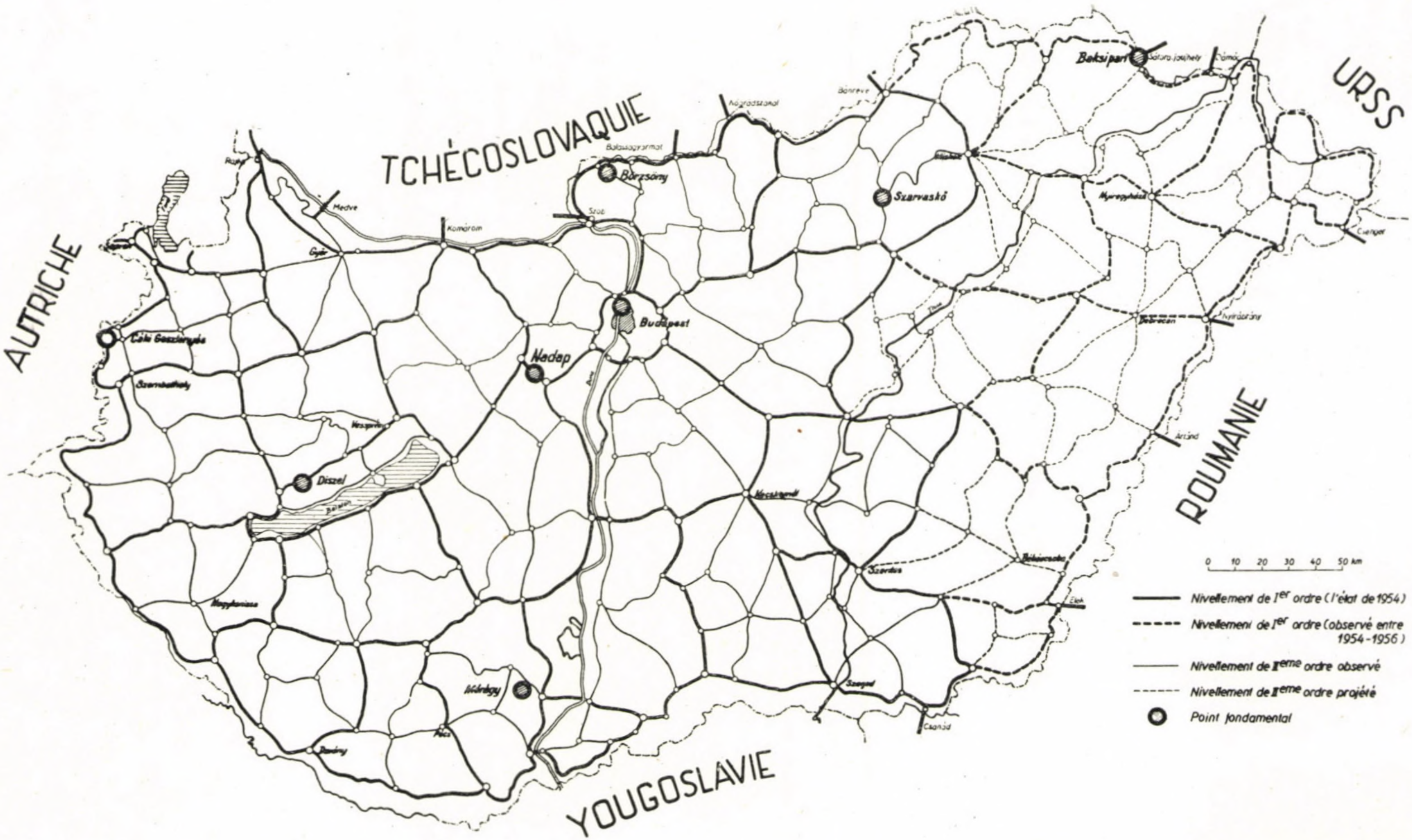


Fig. 3. Réseau de nivellement

Nivellement

Le développement du réseau de nivellement de haute précision de la Hongrie a été commencée en 1921, et pouvait être considéré comme achevé en 1939. La longueur totale du réseau était de 5939 km, mais il était rendu plus dense par des lignes de nivellement de précision d'une longueur d'environ 1900 km, à l'intérieur des polygones fermés de nivellement de haute précision. La compensation du réseau fut effectuée en 1949 [1].

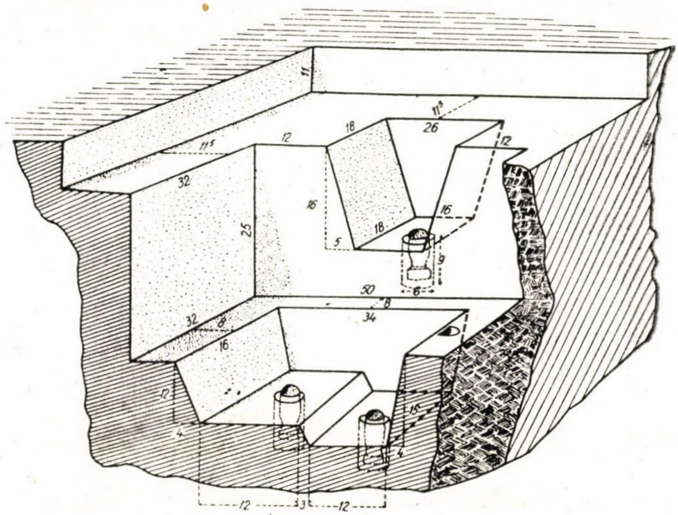


Fig. 4. Stabilisation des points fondamentaux de nivellement

La majeure partie du réseau fut détruite au cours de la guerre. Il devint donc nécessaire de développer un nouveau réseau de nivellement de haute précision et un nouveau réseau de précision (voir Fig. 3).

Le point de référence du nouveau réseau de nivellement de haute précision est le même point fondamental nommé *Nadap* (I) sur lequel s'établissait déjà le réseau développé entre 1921 et 1939. Sa hauteur est restée invariablement 173,83850 m.

Étant donné que le réseau de nivellement de précision hongrois ne possédait jusqu'à maintenant que ce seul point fondamental, et que celui-ci même fut détruit presque entièrement pendant la guerre, nous avons établi 7 autres points fondamentaux dans les contrées montagneuses du pays, et en plus un nouveau point fondamental nommé *Nadap* (II) dans le voisinage de l'ancien point *Nadap* (I). La place des points est marquée sur le schéma (Fig. 3) par de plus grands cercles.

Les points fondamentaux consistant en trois repères sont placés dans une espèce de petit caveau [2]. L'un d'eux est en verre spécial résistant aux acides, les deux autres étant en acier antirouille Krupp (V_4 A supra et V_2 extra). Entre les repères il y a une différence de hauteur de 4—5 cm. Le caveau renfermant les repères a été couvert de 4 plaques de marbre. L'étanchéité des caveaux, ainsi que des fentes à côté des pierres de couverture, est assurée par une couche de bitume. Chaque point de base principal est pourvu de 2—3 repères d'assurance [2].

Les noeuds du réseau de nivellement de précision sont munis de repères d'assurance souterrains. Ce sont des colonnes en béton banché d'une longueur de 120 cm et d'un diamètre de 30—35 cm, fabriquées sur place et placées dans des forures exécutées, à cause de la frontière de gel, à une profondeur de 140 cm au-dessous du niveau du sol.

Le repère d'assurance est marqué par le bout arrondi et saillant d'un fil de fer ancré profondément dans la colonne, protégé contre les détériorations par un couvercle en métal.

La mesure du nouveau réseau primordial a été commencée en 1950 et fut terminée en 1956. On s'est servi des niveaux à lunette Wild N. III., et des mires en invar Wild. Le réseau secondaire a été mesuré avec le même instrument (voir les lignes minces sur la Figure 3).

La mesure s'effectue selon les règles généralement connues, la distance niveau-mire est au maximum de 40 m, les sections sont observées deux fois en sens inverse (aller et retour).

Le réseau est rattaché tant au réseau de la République Tchécoslovaque, qu'à celui de la République Populaire Roumaine.

La compensation de réseau aura lieu au cours de cette année. Les corrections orthométriques sont calculées à la base des valeurs effectives de la pesanteur, selon la formule de HELMERT.

RÉFÉRENCES

1. BENDEFY, L. : Felsőrendű szintezési hálózatunk az 1949. évi kiegyenlítés tükrében. — (Földméréstani Közlemények 1952.)
2. BENDEFY, L. : A magyar országos felsőrendű szintezés új főalappontjai. — (Földméréstani Közlemények 1952.)

Observations d'astronomie de position

En Hongrie, c'est le Service Géodésique et Cartographique National qui effectue les observations d'astronomie géodésique. Au cours de la période 1951—1956, une, resp. deux équipes ont opéré sur le terrain, pendant 5 à 6 mois chaque année. Les équipes ont été composées de deux ingénieurs-observateurs et du personnel auxiliaire.

Le but des observations a été, entre 1951 et 1953 surtout, la détermination des points de Laplace dans les chaînes de notre nouveau réseau trigonométrique et, dès 1953, l'établissement d'un réseau des points astronomiques, assez dense

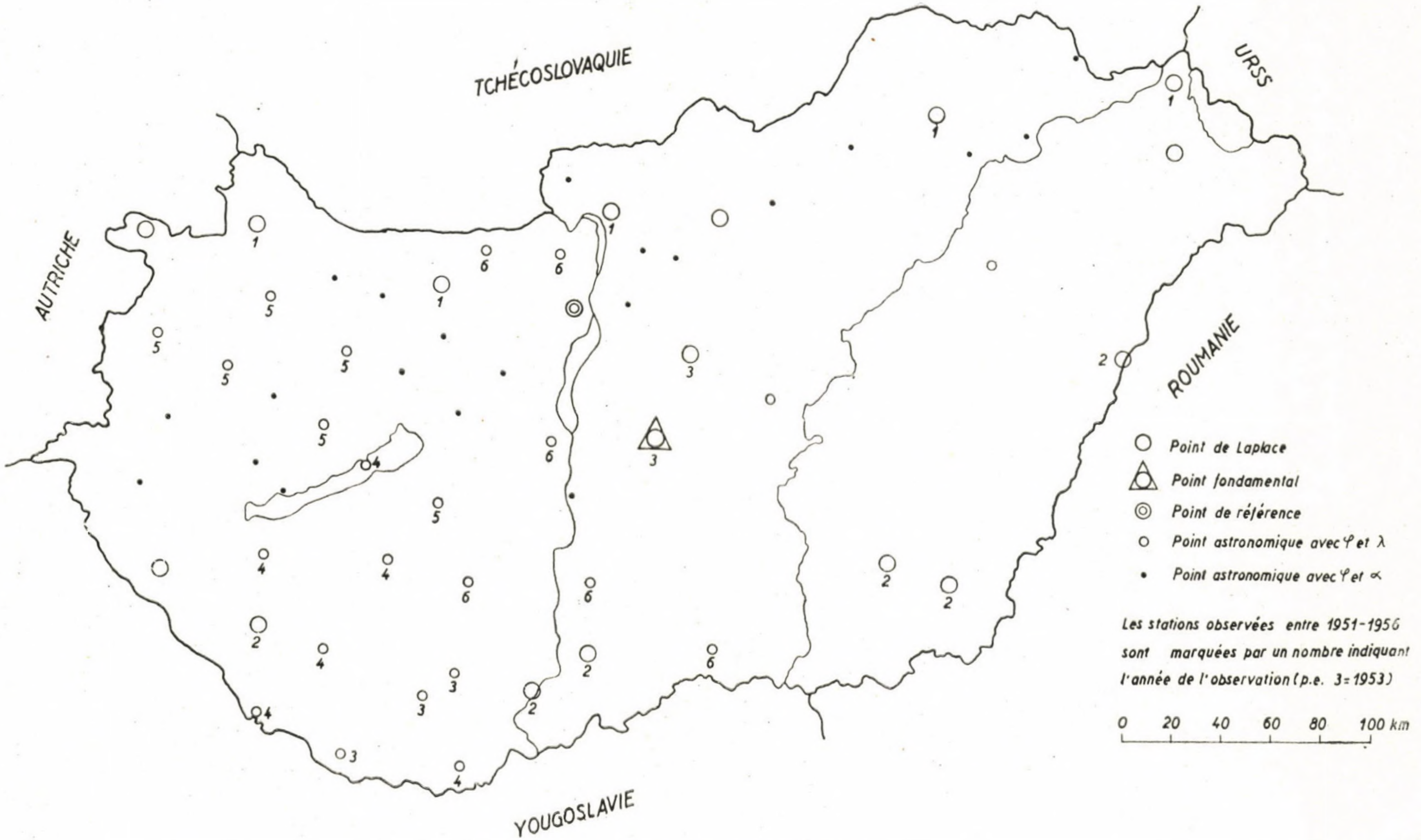


Fig. 5. Stations astronomiques

pour l'étude de la forme du géoïde. Le cadre du réseau primordial formant un système d'anneau double, contient 17 points de Laplace marqués sur le schéma ci-joint par des cercles un peu plus grands, resp. par un petit triangle. Ce dernier est notre point fondamental (Geodetic Datum). L'observation des points de Laplace fut achevée en 1953, en outre 13 points entre eux furent observés durant la période considérée. En tout, nous avons observé sur 31 points pendant cette période, les 18 points astronomiques non utilisés dans la compensation du système annulaire servent à la détermination du géoïde (points marqués sur le schéma par des cercles plus petits). Dans ce but, nous utilisons aussi les points déterminés avant la deuxième guerre mondiale (petits cercles noirs sur le schéma). Les travaux sur terrain continuent naturellement, en vue d'obtenir un réseau convenablement dense.

Sur les points de LAPLACE, on a déterminé généralement tous les trois éléments, c'est-à-dire la longitude, la latitude et l'azimut. Les points de Laplace situés dans les points de jonction des chaînes, comme le point fondamental et son voisin, sont des points jumeaux, dont l'un est toujours la station principale, l'autre la station secondaire. La différence en est le poids (le nombre des soirées) de l'observation. Sur les points servant à la détermination du géoïde, nous ne déterminons en général que la latitude et la longitude, tandis que sur les points déterminés avant la guerre, c'est la latitude et l'azimut qui étaient observées.

Les observations sont effectuées par théodolites Wild T4, resp. par un instrument des passages fourni par la maison Askania, avec support Döllen. L'instrument des passages est muni d'un micromètre impersonnel pour la mesure de la longitude, et d'un micromètre selon HORREBOW pour les latitudes. Les théodolites Wild n'ont qu'un seul micromètre.

Nous utilisons des signaux horaires rythmiques émis par les stations soviétiques, françaises, et anglaises. La réception, resp. l'enregistrement s'effectue selon la méthode de HÄNNI, à l'aide d'un chronographe Favag à deux plumes, dont la tension de travail est de 12 V, et la vitesse de déroulement de 1 cm/sec. Le récepteur est une radio à ondes courtes (20—38 m) type Zellweger ZZE.

L'une des équipes a été munie d'un garde-temps pendulaire Riefler, l'autre s'est servie d'un chronomètre marin Nardin. Les deux instruments sont réglés sur le temps sidéral.

Pour déterminer la longitude, nous procédons selon la méthode de MAYER, en observant en deux positions de la lunette. Le programme des étoiles est choisi de manière que la moyenne aritmétique des coefficients de l'azimut soit zéro. Sur les points principaux, on observe généralement pendant 10, sur les autres points pendant 5 à 7 soirées. L'état du garde-temps, déterminé sur base des passages des étoiles de même soirée, est rapporté à l'époque correspondant à la moyenne arithmétique des moments d'observation des étoiles. Pour ce calcul, on utilise la marche horaire moyenne pendant la série d'observations, déduite des réceptions de signaux horaires, en les supposant exactes, car les corrections définitives n'arrivent qu'après un délai assez grand. Le calcul est établi de sorte que les réductions, dues aux corrections définitives des signaux horaires et aux coordonnées momentanées du Pôle, n'exigent qu'une modification des résultats préalablement déterminés, sans réfection des calculs intermédiaires. En outre on calcule, à la base de chaque soirée, une valeur de longitude. La valeur définitive en est la moyenne, et l'erreur moyenne est calculée des écarts entre la moyenne et les valeurs des soirées. Nous remarquons encore qu'on détermine l'azimut instrumental par observation des étoiles circumpolaires.

Pour déterminer la latitude, nous utilisons la méthode de HORREBOW-TALCOTT, sous condition que la somme algébrique des différences zénithales des paires d'étoiles mésurées pendant la même soirée, de même que la somme algébrique des corrections de niveau de la même soirée, soient approximativement zéro. Sur les points principaux, nous observons 10 à 16, sur les autres, 6 à 10 paires d'étoiles pendant une soirée. Pour terminer un point, on doit observer durant 6 à 10 soirées, afin d'obtenir la quantité d'observations prévues. Quant au calcul des latitudes, il faut remarquer que la valeur angulaire du tour de la vis oculaire et le constant du niveau Horrebow, déterminés par mesures séparées, ne sont considérés que comme des données préliminaires, les valeurs définitives étant déduites ensemble avec la valeur définitive de la latitude d'une compensation commune. C'est cette compensation qui nous offre aussi l'erreur moyenne caractérisant l'observation.

Pour déterminer l'azimut, nous utilisons l'étoile polaire en réalisant 48 séries de mesures, dont la moitié est effectuée de jour, l'autre de nuit. Pour mieux limiter l'influence de la réfraction latérale, les mesures sont réparties sur 6 à 10 jours.

Nous nous sommes servis des catalogues anglais (Apparent places of fundamental stars) du système FK 3, et pour complèter — des catalogues soviétiques (Astronomisheski ejegodnik), dont le tableau des deuxièmes différences est plus maniable et plus précis que celui du catalogue anglais.

Quant à la précision des résultats, nous faisons connaître les erreurs moyennes ci-après :

longitude	$\pm$ 0,004—0,008 sec
latitude	$\pm$ 0,07 —0,09″
azimut	$\pm$ 0,12 —0,18″.

Ajoutons encore, quant aux azimuts, que l'erreur moyenne donnée ci-avant est calculée des écarts entre les résultats des séries et leur moyenne. L'erreur moyenne calculée des écarts des observations faites entre les points jumeaux est

$\pm$ 0,425″.

En été 1955, nous avons effectué la liaison de notre point de référence, (le pilier de l'instrument des passages, à l'Observatoire de Budapest-Szabadsághegy) et du point fondamental de Potsdam.

Les mesures avaient lieu simultanément sur les deux stations et ont été répétées après changement des instruments et du personnel.

Déviations de la verticale et études de géoïde

Avant le calcul de notre nouveau réseau, nous avons procédé à la compensation de la déviation de la verticale, à la base de toutes les données astronomiques identificables, mesurées sur le territoire du pays. Ces mesures ont été effectuées en vue d'en déduire les coordonnées préliminaires du point de départ astronomique. Dans cette compensation, nous nous sommes servis des valeurs de latitude et d'azimut déterminées encore par l'Institut Géographique Militaire de Vienne. Comme réseau géodésique, nous avons utilisé le réseau actuellement existant, qui remonte à 1853. Malheureusement, ces données se répartissent d'une manière assez inégale sur le territoire du pays, de sorte que — tout en ayant à notre disposition près de 60 valeurs de déviation de la verticale, et dans la direction du méridien et dans celle y perpendiculaire — l'établissement d'une carte du géoïde pouvant être considérée comme exacte et basée sur les valeurs de déviation de la verticale, n'était possible que pour la partie septentrionale du Dunántúl (Transdanubie) [1].

A la base des coordonnées préliminaires du nouveau réseau et des résultats des nouvelles mesures astronomiques, on constate que les coordonnées établies préalablement et les coordonnées définitives, déduites du résultat de la compensation astrogéodésique effectuée à la base des nouvelles données, différeront tout au plus de 1″ en latitude et de 1,5″ en longitude. La différence entre l'orientation préliminaire et définitive du système sera inférieur à la valeur de 1″.

Nous avons l'intention de dresser, d'après le nouveau réseau de triangulation et les nouvelles mesures astronomiques, la carte de tout le secteur hongrois du géoïde. Nos mesures y relatives sont en cours.

RÉFÉRENCES

HOMORÓDI, L.: Vizsgálatok új háromszögelési hálózatunk elhelyezésére és tájékozására. — (Földméréstani Közlemények 1952.)

REPORT
ON THE GRAVITATIONAL INVESTIGATIONS IN HUNGARY IN 1954—56

J. RENNER
D. ENG. SC.

Gravitational investigations in Hungary in the years 1954 to 1956 have been chiefly carried out in the Hungarian Geophysical Institute Roland Eötvös. The accomplished works are concerning the following subjects :

1. Completion of the national gravimeter base network and working up of the results.
2. Detailed exploratory surveys.
3. Theoretical investigations.
4. Construction of a new model of the Eötvös' torsion-balance.
5. Investigations concerning gravimeters.
6. Researches about the deviation of the vertical.
7. Corrections of levelling data on the basis of gravity measurements.
8. Relative pendulum measurements.
9. Handbooks.

1. Completion of the national gravimeter base network and working up of the resu lts

The Hungarian Geophysical Institute Roland Eötvös has finished in May 1955 the surveying of the national *gravimeter base network* started in 1950. In August and September 1951 observations have been carried out on 16 first order base points using aircraft to transport the instrument. The number of the second order stations of the network is 509, including the 16 first order base points which are, simultaneously, points of the second order network. The measurements have been carried out by a Heiland gravimeter. The mean error of the surveys is about $\pm$ 0,03 mgal. The measuring data have been provisionally worked up already in the course of field work. These provisional results have been published by L. Facsinay and J. Szilárd in the *Geofizikai Közlemények* (Geophysical Bulletins), Vol. 5., No. 2. 1956, under the title : "The Hungarian network of gravity bases".

The paper gives a description of the survey, the coordinates and heights of the base points, the observed and normal values of gravity, the Faye-, Bouguer- and isostatic anomalies accompanied by sketch maps. The observations on the 16 first order bases have been preliminarily adjusted, then the whole territory of second order base network was divided into 16 zones and the data of each zone were adjusted so that gravity values of the connecting points of the already adjusted zone have been considered as conditions. The reference station for the base network is a pillar in the Geodetical Department of the Technical University in Budapest, where the gravity has previously been determined by means of a relative pendulum and its gravity value was taken as 980 853 gal in the Potsdam system. At the beginning of 1956 the final systematical working up of the network was commenced. The effect of Sun and Moon was calculated for every date of the gravimeter readings, multiplied by 1,2 and subtracted from the readings. A correction was applied because of the influence of the geomagnetic field on the gravimeters. In the final working up a correction has been applied to, which — basing on the investigations of I. Komáromy — takes into account the fact that the scale sensitivity is diverging from linearity. The final processing of the observed material is still in course under the auspices of the Hungarian Academy of Science.

2. *Detailed exploratory surveys*

Prospecting surveys were carried out in the years 1954—1956 in different parts of the country, partly with *Eötvös' torsion-balances*, partly with *gravimeters*. When working up the measurements, the preliminary values of the network of bases were taken into consideration. The mean distance of gravimetric points was 500 m, whereas the distance of observation points made with the torsion balance was about 1 km.

We may point out that detailed gravimeter surveys have been carried out also in the surroundings of the 17 Laplace-points. The gravimeter surveys used chiefly two Heiland gravimeters, but to some extent a Nørgaard gravimeter, too. The mean error of the measurements made with the Heiland gravimeters has been about $\pm$ 0,03 mgal, with the Nørgaard gravimeter about $\pm$ 0,2 mgal.

The results of surveys with the torsion balance have been worked up as usual. The horizontal gradients, the horizontal directing tendencies calculated from curvature data and the isogam-lines have been represented on maps. The accuracy, i. e. mean error of these surveys is about $\pm$ 1 E. The $\triangle g$-values necessary for the construction of isogams were usually so calculated that the change of gradient between two neighbouring points has been supposed to be linear and at every point the Δg-values deduced from the neighbouring points, and differing frequently from each other, have been averaged. It has been already in 1949 that A. Tárczy-Hornoch, member of the Academy, developped a method of adjustment where the values of the gradient themselves have to be provided with corrections. This method is strictly corresponding to the principles of least squares.

Theoretically, close to this method is that applied by Sz. Oszlaczky, who interpolates the gradients to the points of a quadratic network and thus he obtains a somewhat smoothed distribution of the errors of gradients. The computation of gravity differences for the sides of the quadratic network is carried out on the assumption of a linear change ; the computation of

△g-anomalies is accomplished by means of least squares. The values at the points of the network of gravimeter bases in the area in question are taken into consideration as conditions. The collaborators of the Geophysical Institute have worked up several territories of the torsion balance survey with this method.

In most cases Bouguer-anomalies have been computed on the basis of detailed gravimeter surveys. With this computation great care has been taken of the determination of most realistic density values, whilst considering geological data. Normal values of gravity have been computed with the international formula of Cassinis.

In order to get a more detailed idea about the layers in the subsoil, *residual* anomalies were also computed on some interesting territories. With these computations several methods have been used, that of Peters, Elkins, Rosenbach, and chiefly that of Baranov. On some territories the second vertical derivatives of gravity — which have also the character of residual anomalies — have been computed from the gradients of torsion balance surveys.

As to the mean density, the following study has been published : L. Egyed: "New method for the determination of mean density". *Geofizikai Közlemények*, IV. 1955.

3. *Theoretical investigations*

Among the theoretical investigations several studies dealt with the gravitational or magnetic *effects of masses* having *different shape* and *position*. Hungarian authors have recently published the following papers :

I. B. Haáz : "Determination of the dip, density and susceptibility of an infinite inclined dike from its gravity and magnetic effects." *Geofizikai Közlemények*, Vol. IV. No. 2. 1955.

This study is completing the paper of the author published in the *Geofizikai Közlemények*, Vol. I. 1952. It proves that dip and density (susceptibility) of the dike may be determined without ambiguity from the positions of extreme values of gravity (magnetic) anomalies as well as from the character of these extreme values.

I. B. Haáz : "Relations between the potential of the attraction of the mass contained in a finite rectangular prism and its first and second derivatives". *Geofizikai Közlemények*. Vol. II. 1953. This study gives simple and well manageable solutions by means of Euler's theorem concerning homogeneous functions. The advantageous applicability of the method has been proved by practical calculations.

Sz. Oszlaczky : "Tables for the gravimetric effects of cylindric masses". *Geofizikai Közlemények*. Vol. V. 1. 1956. This paper contains tables for an easy application to mass effect computations.

Several papers are discussing the *gravity effect of Sun and Moon*. The researches of K. Lassovszky and Sz. Oszlaszky have been dealing with this theme. Their previous studies were published in the *Geofizikai Közlemények*, Vol. I. 1952. Further papers on this subject are as follows :

K. Lassovszky and Sz. Oszlaczky : "The tidal variation of gravity II". *Geofizikai Közlemények*, Vol. III. No. 2. 1954. Using the data of some selected series of continuous gravimeter observations carried out in Budapest in 1951 they found for the deformation coefficient of the Earth a mean value of 1,15.

K. Lassovszky : "Determination of the deformation coefficient of the Earth from gravimeter observations". *Geofizikai Közlemények*, Vol. V. 1956.

K. Lassovszky : "Determination of the coefficient of the lunisolar gravity effect from the observations made in the course of 37 days in 1951 in Budapest". *Geofizikai Közlemények*, Vol. V. 1956. The author is discussing in these papers a method to eliminate on the one hand the tares in gravimeter readings, and on the other hand the continuous drift of the instrument. The mean value of the deformation coefficient obtained thus by means of all gravimeter readings, made in Hungary, is 1,20.

Isostasy and related problems are dealt with in the following studies :

L. Facsinay : "Gravity measurements and isostasy". *Akadémiai Kiadó,* 1952. This paper has the character of a summarizing handbook.

L. Egyed : "Some notes concerning the question of isostasy". *Acta Technica* IV. 1952.

V. Scheffer : "Isostasie". *Acta Technica* IX. 1954.

V. Scheffer : "Über den Zusammenhang zwischen isostatischen Anomalien und Vergenzen der Gebirgsbildung". *Acta Technica,* X. 1955.

V. Scheffer : "Der isostatische Charakter der ungarischen Niveauveränderungen und die Möglichkeit der zeitlichen Korrektion der Höhenwerte der Nivellementhöhenfestpunkte". *Acta Technica:* X. 1955.

L. Egyed : "Equilibrium of the Earth's Crust". *Földtani Közlöny,* 1955.

L. Egyed, Professor of the Geophysical Department of the University in Budapest, developped *a new theory* of the *internal constitution of the Earth* based on a summary of gravitational and other geophysical interpretations, in the study : "A new theory on the internal constitution of the Earth and its geological-geophysical consequences". *Acta Geologica,* IV. 1956.

Regional geophysics and its problems has been summed up in the following study :

V. Scheffer : "Data to regional geophysics of the Carpathian Basin". *Geofizikai Közlemények,* VI. 1957.

The problem of *regional* and *residual anomalies* has been discussed in the paper :

L. Egyed : "Some notes concerning the principles of regional anomalies". *Geofizikai Közlemények,* Vol. V. No. 3. 1956. This study deals with the correct definiton of the residual anomaly and shows that its value — according to the definition given in the paper — is the 4π-th part of the second vertical derivative of gravity.

Gy. Barta : "About the periodic variation of the gravity field". *Geofizikai Közlemények,* Vol. V. No. 4. 1956. This paper is discussing the *periodic variation of gravity* on the basis of studies of the fluctuations of the sea level.

I. Müller : "Distribution of gravity on the surface of the ellipsoids of Krassovskij, Hayford, and Bessel". *Geofizikai Közlemények,* Vol. IV. 1955. This paper is applying *the normal formula of gravity* to different ellipsoids.

4. *Construction of a new model of Eötvös' torsion-balance*

The following studies have been published in 1952 concerning the *Eötvös' torsion-balance:*

I. Rybár : "Reliability of the Eötvös' torsion-balance. Preparation of torsion wires". *A Magyar Tudományos Akadémia Műszaki Tudományok Osztályának Közleményei.* 1952.

I. Rybár : "Problem of the reduction of relaxation time of the Eötvös' torsion-balance". *A Magyar Tudományos Akadémia Műszaki Tudományok Osztályának Közleményei.* 1952.

Hungarian researchers engaged in the Eötvös' torsion-balance have been carrying out experiments for several years for the purpose to construct an *Eötvös' torsion-balance satisfying all modern requirements.* It has been in 1954 that the prototype of the up-to-date torsion-balance got ready as a construction of Dr. I. Rybár and Gy. Banai, research workers of the Geophysical Institute Roland Eötvös. The building of the instrument was directed by I. Herbály, technician manager of the instrument workroom of the Institute. A serial production of the new type Eötvös' torsion-balance started after finishing the prototype. Chief advantages of the new balance as compared to the previous types are as follows : good temperature protection obtained in the first place with the quadruple protective casing and in consequence of which the rest position of the instrument is practically insensitive to changes of temperature ; another innovation is that in place of light-spots it takes the picture of the graduated scale and the reticle, besides the numbers of the instrument and the station ; the driving mechanism can be set for 3, 4 or 5 azimuthal observations. The sensitivity of the instrument is unaltered, being some tenths of eötvös-unit. It is easy to adjust the instrument to visual reading. The study of Dr. I. Rybár about the new model of torsion-balance shall be published in the volume 1957 of the *Geofisica Pura e Applicata (Italian)*.

5. *Investigations concerning gravimeters*

The great number of observations carried out with gravimeters gave plenty of opportunities for studying the characteristics of these instruments. Besides, there have been experimental tests with particular objects.

Some results of these tests have been dealt with by I. Komáromy in his paper "Proof of the azimuth effect of a Heiland gravimeter". *Geofizikai Közlemények*, Vol. I. 1952. According to his studies, the readings of the Heiland gravimeters are influenced by the geomagnetic field, hence a correction has to be applied depending on the azimuthal position of the instrument.

Experiments have been made for years to determine how the gravity differences with Heiland gravimeters are diverging from the linearity of disk-readings. It was I. Komáromy again who carried out thorough scientific investigations.

There have been surveys with gravimeters in mines, too. Data of these surveys have been published by L. Facsinay and Mrs. H. Haáz : "Density determinations of rocks based on subsurface gravimeter measurements at different depths". *Geofizikai Közlemények*, Vol. II. 1952. Similar experimental surveys have been carried out in 1956, too.

6. *Researches about the deviation of the vertical*

Gravity measurements can be used also for the determination of deviations of the vertical as referred to a reference ellipsoid. Collaborators of the Geophysical Institute have calculated the deviations of the vertical using two methods.

One of the methods is based on the *theorem of Stokes* and is using the gravity anomalies around the point in question. In these calculations the anomalies inside a circle of about 40 km radius have been used, but it is planned to compute the deviations at least at one Laplace-point by using the gravitational data of a more distant region, even of the whole surface of the earth.

The other method, initiated by Eötvös, uses the *curvature data of the niveau surface measured by the torsion balance*. Results of recent investigations can be found in the following studies :

J. Renner : "The deviation of the vertical". *MTA Müszaki Tudományok Osztályának közleményei* 1952.

J. Renner : "Untersuchungen über Lotabweichungen". *Acta Technica*, 1956.

The main part of the method applied by the author is that the curvature data are interpolated to the points of a quadratic network and further computations are carried out in this network, which considerably simplifies the calculations. As it is possible to compute the deviation of the vertical at each point of the network from different directions, the most probable values are obtained by the method of least squares. The calculation of the relative deviations from the curvature data can only be done in the case the area contains two astrogeodetic points, at least one of which is a Laplace-point. Only topographically corrected astrogeodetic data may be connected through the curvature data of the torsion balance. A. Tárczy-Hornoch, member of the Academy, pointed out that in such a case the topographic effect of the immediate vicinity of the astrogeodetical point should be considered too, in order to bring the deviation into harmony with the corrected curvature data indicating subsurface anomalies. The values of the potential can be computed and equipotential lines can be constructed from the components of the deviations of the vertical. With this method the computation of the deviation has been carried out for several areas of Hungary using subsurface anomalies obtained by the torsion balance. The deviations of the vertical and the potentials computed in this manner are reflecting the effects of buried masses and are in accordance with the gravitational picture characterized by the gradients and isogams. The values of the potential divided by the gravity accelerations give the undulations of the geoid. If we use in the calculation the subsurface anomalies, the undulations of the geoid are due to the masses of the subsoil, but if we neglect the topographic corrections both in the curvature data and in the deviations of the vertical at the Laplace-points, we obtain the undulations of the actual geoid.

The astrogeodetically measured relative deviations at a Laplace-point are comparable with the gravity anomalies at the same point. Investigations concerning this matter have been dealt with in the paper of J. Renner : "Regional character of the deviations of the vertical". *Geofizikai Közlemények*, 1957. For the purpose of comparison the author corrected topographically the astrogeodetically measured deviations. According to the maps enclosed to this study, the regional deviations of the vertical in Hungary are in most cases in harmony with the regional gravity anomalies originating in masses which probably lay in greater depths

7. *Corrections of levelling data on the basis of gravity measurements*

Theoretical investigations have been carried out about the question of a suitable correction of the *levelling data* on the basis of gravity data. Studies concerning this question are as follows :

I. Rédey : «Sur l'altitude dynamique». *Acta Technica*, VI. 1953. The author introduced in this study a new interpretation of the dynamical height.

I. Müller : "Determination of mean gravity values for the computation of the orthometric heights". *Geofizikai Közlemények*, Vol. V. No. 3. 1956.

Geodetists and geophysicists are working together to compute on the basis of the available gravity data the corrections of orthometric heights. Gravity surveys along the first order levelling lines are in course.

8. *Relative pendulum measurements*

There have been recently no relative pendulum surveys in Hungary.

A. Tárczy-Hornoch, member of the Academy, dealt with the question of the accuracy of measurements with relative pendulums in his study »Über die Genauigkeit von aus geophysikalischen Messungen errechneten Werten«. *Freiberger Forschungshefte*, 1956. He pointed out that in general the problems of precision of the geophysical measurements in the future have to be dealt with more intensity than before.

9. *Handbooks*

There have been published recently in Hungary two general geophysical works :

L. Egyed : "Geophysical fundamentals" ; University textbook. Tankönyvkiadó, Budapest 1955. (Hungarian).

L. Egyed : "Physics of the Earth". Vol. 1. General Geophysics. Akadémiai Kiadó Budapest, 1956. (Hungarian).

These works are treating the theoretical and practical questions of gravitational investigations according to the present state of knowledge.

INVESTIGATIONS ON SEISMOLOGY AND THE PHYSICS OF THE INTERIOR OF THE EARTH, IN HUNGARY, 1954—1956

L. EGYED

D. ENG. SC.

The territory of Hungary is not particularly seismic, although earthquakes causing smaller or greater damage may sometimes occur. In spite of this, the attention of Hungarian natural scientists was soon drawn to the phenomenon of earthquakes, and it is perhaps of interest to mention that the first isoseist map in the world was constructed by the Hungarian KITAIBEL, in connection with the earthquake of Mór in 1810.* The systematic study of earthquakes was first proposed in our country by J. SZABÓ, Professor of geology in Budapest, around the middle of the past century, in the scope of the work of the *Geological Society of Hungary*. This work was later taken up by R. KÖVESLIGETHY, whose name is familiar in world-wide seismological circles and whose work fell into the heroic age of seismology. After KÖVESLIGETHY, seismological work in Hungary was chiefly concerned with collecting the data of past and present shocks beside instrumental registrations. However, this was strongly inhibited and then reduced to a minimum by the increase of international tension and subsequent World War II.

This period was concluded by the monography of K. RÉTHLY on the Earthquakes of the Carpathian Basins (Budapest 1952), summarizing all macro-seismical observations from the time of the first written historical documents to 1918.

In the last four years, a new blossoming of investigations concerning seismology and the internal structure of the Earth has come up. This is the period I wish to discuss here.

The first results have grown out of seismic exploration work. The *crusta structure* of the Hungarian Basin was determined, with new seismic apparatus of Hungarian construction, in the environment of *Hajdúszoboszló* by L. STEGENA (Geophysical Institute of the Eötvös University) and by J. GÁLFI (State Geophysical Survey). On evaluating deep reflections, the velocity values of former exploratory work were used for the sediments and the data of REICH from Blaubeuren for the deeper horizons. During previous work the average velocity

*KITAIBEL P. et TOMTSÁNYI A. : Dissertatio de terrae motu in genere ac in specie Mórensi Anno 1810. die 14. januario ort. Budae 1814.

of a Tertiary complex of 1,3 kilometer was found to be 2,2 km/sec. Beneath the Tertiary cover an overall velocity of 5,8 km/sec was assumed. The wave velocity for Triassic limestone was found to equal 5,1 km/sec during previous investigations.

Considering the above circumstances, a reflection occurring at 8,6 sec was generated by a reflecting surface at a depth of 22,7 kilometers. No other characteristic reflexion was encountered, except traces at 7,5 sec.

The deep reflection work was carried forth by L. STEGENA and has yielded up to now the following data :

Locality	Depth of the CONRAD-discontinuity in km	Depth of the MOHOROVIČIĆ-discontinuity in km
Kapuvár	16,5	20,0
Hajdúszoboszló	19,4	23,6
Karád	21,2	—
Komló	19,6	25,2
Bonyhád	21,8	28,9

The determination of these data at further 17 points is planned in the course of the IGY.

A further possibility for determining crustal structure beneath our country has arisen with the *earthquake of January 12, 1956, at Dunaharaszti* near Budapest. The instrumental data of this shock have been evaluated by E. BISZTRICSÁNY (Geophysical Institute of the Eötvös University, Budapest) and by D. CSOMOR (Seismological Section of State Geophysical Survey). In this work the data of the following stations were used :

Station	Δ_n (km)
Budapest	16,3
Kecskemét	69,1
Hurbanovo	86,7
Kalocsa	89,2
Szeged	156,6
Wien	240,8
Zagreb	287,7
Beograd	300,0
Câmpulung	495,3
Bacău	607,7
Jași	646,6
Jena	674,4

As a result of this evaluation, the average depth of the CONRAD-discontinuity was determined to be 20,2 km, that of the MOHOROVIČIĆ surface to be around 33 km.

The following data were obtained for wave velocities :

Wave	Velocity in km/sec	Wave	Velocity in km/sec
P_g	5,49	S_g	3,59
P^*	6,98	S^*	uncertain
P_n	8,18	S_n	4,62

As a matter of fact, these are the first data for the Hungarian basin to be derived from earthquakes.

The study of the *seismicity of Hungary* was commenced by D. Csomor and Z. Kiss, both of the Seismological Section of State Geophysical Survey. For this purpose the data of the last 50 years were used almost exclusively, so as to grant the homogeneity of registrations. According to the to-date results of this work — as it has been reported at the International Conference of Prague —, the annual average number of shocks amounts to four and generally does not exceed ten. Magnitudes are normally small. Great shocks occur at the intervals of about 25 years, but even the magnitudes of these do not exceed 6. (The magnitude of the 1956. I. 12 shock was 5,6, according to Prague, and 5,9, according to Moscow). It is interesting to observe that the annual number of shocks generally increases previous to larger earthquakes. The strain-rebound curve is almost linear with time, with discontinuities occurring only at the time of greater earthquakes. The frequency maximum of hypocenter depth lies between 4 and 7 kilometers, i. e. in the upper part of the crust or the metamorphic rocks above.

There have been studies on the problems of *magnitude determination*, too. It was the task of E. Bisztricsány (Geophysical Institute of the Eötvös University, Budapest) to determine the magnitude equation of the Wiechert-pendulum at Budapest for long-period waves. The seismograms he evaluated dated from between 1930 and 1955, as this series of registrations can be considered homogeneous as to characteristic frequency (T_0) and static magnification (V_0). The magnitude data used have been those of Gutenberg and Richter for Pasadena. The magnitude equation of the horizontal Wiechert pendulum for shallow shocks reads :

$$M = \log A_{20} + 1{,}39 \log \Delta^\circ + 2{,}63$$

for magnitudes given by Pasadena.

It was found on investigating the phenomena of blasts that the duration of ground oscillation seems to be a monotonous function of the quantity of the explosive. Considering the monotonous relation between the mass of dynamite D and the duration t of the attenuation process to be

$$D = C\,t^3$$

and making the matter-of-course assumption that — in certain limits — the elastic energy generated is proportional to the quantity of explosive used, i. e.

$$E = \gamma D.$$

This may be rearranged as follows :

$$\log E = \log \gamma + \log D = \log \gamma + \log C + \beta \log t$$

or

$$\log E = \alpha + \beta \log t\,.$$

Comparing with the magnitude-energy relation

$$\log E = a + bM$$

one obtains

$$M = \lambda + \mu \log t$$

t being the attenuation time of the process. This attenuation is observed only on waves of long period.

E. Bisztricsány (Geophysical Institute of Eötvös University, Budapest) has also studied the duration of long-period waves t_L and plotted the magnitude of shallow shocks against the logarithm of the duration of long-period waves, according to data of the Budapest Wiechert pendulum. The magnitude data of Pasadena were used for distant shocks, while those of Prague were applied for small-distance ones. The equation

$$M = 2{,}25 \log t_L - 0{,}001\, \Delta^\circ + 2{,}92$$

was derived by the method of least squares from about 300 data. It gave the remarkable result that the coefficient of Δ° is negligibly small so that the duration of the long-period waves can be used for the unequivocal determination of the magnitude, independently of epicentral distance. We consider this result to be the most important one in the realm of magnitude investigations, since the work of Richter that led to the definition of the magnitude concept.

It is further interesting to mention that the new magnitude relation thus derived was applied by Bisztricsány to define a relationship between the magnitude as derived from log t_L and the pleistoseismal intensity I_0 for Hungarian shocks. The relation obtained was

$$M = 0{,}53\, I_0 + 1{,}4$$

almost completely identical with the similar relation obtained by Gutenberg for California.

The studies on the internal structure of the Earth have begun with the investigations on the nature and mechanism of deep-sea troughs carried out by L. Egyed (Geophysical Institute of Eötvös University, Budapest). The theoretical research has led to the assumption that along the boundary of the continents and oceans the crust, reacting on the whole as an elastic plate is subjected to a couple of tectonic forces. Hereby the well-known superficial morphology and the deep-fault surface along the volcanic line are formed. As a consequence of the deformation the isostatic anomalies arise. It was possible to compute on the theoretical assumption described above the distance of the volcanic chain from the edge of the trough as well as the course of the anomaly axis for a section through Java. Furthermore, the thickness of the crust and the intensity of the stresses arising in the same could be derived from the value of Young's modulus for 33 km depth. The thickness of the crust was calculated to be 45 km to be interpreted by assuming that this is the thickness of the layer under elastic stress.

In the first phases of this research it was impossible to account for the forces and the couple causing the deformations described. Further process was aided by the results of RAMSEY* and BIRCH.** A further clarification of ideas was brought about by the fact that the two books "*Textbook of Geophysics*" and "*Physics of the Earth*" written by this author in the meanwhile necessitated an unequivocal synthesis of observations and results. This work has focused attention upon the internal structure of the Earth together with a critical analysis of facts and ideas.

The material composition of the Earth was regarded by RAMSEY to be homogeneous below a given depth, and the assumption of an iron core was substituted by the idea that the GUTENBERG—WIECHERT-discontinuity corresponds to a state transition due to high pressure.

According to the results of BIRCH, the part of the mantle between 900 km and the core can be regarded as homogeneous and only the part above is characterized by a set of phase transitions caused by increasing pressure. This is in accordance with the ideas of RAMSEY as regards the parts above the core. However, BIRCH is in favor of the iron-core model, on the assumption that to induce the density of the core in silicic materials at least ten times the actual pressure should be necessary at the boundary of the core.

Recurring to the hypothesis to RAMSEY, and regarding, somewhat differently, the GUTENBERG-discontinuity as a surface defined by temperature as well as pressure, i. e. considering the Earth as a thermodynamical system of homogeneous composition, wherein the phase equilibria and transitions are determined by temperature and pressure, we reach the interesting conclusion that the boundary of the core is no stable surface, because the changes in temperature distribution result in changes of this surface. A cooling process will cause a shifting of this surface towards the center of the Earth. Considering the actual density distribution this would mean the decrease of the average density and

*RAMSEY, W. H.: On the nature of the Earth's core. *Monthly Notices. Roy. Astr. Soc. Geophys. Suppl.* 5. 1949.

BIRCH, F.: Elasticity and constitution of the Earth's interior. *Journ. Geophys. Research*, **57. 1952.

the increase of the volume of the Earth. With other words, the cooling of our planet would result in an Earth expansion. This idea could readily account for the formation of continental and oceanic areas, for continental drift, formation of fracture systems, decrease of water-covered continental areas in the course of geohistory, and would give a possibility to explain many morphotectonical features as well as the decrease of the Earth's angular velocity and the energy of the earthquakes.

The ideas delineated above are summarized in the paper of L. EGYED (Geophysical Institute of Eötvös University, Budapest) entitled: „A Föld belső szerkezetének új elmélete és annak földtani-geofizikai következményei" (The new theory of the internal constitution of the Earth and its geological-geophysical consequences; in Hungarian).

However, the above plausible ideas could not stand upright in the light of energetical considerations. The criticism of BIRCH concerning the RAMSEY theory has suggested the thought to reduce the importance of temperature and to regard the state of the core material to be an ultra high-pressure one, as contrary to the simple high-phase state of RAMSEY, being formed at pressures having existed at the origin of the Earth and larger by at least one order of magnitude than those existing at present. It is further assumed that the decomposition of this material unstable at present, proceeds gradually, in the manner of a statistical process. The end result is earth expansion, similarly to the above considerations. Investigations into a series of details, have yielded the annual radius increase to be 0,5 mm as the result of a number of entirely independent considerations. It became further possible to compute the energy of earthquakes and to shed some new light upon the formation of orogenic mountain chains. These ideas are summarized in the English written paper "A new theory on the internal constitution of the Earth and its geological and geophysical consequences" by L. EGYED.

In the course of detail studies a possibility of estimating the radius increase free of all hypotheses from the variations of the distribution of sea water in the geological past was found. The duration of the ideal transgression-regression cycle was also calculated on the hand of mechanical considerations and was found to be 50 million years, in sufficient accordance with the 47 million years derived from palaeogeographical data. (L. EGYED: The change of the Earth's dimensions determined from palaeographical data, and L. EGYED: Determination of changes in the dimension of the Earth from palaeographical data.)

On the basis of the described theory, a new definition for the concepts of orogenic and epeirogenic movements as well as an explanation for the same could be derived. (L. EGYED: The origin of the tectonic forces; in Hungarian).

Some reasoning concerning the delineated theory has shown that it is possible to derive from this mechanism the couple anticipated a sthe cause of deep-sea trough formation. It was further deduced that the frequency curve of deep-focus earthquakes must exhibit a deep maximum beside the near-surface one. This idea was corroborated by observations on South American trenches as well as by the statistical analysis of KONING. A number of further features of deep-focus earthquakes is similarly explained by the new expansion theory.

The large polar wanderings deduced from palaeomagnetic observations is also readily explained by an expansion model postulating the tearing apart of the crust. The latter process would cause large horizontal and torsional forces as well. (L. EGYED : Continental drift, polar wandering and the internal constitution of the Earth.)

A point to be cleared is the physics of the state transition connecting the ultra high-pressure state of matter with the normal one. The idea of a thermal transition had to be rejected because of energetical considerations. A nuclear process can also be thought of. However, of the estimated amount of $2 \cdot 10^{29}$ ergs of annually liberated energy no more than 30 eV falls upon one molecule. This amount is well within the range of ionization energies and smaller by some five orders of magnitude than usual nuclear energies. Although nuclear processes of similarly small energy are also known, a different way of explanation seems to us more likely.

It was observed by BRIDGMAN that liquid carbon disulphide, intensely volatile at room temperature, was transformed into a black solid of approximately 3 g cm $^{-3}$ density at a pressure of 40 000 bars and at a temperature of 170 centigrades. This substance was found to be stable even after the removal of pressure. On the communication of thermal energy this modification could be reduced to the original one.

This observation clearly indicates that any substance may possess several thermodynamically stable modifications beside the usual ground-level one. The demodification into the lower-energy state is induced by energies far smaller than in the case of the reverse process, the excess energy being liberated in the form of thermal or mechanical work. Random thermal agitation may cause the molecules to pass the state transition border one by one, thus resulting in a statistical decomposition connected with large-scale energy liberation. The theoretical and eventually experimental scrutiny of the possibilities of this kind of process is to be the goal of some further research.

As by-products of work on the main theme will be mentioned the determination of relations between atomic volume and initial compressibility (L. EGYED : The compressibility of elements), and the analysis of the connections of drainage systems and faulting.

The investigation of the relations of geophysical data to crustal structure have led to some interesting advances in the synthesis of geodesic, geological and geophysical facts. In this respect the work of V. SCHEFFER (Hungarian Oil Trust) : "Some aspects of the regional geophysics of the Hungarian Basin" has to be mentioned.

Studying the microseisms E. ANNAU and K. POSGAY (State Geophysical Survey) has shown that the intensity of microseism is closely connected with the depth of the basement beneath loose sediments.

Of the results of practical seismic work especially the experiments on blast mechanism and energy relations are closely connected with the field of seismology.

In the following a list of the papers dealing with seismology or the internal structure of the Earth will be given. For the sake of completeness the papers on exploration seismics are included.

PAPERS ON SEISMOLOGY AND PHYSICS OF THE INTERIOR OF THE EARTH

ANNAU, E. and POSGAY, K. : A talajnyugtalanság. (Microseismic agitation of the soil ; *in Hungarian). Geofizikai Közl.* **V**.

BISZTRICSÁNY, E. : Determination of the magnitude equation for Budapest. *Acta Geol.* **IV**. 1957.

BISZTRICSÁNY, E. and CSOMOR, D. : Microseismal evaluation of the Earthquake of January 12, 1956, and the crustal structure of the Hungarian Basin. *Acta Geol.* **IV**. 1957. and *Geofizikai Közl.* **VI**.

CSOMOR, D. and KISS, Z. : Seismicity of Hungary. (Preliminary report on the Seismological Conference in Prague. 18—22, March, 1957).

EGYED, L. : The formation of deep-sea troughs and related geophysical phenomena. *Acta Geol.* **II**. 33—50.

EGYED, L. : A mélyszerkezetek és a morfológia kapcsolata Dunántúlon a geofizikai vizsgálatok tükrében *(Hungarian). Eötvös Loránd Tudományegyetem Évkönyve*, 1954.

EGYED, L. : On the compressibility of elements. *Acta Geol.* **II**. 213—214. 1954. and *Földtani Közlöny* LXXXIV. *(in Hungarian).*

EGYED, L. : A földkéreg egyensúlya. (On the equilibrium of the Earth's crust ; *in Hungarian) Földtani Közlöny* **LXXXV**. 44—69. 1955.

EGYED, L. : A Föld belső szerkezetének új elmélete és annak földtani-geofizikai következményei. (A new theory on the internal constitution of the Earth ; *in Hungarian.) Földtani Közlöny*, **LXXXV**. 277—318. 1955.

EGYED, L.: A new theory on the internal constitution of the Earth and its geological-geophysical consequences. *Acta Geol.* **IV**. 43—83, 1956.

EGYED, L. : A tektonikai erők eredete és a kéregmozgások. (The origin of tectonic forces and crustal movements ; *in Hungarian with English abstract.) Földtani Közlöny.* **LXXXVI**. 1956.

EGYED, L. : The change of the Earth's dimensions determined from palaeogeographical data *Geofisica pura e applicata.* **33**. 1956. and *Földtani Közlöny*, **LXXXVI**. *(in Hungarian.)*

EGYED, L. : Determination of Changes in the Dimensions of the Earth from Palaeogeographical Data. *Nature. Sept. 8. 1956.*

EGYED, L. : A new dynamic conception of the internal constitution of the Earth. *Geologische Rundschau.* 1957.

EGYED, L. : Kéregmozgások okai és a magyarországi kéregmozgások. (Origin of crustal movements and crustal movements in Hungary.) *Geofizikai Közlemények.* **VI**. 1957.

EGYED, L. : Zur Entstehung der Tiefherdbeben und Begleiterscheinungen. (Seismological Conference in Prague, 1957. III. 18—22.) *Studia geophysica et geodetica.*

EGYED, L. : The role of tectonics and morphology in the development of the drainage-pattern. *Gerlands Beiträge zur Geophysik.*

EGYED, L. : Continental drift, polar wandering and the internal constitution of the Earth. *Acta Biol. Hung.* 1957.

GÁLFI, J. és STEGENA, L. : Nagymélységű reflexiók Hajduszoboszló vidékén. (Deep-reflexions in the region of Hajdúszoboszló, in *Hungarian.) Geofizikai Közlemények*, **IV**. 1955.

GÁLFI, J. and STEGENA, L. : Deep-reflexions in the environment of Hajdúszoboszló, North-Eastern Hungary. *Acta Geol.* **IV**. 1956.

KISS, Z. : Az 1953. évi magyarországi földrengések. (Ungarischer Erdbebenkatalog für das Jahr 1953.) *Orsz. Földr. Kiadv.* 1954.

KISS, Z. : Az 1954. évi magyarországi földrengések. (Ungarischer Erdbebenkatalog für das Jahr 1954.) *Orsz. Földr. Kiadv.* 1955.
KISS, Z. : Az 1955. évi magyarországi földrengések. (Ungarischer Erdbebenkatalog für das Jahr 1955.) *Orsz. Földr. Kiadv.* 1957.
SCHEFFER, V. : Adatok Magyarország regionális geofizikájához. (Some aspects of the regional geophysics of Hungary ; *Hungarian.) Geofizikai Közlemények*, **VI**. 1957.
MME SZILBER, M. ; TURI, ST. et CSOMOR, D. : Rapport microseismique de l'Institut National Seismologique de Hongrie 1953. *Orsz. Földr. Kiadv.* 1954.
MME SZILBER, M., CSOMOR, D. et KISS, Z. : Rapport microseismique de l'Institut National Seismologique de Hongrie 1954. *Orsz. Földr. Kiadv.* 1955.
MME SZILBER, M. et CSOMOR, D. : Rapport microseismique de l'Institut National Seismologique de Hongrie 1955. *Orsz. Földr. Kiadv.* 1957.

PAPERS ON SEISMIC EXPLORATION

ÁDÁM, O. : Egyes DNY-Dunántúli területek némaságának okai. (Causes of non-reflexion of some South-Western Transdanubian Areas.) *Geofizikai Közlemények*. **IV**. 1955.
GÁLFI, J. és LIPTAY, I. : Nyomásmérő szeizmikus kutatási célra. (Pressure gauge for seismic investigation purposes). *Geofizikai Közlemények*, **III**. 1954.
GÁLFI, J., GELLÉRT, F., SÉDY, L. : Nyomáshullám kialakulása a légrobbantásnál. (Development of pressure wave by air shooting.) *Geofizikai Közlemények*, **IV**. 1955.
KILCZER, GY. : Átlőtt és inverz réteg kimutatásának lehetősége szeizmikus refrakciós méréssel. (Possibility of the detection of short and inverse strata by means of seismic refraction measurements.) *Geofizikai Közlemények*, **IV**. 1955.
LÁNYI, J. : Gépjárművek által okozott útrezgések mérése szeizmikus mérőeszközökkel. (Measurements of road vibrations due to motor vehicles by means of seismic instruments.) *Geofizikai Közlemények*, **III**. 1954.
POSGAY, K. : Szeizmikus reflexiós mérések középhibája. (Mean error of seismic measurements.) *Geofizikai Közlemények*, **III**. 1954.
POSGAY, K. : Robbantási körülmények figyelembevétele sekélyszeizmikus méréseknél. (Consideration of explosion conditions in shallow seismic measurements.) *Geofizikai Közlemények*. **IV**. 1955.
POSGAY, K. : Erősen tagolt töréses szerkezeteken végzett reflexiós szeizmikus mérések középhibája. (Mean error of seismic reflexion measurements in case of intensely jointed fault structures.) *Geofizikai Közlemények*, **IV**. 1955.
POSGAY, K. és ERŐS, J. : Rengéshullámok terjedési sebességének meghatározása felszínközeli rétegekben. (Determination of the propagation rate of seismic waves in layers close to the surface.) *Geofizikai Közlemények*, **III**. 1954.
POSGAY, K. : 1955. évi szeizmikus mérések az esztergomi szénmedencében. (Seismic survey in the coal-basin of Esztergom, 1955.) *Geofizikai Közlemények*, **V**. 1956.
POSGAY, K.—ANNAU, E. : Szeizmikus rengéshullámok diffrakciója. (Diffraction of seismic waves.) *Geofizikai Közlemények*, **V**. 1956.
STEGENA, L. és JÁRÁNYI, I. : Horizontális torziós szeizmométer. (Horizontal torsion-seismometer.) *Geofizikai Közlemények*, **IV**. 1955.
SZÉNÁS, GY. és GEREBEN, L. : Szeizmikus refrakciós mérések alkalmazása a bauxitkutatásban. (An application of seismic refraction method in exploration of bauxite.) *Geofizikai Közlemények*, **IV**. 1955.
TÁRCZY-HORNOCH, A. : A terjedési sebesség meghatározásáról a reflexiós szeizmikus módszernél. (Determination of propagation velocity with the seismic reflexion method.) *Geofizikai Közlemények*, **III**. 1954.
TÁRCZY-HORNOCH, A. : Über die Bestimmung der durchschnittlichen Fortpflanzungsgeschwindigkeit bei der seismischen Reflexionsmethode. (Determination of the average travel speed of seismic reflexion waves.) *Acta Technica Hung.* **IX**. 1954.
TÁRCZY-HORNOCH, A. : Zur Bestimmung der reflektierenden Ebene bei den seismischen Reflexionsmessungen. *Geofisica pura e applicata.* **27**. 1956.
TÁRCZY-HORNOCH, A. : Nachtrag zur Studie »Zur Bestimmung der reflektierenden Ebene bei den seismischen Reflexionsmessungen«. *Geofisica pura e applicata.* **28**. 1956.

MAIN RESULTS OF METEOROLOGICAL RESEARCH DONE IN HUNGARY DURING THE YEARS 1954—56

Dr. B. BÉLL

The chief results of meteorological investigations executed in Hungary are presented here for the six main branches of meteorology, namely :

I. Climatology
II. Solar radiation research
III. Agricultural meteorology
IV. Synoptics, weather forecasting and dynamic meteorology
V. Aerology
VI. Ionospheric research.

As reports on these particular subjects have not yet been prepared, the more important results of previous investigations are briefly summed up in addition to those achieved during the recent three-year period.

It was intended to produce, by the present report, a general picture of the development which occurred in each of the particular branches, including progress in methods of measurement, establishment of new observatories, and, finally, a somewhat detailed review of the more important publications.

Ionospheric research is carried out, in Hungary, by the Central Institute of Meteorology. These investigations are made with the aim of clarifying the connections of ionospheric phenomena with problems of climatic control and weather forecasting. It is for this reason that the results obtained are discussed in the present report, together with meteorological research work.

I. Climatology

It is a consequence of the situation of the country in the Carpathian Basin that Hungarian climatic researches paid attention in the first place to the study of special flow, radiation and convection conditions caused by the climatic and orographic peculiarities of the location in a basin.

Some macrosynoptic processes may — as a consequence of surface forms and surface quality prevailing in the Carpathian Basin — degenerate into extremely dry and warm or, on the other hand, into cool and wet synoptical periods which render our weather changeable and our climate extreme. It is for this very reason that our main efforts are directed towards a clarification of the background, in temporal and spatial extension of extreme weather conditions.

The need for such investigations was enhanced in recent years by the repeated occurrence of frosts in the late spring, of dry springs and droughty summers, alternating with some summer and autumn periods of abundant precipitation.

In the Climatological Department of the Central Meteorological Institute a collection of Hungarian Climatic Charts (Climatological Atlas) has been completed in 1954—56 which is ready for publication ; in accordance with the plans for the projected Meteorological World Atlas, it is presenting on 128 charts and on a scale of 1 : 1 000 000 the geographical and temporal distribution of every climatic element on Hungarian territory according to observations made in the years 1901—1950.

Considering that each territory is a composition of innumerable local climates where the form and quality of surface are connected by a reciprocal effect to the physical state of air-masses in contact with them, our climatological research concentrated to a greater extent on the research on local climates and microclimates. Our investigators were in this respect engaged in the problems of energy-, heat- and water-balances.

To research on local climate belong as well the investigations started in the surroundings of the greatest lake of Central-Europe, the Balaton, being a territory interesting from the point of view of recreation, health-resorts and aquatic sports, etc. It was for this purpose that our new establishment built in Siófok, the Balaton Meteorological Observatory, started its activity in 1956. It is destined to solve with its staff of five persons (2 research workers, 3 technicians) peculiar questions in local climatology and synoptics (including a storm-warning service).

The results obtained in the field of climatological research are represented by the following review of papers :

WAGNER, R. : The concept of climate. *Időjárás*, 59. 1. 1955. pp. 42—44.

When defining climate, the classical views of climatology must be, in the opinion of the author, discarded ; it is undesirable to define climate by determining factors, as climate should be conceived rather as a phenomenon. Climate is, in this manner, the process of rhythmical, periodical changes of conditions of the air strata which are covering our planet.

BERKES, Z. : About the definition of the notion of climate. *Időjárás*, 59. 1. 1955. pp. 44—45.

This study points out that climate — as the integration of physical and geographical factors — is determining on any place of the globe the pattern (the order, the system) followed by weather phenomena, but is, on the other hand, characterized by the entity of past events in the weather, with which it is notwitstanding not identifiable, neither in a logical, nor in a physical sense. The definition proposed by the author may be applied to macro-, meso- and micro-climate as well.

PÉCZELY, GY. : Changes of the temperature on the Earth. *Időjárás*, 59. 5. 1955. pp. 275—281. 2 figs. 2 tables.

For the period 1881—1940 the anomalies of the annual mean air temperatures of each zone and the anomalies of the annual means of the whole Earth are computed. Temperatures are found for the entire period, but especially from 1920, to be generally rising. It is pointed out that the solar constant is not showing a unidirectional rise, and, accordingly, the phenomenon cannot be explained by variations in the solar constant. The carbon dioxide theory is not acceptable either, as the present quantity of carbon dioxide is already exerting a maximum of absorption. It is most probably the rise of the quantity of water vapour being related to the small fluctuations of the solar constant which is the deciding factor.

BERKES, Z. : Thermal advection on the surface of the Northern Hemisphere. *Időjárás*, 60. 1. 1956. pp. 12—16. 2 figs. 2 charts.

Charts of advection are presented in the form of thermobarical charts used in aero-synoptical practice and computed by using atmospheric pressure and temperature data reduced to sea level for the decade between 1921 and 1930. By these charts, the mean drifting direction of cold and warm air masses are illustrated in a climatic relation. The author is comparing further the results with annual mean isoanomals.

BERKES, Z. : Interrelation of the atmospheric centres of action in the course of the general circulation. *Időjárás*, 60. 2. 1956. pp. 82—87. 10 figs.

In this paper the transfer of air masses is surveyed among the main centres of action on the basis of isocorrelation charts, using Exner's anomaly values of atmospheric pressure in each month during the thirty years between 1887—1916. The most important correlations are found between areas in the polar regions and the temperate zone. A peculiarly strong correlation exists between atmospheric pressure of the regions of the Azores and Island on the one hand, and further between Northern Norway and Northern Italy. The cyclonic centre of Genova is found to be in relation even to the atmospheric pressure in Central Siberia.

PÉCZELY, GY. : Variation of the mediterranean climatic features in Hungary. *Időjárás*, 58. 4. 1955. pp. 214—217. 2 figs.

A quantity is introduced for the characterization of the intensity of mediterranean climatic influence. This quantity is defined as the product from the standard deviations of average temperature and average rainfall of each month of the examined year from some standard mediterranean series. By means of this reference number and making use of the temperature and rainfall series of Budapest between the years 1941 and 1953, the secular trend of mediterranean climatic influence and the longer periods within this trend have been determined. There appears satisfying correspondence between the strongest periods found and Abbot's periods of the solar constant.

BERÉNYI, D. : Application of recent statistical methods in climatology. *Időjárás*, 58. 5. 1954. pp. 261—272. 2 figs. 3 tables.

After having discussed the theory of dispersion analysis this method is applied to annua· mean values of the temperature series of 5 Hungarian and 2 foreign stations. In the Hungarianl series there appears around 1893—94 a break indicating a variation of climate. In the series of Szeged and Budapest an inhomogeneity may be disclosed due to different causes. The conclusions of dispersion analysis are proved by examination of trend equations too. Dispersion analysis proved to be suitable for the investigation of homogeneity of long series and renders possible even the determination of individual periods occurring during variations of climate.

PÉCZELY, GY. : Study of frequency curves of pentade mean temperatures in Budapest. *Beszámolók*, 1955. pp. 173—196. 2 figs. 3 tables.

Anomalies of 5-day average temperatures at Budapest in the years 1851—1954 are discussed. Frequency distributions of the temperature of every pentade are determined and the frequency curves are studied by reducing them to components. Thus the development of radiation influences is estimated, the annual trend of temperature distribution is determined as well as the probability for the occurrence of a normal distribution of pentadic mean temperature values.

PÉCZELY, GY. : Analysis of the normal distribution in a lengthy series of observations. *Időjárás*, 58. 5. 1954. pp. 278—282. 1 fig. 2 tables.

Analysing from the point of view of normal distribution the annual means of temperature of 32 stations at the Northern Hemisphere, on the basis of series of the lengths of 60 years, it is pointed out that a normal distribution is in the least realized in the polar and tropical zones. It is further demonstrated that the degree of realization of normal distribution is a suitable means for efficiently characterizing the macrosynoptical conditions of some station.

Dobosi, Z. : The role of vertical heat transport in diurnal temperature variation. *Időjárás*, 60. 1. 1956. pp. 45—51. 1 fig.

There are many winter days on which persists, during the whole day, an inversion near the soil, and, accordingly, the soil surface is receiving constantly thermal energy from the air. The causes of diurnal temperature variation on days like that are discussed.

Berkes, Z. : Interdiurnal temperature variations at Buda, 1855—1955. *Beszámolók*, 1955. pp. 120—128. 2 figs. 2 tables.

Taking as a starting-point the temperature data observed in the observation garden of the Central Meteorological Institute since May 1910, as well as the observations made in the years 1873—1899, it was possible to obtain a homogeneous series of secular interdiurnal variation on the basis of all the observations carried out in Buda since 1856. This series is studied by the author chiefly from the standpoint of secular variation, resp. in connection with solar activity. Parallel with the rise of temperature to be observed since 1880 there was a decrease of interdiurnal variation. Solar activity, at the same time, has increased. Before 1880 there is a relation of opposite sign. The same can be said of the relations within each individual sun-spot cycle. The secular series thus obtained is suitable for the estimation of the importance of the advective component of climate, resp. of the variations of the same. The interdiurnal variation is, namely, reflecting in the first place the advective variations of temperature.

Bacsó, N. : Number of winter-days in Hungary. *Beszámolók*, 1954. pp. 86—97. 3 figs. 7 tables.

The study is dealing with the frequency of winter-days according to observations made between 1901 and 1950. When examining the annual variation of mean values from many years, there is found a striking maximum of frequency in January as well as higher frequency values in November and December as compared with February and March. This fact can be explained by the increasing rise in temperature during the day. Comparing the maximum of frequency values of severe winters to their minimum, continental climatic characteristics are obtained. The charts illustrating the spatial distribution of the frequency of winter-days are proving the close connection with sunshine-, wind, and orographic conditions ; the spatial distribution of average dates of the first and last winter-day is, at the same time, characterizing the climatic regions of the country.

Bacsó, N. : Number of severe days in Hungary. *Beszámolók*, 1955. pp. 108—119. 3 figs. 6 tables.

The paper is discussing — on the basis of 50 years' observations (1901—1950) — the frequency of those days where the minimum of temperature is lower or equal to —10 degrees centigrade. Tables are showing the frequency of "severe days", the percentage of months, years and winters without severe days, maximum values of the frequency of severe days in the course of these 50 years, the frequencies in the five hardest and five mildest winters, the connection of severe days with the snow-cover, the depth of the frozen surface layer and, finally, the average date of the first and last severe day.

Mrs. Békéssy, A. : Frequency of frosty hours in Budapest and Debrecen. *Beszámolók*, 1955. pp. 129—136. 1 fig. 4 tables.

According to requirements arisen from the part of the building industry in connexion with work done during the winter, the average number of hours below 0, —5, —10° C during the winter half-year has been determined for every month, on the basis of thermograph records of the period 1918—1955 in Budapest and 1928—1955 in Debrecen. In addition to average values, median, quartile and decile values are presented for characterizing the frequency distribution. Conclusions may be drawn from the mean number of frosty hours on a certain frosty day concerning the spatial distribution on these data. It was finally tried to classify the Hungarian winters according to the difference in the number of frosty hours of the three winter months from the average value.

PÉCZELY, GY. : Study of simultaneous frequencies of temperature and cloudiness values. *Időjárás*, 59. 2. 1955. pp. 80—35. 1 fig. 3 tables.

This is a month to month study of the frequencies of the daily average values for temperature and cloud amount derived from the observation series 1901—1950 of Budapest. Ten types are determined on the basis of temperature and cloudiness values and their annual trend is studied. The relation of these types to the prevailing macrosynoptical situations is shown and it is stated that these types can synoptically not be considered as homogeneous.

DOBOSI, Z. : Heat balance of the ground surface and its measurement. *Időjárás*, 59. 5. 1955. pp. 292—298. 4 figs.

This paper is discussing the connection between the factors of the heat balance of the soil surface and the vertical gradients of temperature and humidity in the air space near the ground. It is, moreover, dealing with the method of Albrecht for the measurement of surface heat balance, and proposes, making use of the exchange formula of Budüko, a heat-balance surveying method rendering unnecessary the direct measurement of the factor of conduction from the soil, and, accordingly, suitable even for the survey of the heat-balance of cultivated ground surfaces and of the effective surface of a vegetative cover.

BATTA, E. : Data of freezing of the soil in this country. *Időjárás*, 58.2.1954. pp. 81—90. 2 figs. 1 table.

The first part of the paper is generally discussing the phenomenon of surface frost ; the second part gives large-scale informations concerning the conditions of surface frost in Hungary according to the series of observations of soil-temperature collected at Budapest during 42 years as well as to many years' soil-temperature observations at stations in different parts of the country (Debrecen, Tarcal, Kecskemét, Ásotthalom, Sopron).

BATTA, E. : Practical application of soil—frost data. *Beszámolók*, 1954. pp. 98—108. 2 figs. 2 tables.

A study of soil-frost is carried out in this paper according to the three most important parameters, i. e. penetration of frost, its intensity and frequency, utilizing the data of the 42 winters between 1911—12 and 1952—53. Studying the significance from the points of view of complex climatology, the author is surveying the factors causing the formation of soil-frost.

MRS. SZAKÁCS, GY. : Rainfalls during the droughty period. *Beszámolók*, 1954. pp. 55—60. 8 figs.

A study of the conditions and anomalies of rainfall during the droughty period of June 27 to August 17, 1952. A parallel is drawn between the conditions of rainfall in the summers of other years of drought (1935, 1904). The conclusion is that the drought of 1952 is surpassing the droughts in the years in comparison from the point of view of lack of rainfall as well as of geographical extension.

KAKAS, J. : Drought in Hungary during March 1953. *Időjárás*, 59. 3. 1955. pp. 153—164. 16 Figs.

A characteristical feature of the climate of Hungary is the scanty rainfall in late winter and in early spring. If there is a general lack of rainfall in the macrosynoptical development on the European continent, this is developping on the territory within the Carpathian Basin, as a consequence of the orographical situation, to an extreme drought. This is proved by the particular case of drought in early spring of 1953 which is, for this very reason, studied in all details from the climatological point of view by means of an ensemble of elements.

KAKAS, J. & KÉRI, M. : The wet summer of 1955 as represented by deviations from normal values. *Időjárás*, 59. 6. 1955. pp. 359—374. 17 Figs. 3 tables.

The summer 1955 has been in certain parts of the country extremely wet and, on the whole, chilly. This phenomenon is, in our climate, — as compared with the annual means for 1901—1950 — not at all unprecedented and its degree of development was, moreover, highly different in the various parts of the country, in consequence of which the difficulties arisen in certain domains of public economy should be examined in terms of the peculiar weather conditions which prevailed at the particular place of their occurrence.

KAKAS, J. & OZORAI, Z. : Absolute maximum of 24-hour rainfall in Hungary. *Időjárás*, 59. 6. 1955. pp. 344—350. 2 figs.

There has been on 9th June, 1953, a cloud-burst of 260 mm in the village Dad (Komárom megye). This quantity of rainfall being the absolute maximum till now of a 24-hour rainfall for this country, authors have been studying from the point of view of climatology and aerological synoptics the conditions of the formation of this extraordinary cloud-burst.

KULIN, I. : Singularities of rainfall at Budapest. *Beszámolók*, 1954. pp. 117—155. 8 figs. 10 tables.

This report classifies on the basis of eighty years' observations (from 1871 till 1950) and in order of size 10 extreme cases of the greatest, resp. least rainfalls, as follows : monthly, quarterly, half-year and annual rainfall, 24-hour rainfall-maxima, the most rainy and the driest periods of 1, 2, 3, 4, 10, 20, 30, 40, 50, 60, 70, 80 years beginning with the first day of the calendar year and quite apart from it. These cases are, besides, expressed in percentage of 80 years' means and the probability of different categories of abundance are determined. Further, an average value is computed out of the periods of different lengths and the conclusion is drawn from the greatest and least rainfalls of several decades that for the computation of a reliable annual mean value even a period of 60—70 years is insufficient. There follows the survey of the lengths of the driest and most rainy periods, and the probability of their occurrence is determined. Finally, different climatic conclusions are drawn from these examinations.

BACSÓ, N. : Frequency and output of hourly rainfalls. *Időjárás*, 59. 1. 1955. pp. 13—28. 3 figs. 15 tables.

A discussion in all details of the frequency of rainy hours and the values of hourly rainfalls according to the ombrograph data of Budapest, Szombathely and Nyíregyháza. Summarizing, according to certain quantitative categories, the average course of frequency and quantity, the results are presented in 15 tables and 3 figures containing absolute values and percentage data. Small rainfalls (0,1—0,9 mm) take the lead in frequency with a winter maximum and summer minimum, then follow the average rainfalls (1,0—4,9 mm) with a varying annual distribution, finally the great ones (5,0 mm) with a summer maximum and a winter minimum. The average category is leading in output, then follow, with insignificant differences between each other, the groups of low and high hourly values. The reason for this is the different annual variation of rainfalls on cold fronts and warm fronts. The paper is dealing also with exceptancy values of greatest precipitation in an hour, with theoretical computations and the comparison of observational results and, finally, with the utilization of these findings in national economy.

KÉRI, M. & MRS. SZAKÁCS, GY. : Separation of warm front and shower precipitations without the use of a frontal calendar or registering instruments. *Időjárás*, 58. 4. 1954. pp. 218—223. 1 fig. 3 tables.

Authors tried to separate four years' data (1946—1949) of Budapest and Debrecen into warm front and shower precipitations only by the help of pluviometer data and visual observations. The results are, for the summer half-year in good accordance with the results obtained by air-mass analysis, but they are differing from these in the winter half-year in consequence of uncertainties in visual observations.

KÉRI, M. : Territorial means of precipitation. *Időjárás*, 58. 3. 1954. pp. 129—136. 3 figs. 3 tables.

Applying and comparing the four best-known methods for computing territorial averages (arithmetical mean, square-method, isohyets and polygonal method) it is pointed out that it is possible to obtain in Hungary territorial average values of precipitation of required reliability even by the arithmetic mean method. This is valid for all parts of the country but the region of mountains of medium height. Author proposes to call a territorial mean only the averages computed on the basis of standard period reference values and all other territorial values should be called territorial precipitation, temperature, humidity, etc., respectively.

KÉRI, M. : Territorial means of precipitation in the reservoir of the river Zagyva. *Beszámolók*, 1954. pp. 109—116. 2 tables.

Applying the generally known methods for computing the average of precipitation fallen upon a given area author is pointing out the fact that there are mean values of due reliability available for Hungary obtained by the method of arithmetical means. The region of mountains of medium height, however, is here an exception. It is shown by the case of the reservoir of the river Zagyva that these methods are applicable even in areas small parts of which are only mountains of medium height.

HAJÓSY, F. : Data on precipitation conditions in the reservoir of the river Tisza. *Az Országos Meteorológiai Intézet kisebb kiadványai*, No. 29. Akadémiai Kiadó,. Budapest, 1954. 112 pages, 19 charts.

Purpose of the study is to provide precipitation data of the whole reservoir of the river Tisza for hydrological computations, the precipitation conditions of the region of Hungary belonging to this reservoir being unfavourable from the point of view of quantity as well as annual distribution and variation. The territory richest in precipitation, situated in the mountains of Máramaros, is receiving about 1700 mm a year, whilst the driest regions obtain about 500 mm. The annual variation of precipitations possesses a continental aspect, with summer maxima and winter minima, but the highlands differently exposed to weather fronts causing the precipitation show significant differences. Finally, the monthly and annual averages of 910 stations are reported from the years 1901—1940, further the percentage distribution of frequency values of monthly and annual precipitations of 24 selected stations, the quantity of very low and very high monthly precipitations and the minimum, quartile, median and maximum values for these stations. There are 19 charts concerning the annual, seasonal and monthly distribution of precipitation.

SZESZTAY, K.: Double-mass analysis for adjustment of precipitation data. *Időjárás*, 58. 2. 1954. pp. 96—102. 3 figs. 2 tables.

Changes in environment and in techniques of measurement are often disturbing the homogeneity of precipitation data series. The author is introducing on the basis of data found in literature and experiences made in this country the method of "double-mass curves". The reduction factors may be determined by the trend-variations appearing in the relation between reference stations and tested stations.

KÉRI, M. : Snow-conditions at Budapest. *Beszámolók*, 1955. pp. 166—172. 1 fig. 4 tables

Climatic differences are demonstrated within the territory of Budapest which are partly a consequence of the different density of building in the metropolitan area, and partly consequences of difference in level. There are thirteen stations situated chiefly at the right river of the Danube the data of which are comprising 1. the number of days with snow-cover, 2. the mean thickness of snow-cover, 3. the greatest thickness of snow-cover, 4. the mean periods for remaining, resp. disappearing of snow-cover. There follows the lenght of the period between these two dates given in days and, finally, the value given as per 1/ in percentage of the period between these two dates.

SALAMIN, P. : Research on the melting of snow in the Bükk mountains. *Időjárás*, 60. 5. 1956. pp. 265—276. 6 figs. 3 tables.

Results of research on the melting of snow carried out in a closed reservoir of the Bükk mountains. It is found that snow melting is largely influenced by orographical conditions, by the type of agricultural cultivation, and by other factors determining the heat- and water-balances of the reservoir. The study represents an attempt for organizing research on snow-melting for territories of greater extent and proves the applicability of the experimental method.

KAKAS, J. & MRS. OTTA, E. : Frequency of nebulosity in Hungary. *Beszámolók*, 1955. pp. 152—165. 3 figs. 1 table.

Discussing the results of detailed observations of fog executed between 1940—1954, it may be established, by investigation of the temporal and spatial frequency of fogs, that earlier notions emanating from some previous publications concerning the geographical distribution of the number of foggy days requires a modification. A much greater variability and a wealth of local features is found which are explained by considerations of physical geography and by comparison to other climatical elements ; accordingly, the differences found may be considered as real characteristics of our climate.

WAGNER, R.: Fluctuating ground-fog in a sink-hole. *Időjárás*, 58. 5. 1954. pp. 289—298. 7 figs. 4 tables, 7 pictures.

In 1953 and 1954 the fluctuations of groundfog has been observed in the sink-holes at the foot of Hosszúbérc (Bükk). The formation of fog begins at the bottom of the sink-hole and the fog is appearing to flow out, then to withdraw. This phenomenon is repeated twice or thrice, after which the fog is filling the whole region of the boggy plane to the height of the leafage of the forests. This peculiar weather phenomenon is not caused by the flow of the air, but by the rhythmical variation of fog-formation and fog-dispersion.

KAKAS, J. & MEZŐSI, M.: Study of our wind conditions and national power-economics. *Időjárás*, 60. 6. 1956. pp. 350—364. 5 figs. 6 tables.

The possibilities of utilizing the energy of the wind are rather limited in Hungary. Our power-supplies being, however, scarce enough, it is justified to survey the wind-power available in order to be able to cover at least part of the power demand by means of wind-power plants. Delimiting the technical and meteorological part of the problem and summing up the small number of investigations carried out so far in this country in the interest of a utilization of wind-power, the observational data collected by the five anemographs recently established in the area of Budapest are examined. The conclusion is drawn that there is such a stock of wind-power available in our country as to render it worthwhile, even necessary, to make further researches by means of meteorological instruments and to try to make usé of it by solving some technical problems.

BENEDEK, É.: Frequency of wind-directions and the thermal compass in Szeged, in the years between 1926 and 1940. *Földrajzi Értesítő*, IV. 1. 1955., Budapest, pp. 63—76. 7 figs. 7 tables.

The study is dealing with the prevailing frequency of wind-directions and the mean values of temperature observed on the occasion of winds blowing from the directions of the individual points of the compass, on the basis of 15 years observations at the climatological station of Szeged. The tables prove that there is no exceedingly prevailing wind-direction in Szeged. The author computed the frequency of wind-direction for every season and for each observational hour. It follows from the study that the different wind-directions mean different temperature regimes, the average value of 11,2° C is exceeded in an annual average only by the means of temperature consequent upon the SE, S, SW winds. The relation between frequency of wind-direction and temperature may be found in monthly details in this study.

CZELNAI, L. R.: Data on the wind-conditions of the Lake Balaton in relation with the chief synoptic weather-types of Hungary. *Beszámolók*, 1955. pp. 137—151. 6 figs. 1 table.

Author deals with some characteristic features of the wind-conditions of the Lake Balaton, using methods of dynamical climatology. The characteristical flow pattern is brought into relation to different synoptical situations. The author deals therefore in the first place with the problems much talked of concerning the classification of synoptic weather-types. The purpose of his research has been to test strong winds and windstorms, but because of their particularity he touched also upon the examination of local winds developping in still and clear weather. He processed the data of three anemograph stations at Lake Balaton: Balatonkenese, Siófok and Keszthely. This made possible to throw a light on different local effects, too, thus getting a step nearer to the knowledge of the wind-conditions of Lake Balaton.

CZELNAI, L. R.: Some particularities of the system of circulation on the shores of Lake Balaton. *Időjárás*, 59. 4. 1955. pp. 223—229. 6 figs.

Author studies on the basis of anemograph data of the stations Siófok, Balatonkenese, Keszthely the winds occurring periodically along the shore of Lake Balaton. The method is limiting itself to calm and clear anticyclonic weather. It can be seen that the circulation system mentioned may, from the point of view of the amplitude and the periodicity of the variation in wind-direction and wind-velocity, be brought into accordance with the computations of this type made by Defant.

KÉRDŐ, I.: Climatic health-resorts and their climatological study. *Időjárás*, 58. 1. 1954. pp. 32—39.

This is a survey of the more important climatic factors coming into account for bioclimatology, endevouring to answer the question how to classify our climatic health-resorts and how to carry out climatological studies on places like that.

Riesz, E.—Pál, I.—Konek, L. : Climatological surveys in the health-resorts of the Mátra. *Időjárás*, 58. 4. 1954. pp. 197—205.

Authors carried out in the autumn 1952 climatological surveys in the health-resorts Mátraháza (685 m) and surroundings. A hundred of patients assigned to convalescence have been examined. Results on bioclimatical effects appearing in the state of health of the convalescents are demonstrated.

Kérdő, I. : Fundamental concepts of bioclimatology. *Időjárás*, 60. 4. 1956. pp. 227—235.

The fundamental concepts of bioclimatology are deduced from the most important factors of the relation between a living organism and its surroundings. Numerous constituents of the atmosphere play a decisive part in the normal course of vital processes. Changes in the surroundings, thus in the atmosphere too, are mobilizing the capacity of adaptation of the organism, the reactions produced, however, are depending on the momentary condition of the individuals themselves. It is from these relations that the up-to-date research problems of bioclimatology are to be derived.

Predmerszky, T. : Characterization of comfort in work-rooms. *Időjárás*, 59. 5. 1955. pp. 268—274. 3 figs.

The research on work-room climate is a well-delimited branch having a great practical importance of medical meteorology, rendering necessary the development of numerous new research tools. The meteorological factors of work-room climate are in a high degree influencing the health of employed people, it is therefore an important task to determine official standards for admissible parameters of working-room taking into account the results of researches on comfort. This problem may, however, be solved only in close co-operation of all sciences engaged in bioclimatology.

Horváth, L. G. : Influence of frontal passages on the nervous activity of traffic staff. *Időjárás*, 59. 3. 1955. pp. 139—147. 1 fig.

In order to detect the relation between traffic accidents on high-roads and weather-changes, numerous computations have been carried out based on laboratory tests and on methods of mathematical statistics. The experiments were made with reposed traffic staffs and with tired ones having travelled at least for ten hours at the night preceding the experiment. Evidence for the influence of frontal passages on the central nervous activity is explicitly established. Traffic work of those sensitive to weather is strongly influenced by physiological and psychological reactions occurring in the human organism upon frontal effects. This is proved by the close relation between frontal passages and the tested 3519 high-road accidents.

Wagner, R. : Complex temperature. *Időjárás*, 58. 2. 1954. pp. 72—77. 1 fig.

An electrical instrument has been developped for the measurement of heat losses and gains of the human body as a result of the influences of air temperature, evaporation, wind conditions and radiative interactions. The numerical value indicated by the instrument is called "complex temperature". This value may be converted to centigrade degrees, too. The instrument is destined to bioclimatological and microclimatological research work.

Wagner, R. : Microclimatological observation methods for different ecological regions. *Időjárás*, 59. 3. 1955. pp. 165—169.

Unified programmes of microclimatological observations are proposed for use in different plant associations. Dealing with the projecting of research for microclimatological observation stations, the suitable installation of instruments, the choice of observation periods and observation times are discussed. The necessity of simultaneous macroclimatological observations is pointed out.

Dobosi, Z. : A criterion for the determination of the presence of a dependent microclimate. *Időjárás*, 60. 5. 1956. pp. 287—291. 1 fig.

A method is discussed by means of which there is a possibility to separate in the layer of air near the surface the conditions free of advection from the advectional layer. The method is, consequently, suitable for proving the dependence, resp. independence of microclimate near the soil. The application of the method is illustrated by data obtained at the microclimatical station Erdőhátpuszta.

KISS, Á. : Contribution to the knowledge of the microclimate of quicksands. *Időjárás*, 59. 4. 1955. pp. 235—238.

Local climate of the sands of Üllés are compared with that of the airfield of Szeged and of the town of Szeged. Further the microclimatic conditions of sand-hill tops without vegetation and of depressions between sand-hills covered with vegetation are dealt with. The extreme values, the degree of rise and decrease in temperature, the nocturnal inversion and the stages of daily variation of temperature are presented.

WISCHÁN, Z. : Microclimatological research on the soda soils of Békés. *Földrajzi Értesítő*, V. 1. 1956. pp. 43—53. 6 figs. 8 tables.

An account of microclimatological researches made by the Climatological Institute of the University of Szeged on the sodic soils of Békés in August 1954. Studying the heat—and water-supply of these sodic areas it may be stated that the sodic soils are reaching at every level the highest temperature, the compact, column-like clumps securing a uniformly distributed good thermal condition. The sodic soils that are reaching, in the day, highest temperatures, are at the same time cooling in the least degree even in the course of the night. Several common causes of heat-preservation are assumable, but it seems to be mainly the consequence of higher concentration of salt, too. The total quantity of salt is in every case and at every level directly proportional, whereas the value of capillary water-rise is inversely proportional to temperature.

BENEDEK, É. : Microclimatological research in the Tiszazug. *Földrajzi Értesítő*, III. 3. 1954. pp. 544—553. 5 figs.

This is an account of the results of measurements carried out on the southern sand-line of the Tiszazug. Within a cross-section of 250 m there were established seven measuring stations. Dry and warn weather was prevailing during the period of the experiment. The microclimatological differences caused by differences of level at the hillside have been observed at the time of temperature minima at dawn. The measurements have been carried out in heights of 5, 50 and 150 cm ; the data prove the influence of differences in level. Examinations were carried out on differences caused by the situation to the cardinal points, by the soil as an important factor of microclimate, and on its interaction with vegetation. A natural cover of vegetation found at this locality is, on the whole, characteristic for the whole territory of the Tiszazug.

WAGNER, R. : Contributions to the knowledge of the microclimate of the south-eastern part of the Great-Plain. *Földrajzi Értesítő*, V. 2. 1956. pp. 135—160. 13 figs. 3 tables.

A review of the microclimates of the intensively cultivated areas limited by the rivers Körös—Tisza—Maros, including the microclimate developped in the air enclosed in the interior of the plant stock of cultivated areas and also that of the vegetation-free state after this vegetation has been harvested. It is determined by means of heat-supply examinations to which degree the climatical conditions of small volume are transformed with the increase or decrease of the vegetative cover. The climatic environment of harvesters and threshers is studied simultaneously.

WAGNER, R. : Microclimatological zones and their mapping. *Földrajzi Közlemények, Új Folyam* IV (LXXX). 2. 1956. pp. 201—210. 4 figs.

Examining the cause of the formation of climate and, within the same, of different climatic zones, author is outlining the notion of macro- meso- and local climates and the concept of the substratum. The territorial distribution of different types of climate is dealt with on a particular example in the Bükk-mountains of Borsod, in the region of Hosszúbérc. In the territorial systematization of different kinds of climates author is genetically starting from the substratum as the micro-climate is formed under the influence of the same. There is made a distinction between microclimatological zones of Ist, IInd, IIIrd and IVth order. Knowing a region and its climate it is possible to map down from the genetical point of view these microclimatological zones, but the view-points will be different according to the industrial or agricultural or undisturbed natural character of a given region. It seems to be possible to chart microclimatically even greater territories with the help of charting the individual microclimatological zones.

WAGNER, R.: Geographical arrangement of microclimates at the Hosszúbérc. *Beszámolók*, 1955. pp. 197—211. 13 figs.

Substrata are regions of usually varied substance, but rather uniformly intercepting the sunshine being in this way the effective surfaces for atmospheric processes. The microclimate is originating in the layer of contact between substratum and atmosphere. Research has been carried out on the karstic plateau of the Bükk-mountains in Borsod, in the region of Hosszúbérc, in May, July, August 1953 as well as in May, June, and July 1954. The differently sloping surface of the mountain with an E—W trendline is significantly modifying the angle of incidence of solar radiation whichisinfluencing the daily course of temperature, too. By the screening effect of mountains and forests the length of the insolation period is modified. In the region examined, four types of microclimates of the first order could be found. In consequence of the mutual effect of air-masses in, these microclimatic regions new microclimates of second order are developping.

II. Research on solar radiation

Until 1937 there has been in Hungary no systematic meteorological radiation research besides the usual registration of insolation hours on the climatological stations and some measurements carried out here and there with the actinometer.

On about 20 to 30 stations Campbell-Stokes sunshine-recorders were in operation, obtained data being published in the "Monthly Weather Reports" and the Yearbooks of the Central Meteorological Institute.

In the years 1937 to 1944 systematic measurements were carried out with the bimetallic actinometer of MICHELSON—MARTEN in order to determine the intensity of perpendicularly incident direct radiation from the free solar disk in the full solar spectrum as well as in the spectral ranges separated by means of international normal filters. The filters used are of the Schott-glass-filter type, yellow with the mark OG 1 and red marked RG 2, with which the following ranges of the full spectrum may be separated : violet and blue range having wave-lengths of 310 μ to 0,525 μ, green and yellow range consisting of wave-lengths of 0,525 μ to 0,625 μ, and red and infrared range of the wave-length of 0,625 μ to 2,5 μ. These data became published in gcal cm^{-2} min^{-1} units according to the Smithsonian scale in the volumes 1938—1944 of the official publication "Monthly Weather Report".

It has been in 1937 as well that the registration of total radiation (sun and sky) on a horizontal plane has been started on about 5 to 10 climatological stations and carried out with the bimetal-actinograph type Robitzsch. Daily and monthly data of total radiation values were printed in the above-mentioned publications.

There have been only sunshine-recorders on about 30 to 40 stations and global radiation instruments on 3 to 4 observation places between the years 1945 and 1953.

In 1954 a research group consisting of a few technicians and a scientific research worker has been established in the aerological observatory of Budapest-Lőrinc and is since that time carrying out actinometric measurements with the above-mentioned Michelson—Marten bimetal-actinometer during favourable weather conditions. As the observatory is not yet in possession of an absolute instrument, no publication of data has been undertaken. It was possible, however, to obtain a calibration of the relative instrument in use, Michelson—Marten's bimetal-actinometer, in August 1956, by comparisons made at Potsdam, according to the international Smithsonian scale. Final publication will take place according to the new international scale of radiation established in Davos, September 1956.

It is the task of the research group at the observatory to continue and to develop in the course of the International Geophysical Year actinometric observation for the determination of the intensity of solar radiation in the whole spectrum and in the spectral ranges selected by means of the standard yellow, resp. red filter at three representative places of the country : the Observatory in Budapest-Lőrinc, the Observatory of Siófok, and Kékestető, the observing station possessing greatest altitude above sea-level, according to measurement carried out three or five times a day in this country and, during the international days, at every hour. Data of surveys carried out at different values of solar elevation (at noon, at 3 and 6 hours before and after the highest position of the sun) will be suitable for illustrating climatical radiation differences partly studying polluting effects of nearby urban and industrial areas and partly for demonstrating the advantages of the radiation climate enjoyed at some important health-resorts of the country (surroundings of the Lake Balaton, Siófok) and of the mountaineous regions where sanatoria are situated (Mátra, Kékestető). Preliminary comparison and calibration of the instruments, solarimeters of the type Moll-Gorczynski, has been carried out in the observatory of Lőrinc, according to the new international scale. Three radiation components are measured by the instruments : direct radiation (in the complete spectrum and in the ranges delimited by the filters), total radiation from sun and sky incident on a horizontal plane and finally the scattered sky radiation on the horizontal plane, as well.

A second task of the research group during the International Geophysical Year consists of the organization of a network for the observation of global radiation composed of 15 to 20 stations equipped with Robitzsch bimetallic actinometer, partly for the demonstration of climatical differences in radiation and partly for participating in the establishment of an empirical formula permitting the computation of radiative energy from observations with a sunshine recorder. In the possession of such a relation it should be possible to determine more reliably for the purpose of drawing a detailed picture of the features of radiation climate the reference values of global radiation and other climatological characteristics on the basis of insolation data obtained by earlier and longer observation series on numerous places of the country. The actinographs have been before their installation in the network carefully compared to a standard instrument from the point of view of their relative sensitivity ; the standard instrument located at the observatory of Lőrinc is during the International Geophysical Year permanently controlled according to the international radiation units. The instruments of the network are under permanent control and are recalibrated, if necessary. Thus the comparability of the results is secured not only on a national, but also on an international level.

During the International Geophysical Year the permanent registration of other radiation components : direct solar radiation and scattered radiation shall be realized, if possible, not only at one place (the observatory of Budapest-Lőrinc), but on 2 to 3 other places, further measurements of ultra-violet solar and sky radiation will be assured by means of a cadmium-cell.

III. Agricultural meteorology

The basis of the economical life of Hungary is agricultural production. Our research activities in agricultural meteorology have therefore been closely connected even in the past three years to practical questions of plant cultivation. Some detailed research work has been done on weather phenomena that are favourable or unfavourable for crops, on the agrotechnical implications of these phenomena as well as on microclimatological justifications of agrotechnical methods which are endeavouring to advance in quality cultivation, plant breeding and plant naturalization.

It was for this purpose that the Agrometeorological Observatory of Martonvásár has been established in 1955 working in close co-operation with the Agricultural Research Institute, Martonvásár.

Research work in agricultural meteorology has been engaged in the following main topics :

Microclimatological field surveys carried out on agricultural experimental stations. Meteorological survey of methods of frost protection. Heat- and water-balance of the snow-cover. Investigation of climatic conditions prevailing in the interior of crops. Agrometeorological problems of afforestation and plantations of vineyards. Problems of the cultivation of quicksand and sodic grounds in this country. Statistical handling of the occurrence of extraordinary weather conditions.

Results of this work are represented by the following review of publications :

KULIN, I. : Some problems in agricultural climatology. *Időjárás*, 59. 5. 1955. pp. 258—267. 4 figs.

A summary is given of recent development of methods for the collection, processing and application of data in agricultural climatology. Based on a 85-year series of precipitation and temperature data obtained in Szeged, a rather simple and most demonstrative method of processing and illustrating is introduced which is — in spite of its simplicity — representing a very good basis for the estimation of any weather peculiarities in the light of the statistical probability of their occurrence.

KULIN, I.: Recent questions of agrometeorological research in Hungary. *Időjárás*, 59. 2. 1955. pp. 107—109.

The most important and most urgent tasks before agrometeorological research in Hungary together with the requirements of their solution are discussed. The problems of education in agricultural meteorology and of the co-ordination of research executed by different institutions are outlined. Processing of observational data according to agricultural requirements in Hungary, the necessity of co-operation with the research workers engaged in agricultural sciences, the establishment of agrometeorological stations and observatories are considered.

SZILÁGYI, T.: The extraordinary frosts of May 1952. *Időjárás*, 58. 1. 1954. pp. 15—23. 6 figs.

The following extraordinary features of the frosts that occurred in May 1952 are dealt wiht on the basis of a comparison to observational data for several decades: the frost was unusually late, very strong as compared with its late occurrence, of long duration, extending all over the territory of the country; acting on a vegetation that was — as a consequence of the previous period of warm weather — much more advanced in development as usual, the frost caused serious damages.

SZILÁGYI, T.: Agrometeorological implications of the frosts in May 1952. *Beszámolók*, 1954. pp. 36—49. 15 figs.

The unusual character of the late spring frosts on May 19—26, 1952 are discussed on the basis of observations of several decades and by the examination of previous frost situations similar to those of this year. Observational data of several decades obtained at five stations and concerning late spring frosts are dealt with, whilst charts are illustrating the strength and duration of the frosts of 1952.

SZILÁGYI, T.: Agrometeorological interpretation of the late spring frosts in 1953. *Beszámolók*, 1955. pp. 86—90. 3 figs.

Comparison is made to the frosts in May 1952 and it is shown that the strength and damages of the frost of May 1953 remain far behind that of May 1952.

KULIN, I.: Examination of the extraordinary abundance of precipitation in autumn 1952 and of the extraordinary lack of precipitation in autumn 1953 from a climatological and agricultural standpoint. *Beszámolók*, 1955. pp. 25—40. 15 figs.

Whilst examining the abundance, resp., lack of precipitation, data are compared — in order to lay stress upon the extraordinary character — not only to the averages from many years, but also to the extreme cases occurred since 1901 and charts show those areas where there has been more, resp., less rain as compared to outstanding cases up till now. As to other areas, the probability of occurrence of unusually copious, resp., unusually poor rainfalls in 1952 and 1953, respectively, is expressed and, finally, the agricultural consequences of the weather conditions in these two extreme autumns are outlined.

NAGY, L. & SZABÓ, B.: Alternatingly occurring frosts in Debrecen. *Időjárás*, 59. 5. 1955. pp. 309—311.

In the different depths of the soil alternating freezing and thawing is a frequent occurrence. The maximum frequency is found to be in March. The unusually great number of alternations in a soil without a snow-cover is the source of great damages in agricultural production. Movements in the soil, occurring in consequence of frequent alternating freezing, do considerable damage to agricultural plants sown in the autumn: about 50 to 86 per cent of sowing of wintercorn is ruined because of frost damages in the region of Debrecen.

KULIN, I.: Macro- and microclimatological investigation of the station of frost experiments at Mátraszentlászló. *Beszámolók*, 1954. pp. 156—179. 7 figs. 7 tables.

Climatological comparisons are made among the experimental station situated at an altitude [illegible] 780 m, the peak of Kékes mountain (1000 m) and two stations of lower situation. Macro[illegible]logical investigations are comprising temperature and snow-cover, microclimatological [illegible]tion includes radiation of the soil surface and heat-balance of the snow-cover.

ANDÓ, M. : Contributions to the knowledge of temperature conditions in a sandy soil. *Időjárás*, 59. 4. 1955. pp. 230—234. 3 figs.

Soil-temperature conditions of quicksand in the sandy region of Üllés, in clear and in cloudy weather and in the case of different kinds of substrata are discussed. Daily temperature variations in quicksand and in sand fixed by plants are compared in dry and wet conditions. Conclusion is drawn as to the advisability of taking steps for an agricultural utilization of this area.

BATTA, E. : Daily normal values of soil temperature and the sowing temperature. *Időjárás*, 59. 6. 1955. pp. 351—358. 4 figs. 4 tables.

The annual variation of soil temperature in Budapest and its extreme values in depths between 2 to 400 cm are presented on the basis of 30 years daily normal values (1912—1941). There is a critical boundary layer in the soil, above and below of which the mean propagation velocity of annual extreme values is opposite to each other. The daily normal values are in practice useful for the determination on the sowing temperatures of the main cultivated plants.

FELMÉRY, L. : An experiment for the determination of the evaporation of natural surfaces. *Időjárás*, 59. 2. 1955. pp. 86—96. 1 fig.

Recently developped methods for the measuring of evaporation are discussed, as well as experiments carried out with these methods at the microclimatological station of Erdőhátpuszta. In the second part of the paper, the author endeavours to determine the evaporation of soils under various cultivations by means of the method seeming to be the most reliable, this being treated as a peculiar problem in agricultural meteorology.

BENEDEK, É. : Microclimatological research in a field of hemp. *Időjárás*, 58. 3. 1954. pp. 158—168. 6 figs.

An investigation extending over several days has been carried out in the neighbourhood of Mezőhegyes during July 1952 in order to determine the daily variation of temperature of the air and the soil in a field of hemp in blossom. According to these investigations, the variation of air temperature is much more extreme in the field ; soil-temperature values are considerably lower, and their variations possess a much smaller amplitude than in a forest or in a free region in the vicinity.

BERÉNYI, D. & JUSTYÁK, J. : Phenological surveys in the vineyards of hilly districts. *Időjárás*, 60. 2. 1956. pp. 104—111. 5. figs. 6 tables.

The surveying method of the authors made it possible to determine at two points of Tokaj-Hegyalja the dependence of the intensity of the blossoming of vine on height, inclination and direction of the slope. The advantageous zone of inclination could be precisely marked by means of the percentages of blossom. A treatment of survey data by methods of mathematical statistics is suitably demonstrating differences resulting from agrotechnical and other causes. The statistical interpretation might even be used for directing microclimatological research to be carried out in the vineyards.

HANK, O. & VÁSÁRHELYI, J. : Influence of the colour of the soil on the development of cotton. *Időjárás*, 58. 3. 1954. pp. 137—143. 8 figs. 4 tables.

The influence of colouring of the soil on temperature conditions of the soil and of the air-layer near the soil, resp., on the growth and development of cotton has been studied in the frames of a provisional experiment. The conclusion can be drawn of the experimental results that by means of the method in question and by developping the same there is a possibility of shortening the time of cultivation of cotton and of increasing crops.

VÁMOS, R. : Connection between weather and the bruzone disease of rice. *Időjárás*, 58. 5. 1954. pp. 273—277.

The bruzone disease of rice has its origin in hydrogen sulphide developping in the soil. In the fields with an acid surface soil beyond the river Tisza there are acids developping with the decomposition of organic matter which set free hydrogen sulphide from sulphides reduced of sulphates. The fall in temperature after the summer warmth is increasing the gas-absorbing capacity of irrigation water used in flooding the rice-field, in consequence of which much more hydrogen sulphide is developping. It is for this reason that the disease appears mostly in August when temperature is falling. A long-lasting winter, a cool spring are hindering the decomposition of organic matter and this circumstance is an important factor in biological and chemical processes leading to the disease. The relation between the weather in the years 1940, 1949 and 1954, and the disease may be thus clarified.

PINTÉR, L. : Correlation between the mean crop of winter wheat and the most important meteorological factors. *Időjárás*, 59. 4. 1956. pp. 193—203. 11 figs. 1 table.

The correlations between the chief weather elements (atmospheric temperature, duration of sunshine, precipitation) and some agrotechnical factors and the mean crop of wheat was thoroughly studied for the period between 1920 and 1954 for every pentade, resp., decade, regarding the region between the rivers Danube and Tisza. As a result a very close correlation has been found, on the basis of which even estimations of future crops may be effected.

ÁDÁM, T. & BATTA, E. : Influence of weather on milk-production. *Időjárás*, 60. 3. 1956. pp. 168—176. 4 figs. 2 tables.

The connection between the milk- and butterfat-production of ten Hungarian spotted cows and the external and cow-stall climate in the state farm of Taksony is discussed regarding the period between March 9 and April 16, 1955. A dependence on weather elements, atmospheric fronts and air-masses has been demonstrated.

IV. Synoptics and long-range forecasting; dynamical meteorology

Geographical situation of Hungary is calling for particular synoptical researches, as the mountains surrounding the country (the Alps, the arc of the Carpathians, i. e. the Balkan Mountains) are influencing, in a peculiar way, the climate of this country situated in a basin which is reflected as well in the special features of the individual synoptical processes.

Research aims consisted mainly in the explanation of these particular conditions. In the three years under review research has chiefly been concentrated upon the cases of second type northern cold fronts and orographical occlusion related to the same, respectively, upon the examination of stationary fronts within the basin and related to van Bebber's V/b cyclonic trajectory. Connected with this branch of research is the determination of the frequency of macrosynoptical situations, as well as the explanation of temperature conditions and cloudiness in each type of macrosynoptical situation. Taking into consideration all these problems, a study of droughty periods, resp., those rich in precipitation has been started. In close relation to this is the research on the part played by the friction layer, resp., on forecasting numerical values of windpath and wind pressure.

In long-range forecasting, main stress was laid upon the investigation of connections between variations of macrosynoptical conditions and solar activity. In this respect, it is of basic importance to clarify the effect of solar corpuscular radiation on geomagnetical disturbances and polar weather (cold fronts). A thorough examination of the different periods of solar activity (27, 30 and 40 days, as well as a rhythm of 2 to 3 years) is belonging to this branch of investigation. The determination of the parts of the Northern Hemisphere where cyclonic disturbances are most frequently forming and the problem of regeneration of subtropical anticyclones are of more general significance.

The results obtained are dealt with in the following publications:

BERKES, Z.: Method and results of long-range forecasting in Hungary. *Időjárás*, 58. 6. 1954. pp. 329—340. 15 figs.

The periods of 27 days (rotation of the sun) and 29.5 days (variation in moonlinght) appearing in weather are serving as a basis for the forecasts of two weeks. Among the investigations which are destined to increase the reliability of forecasts some results concerning the period of 355 days, and, further, the fundamental areas of cyclogenesis and its frequency are discussed. It is pointed out that long-range forecasts require the prevision of solar activity, too. (This study has been published *in German* in the "Acta Agronomica", Tom. V. 1955. p. 79.)

PÉCZELY, GY.: Some problems of macrosynoptical forecasting in the winter season. *Beszámolók*, 1955. pp. 220—227. 7 figs. 3 tables.

The first part is looking for relations between the atmospheric pressure of Europe in autumn and the temperature of the following winter in the Eurasian area. The connections found are not applicable for forecasting purposes because of their unsteadiness from year to year. The second part is dealing with the anti-cyclones developping over Scandinavia and it is found that their formation is in close connection with the intensity and location of the cold centre above Northern-Canada. If the cold centre in question is moving in an Eastern direction and is of great intensity the produced drift field is favourably influencing the formation of the maximum in Scandinavia, whereas — if the cold centre is shifting towards West and is feeble — the area of Scandinavia turns to be cyclonic. The cold centres of Siberia play an indirect part in the formation of Scandinavian anticyclones across the polar anticyclones passing over North-America.

BERKES Z. & BORSOS J.: Frequenency of cyclogenesis on the Northern Hemisphere of the Earth *Időjárás*. 59. 6. 1955. pp. 321—330. 8 figs. 4 tables.

The geographical distribution of cyclogenesis is studied on the basis of daily circumpolar weather charts of the decade between 1921 and 1930. Greatest frequencies of cyclogenesis on the Northern Hemisphere are found 1. in the surroundings of the East China Sea,, 2. on the East side of the Rocky Mountains, 3. along the East costal district of North-America, 4. in the region of Genova in the Mediterranean. Near Iceland and the Aleutian Islands cyclogenesis is very rare.

PÉCZELY, GY.: Contribution to the problem of the regeneration of subtropical highs. *Időjárás*, 58. 2. 1954. pp. 65—71. 7 figs.

The anti-cyclones moving from polar regions towards South and feeding subtropical highs from the North are playing an important part in the regeneration of subtropical highs, especially in the case of Azoric anti-cyclones. There is a relation between the outbreak of polar cold air masses and the radiation of the Sun. The inflow of particles produces magnetic storms and in these cases temperature is rising in the upper air over polar districts, whereas on the ground an increase of pressure is found which contributes to the spreading out of anticyclones.

PÉCZELY, GY.: Formation of anticyclones in connection with the variation of solar activity. *Időjárás*, 58. 6. 1954. pp. 407—417. 11. figs.

The formation of polar, Azoric and Scandinavian anti cyclonal systems and their relation to each other is discussed. The parts played of polar anticyclones in the regeneration of anticyclones in the Azores and in the formation of Scandinavian anticyclones are dealt with, then after explanation of the different phases of the process the results are applied to middle-range forecasting. The outbreak of a polar anticyclone is followed after 7—10 days by the spreading out of the anticyclonal system of the Azores in the direction of the British Isles. The connections between solar radiation and polar upper air temperature and pressure in sea-level are again pointed out. (This study has been published *in German* in "Acta Agronomica" Tom. V. 1955. p. 201.)

PÉCZELY, GY.: Typical macrosynoptical situations for Hungary. *Időjárás*, 59. 4. 1955. pp. 212—217. 4 tables.

Ten characteristical macrosynoptical situations are defined for Hungary. Their monthly frequency, the probabilities of their succession as well as the frequency distribution of the daily mean temperature of Budapest for every type and the distribution according to types of precipitation are given on the basis of January and July data of the years 1946—54.

PÉCZELY, GY.: Contribution to the study of temperature conditions in the different macrosynoptical situations in Hungary. *Időjárás*, 60. 2. 1956. pp. 71—81. 2 figs. 7 tables.

Fifteen types of macrosynoptical situations are defined. On the basis of 60-years data the temperature averages are computed for every month by means of the daily temperature averages of Budapest prevailing on the days of the individual types. The monthly means belonging to each type are expressed by Köppen's relative temperature and compared with annual variation at a coastal and a continental station whilst applying the x^2 test. Moreover the average change of temperature is dealt with in the case of anticyclones lasting for five days and connected with a characteristic transformation of air-masses.

ANTAL, E. & PÉCZELY, GY.: Contributions to the question of nebulosity in different macrosynoptical situations in Hungary. *Időjárás*, 60. 5. 1956. pp. 277—286. 6 tables.

In connection with nebulosity values of the types of macrosynoptic situations determined for Hungary it is studied how nebulosity is developing in case of the individual types in every month. The probability of occurrence of clear, cloudy and overcast conditions is discussedfor every type and, applying Pearson's x^2 test, it is determined whether the distribution of the frequencies of each cloud species are significantly differing one from the other. The 27 different cloud species in the synoptical code are classified into 11 groups and the annual variation in their frequency is determined, then probabilities of the occurrence of each cloud species are computed for every season and for each macrosynoptical type.

PÉCZELY, GY.: Development of frosts in the late spring. *Beszámolók*, 1954. pp. 195—200.4 figs.

The synoptical history of formation of frosts in 12 cases of frosts late in spring (1901—1953) is studied. It is pointed out that in the evolution of late spring frosts anticyclones from Greenland, the Azores and those of ultrapolar origin are involved according to a ratio of 3 : 2 : 1.

BERKES, Z. & KADOCSA, F.: Periodicity of May-time frosts. *Beszámolók*, 1954. pp. 8—15. 5 figs. 1 table.

From the series collected at the station of Debrecen between 1855 and 1953 there appear periodicities in May frosts of seven and nine years. There is also a periodicity of about 35 years. composed of the above-mentioned two periods.

MRS. KALLÓS, I.: Synoptical study of May frosts in 1952. *Beszámolók*, 1954. pp. 26—35. 8 figs.

The extraordinary ravaging frosts of May 1952 are found to be of advective origin. The development of frosts is explained by the method of advective dynamic analysis.

MRS. KALLÓS, I.: Synoptical study of May frosts in 1953. *Beszámolók*, 1955. pp. 79—85 4 figs.

The frost periods of May 1952 and 1953 have been compared from a synoptical point of view. The experiences of synoptical surveys of May frosts are discussed on the basis of data of 15 years sea-level charts, and two chief directions of progression are given for the air-masses approaching from regions situated north of the 55th latitude towards the Carpathian-Basin.

KOZMA, F.: Dew-point and local frost forecasting. *Időjárás*, 60. 3. 1956. pp. 159—167. 8 figs. 2 tables.

A method for forecasting local frosts is outlined. The forecasts concerning frosts which are included in general weather reports are often insufficient, giving only general information because of the great differences in local climatic features. The dew-point method generally used in our country shows several fallacies and is therefore not yielding reliable forecasts. The theoretically sound method of Berljand is found to be applicable under Hungarian climatic conditions, too. By means of this, satisfactory local forecasts of frost conditions are obtained.

Csizsinszky, M.: Synoptical explanation of the summer drought of 1952. *Beszámolók*, 1954. pp. 50—54. 6 figs.

The period between June 26 and August 16, 1952 is synoptically described, this having been the drought period of longest duration in Hungary in the past fifty years.

Németh, T.: The summer drought of 1952 as seen from the point of view of long-range weather forecasting. *Beszámolók*, 1955. pp. 61—65. 6 figs.

An aerosynoptical study is carried out of the dry summer of 1952 as compared with the cool and wet summer of 1948. The vapour content of air as well as lability energy are thoroughly studied. Drought is induced by the spreading of warm air-masses in the upper air which is involving a displacement towards the north of the high pressure zone; the reason for this phenomenon is not yet known, it is therefore difficult to prepare long-range forecasts.

Rajkay, Ö.: Study of the rainy period in autumn and winter of 1952 from the point of view of wind, cloud-height and visibility. *Beszámolók*, 1954. pp. 66—76. 8 figs. 8 tables.

Frequency values of wind, cloud-height and visibility are given for this extraordinarily rainy autumn period, using hourly synoptical observations at the six Hungarian airports: Miskolc, Szombathely, Budapest-Ferihegy, Debrecen, Pécs, Szeged. The frequencies of simultaneous occurrence of these elements is dealt with, too.

Berkes, Z.: Macrosynoptical and periodological characterization of the drought in March 1953. *Beszámolók*, 59. 1955. pp. 41—57. 20 figs.

Characteristic features of the weather of March 1953 are discussed on the basis of comparison with long series observations. The five, resp., 2 to 3 years rhythm of air-pressure in March is dealt with. This rhythm is appearing in the variations of meridional circulation and is in connection with the changes in geomagnetic activity. There is a relation between the quantity of rainfall in March and the annual quantity of precipitation, and the conclusion is drawn that in 80 percent of the cases the anomaly of annual precipitation has the same sign as that in March.

Mrs. Tónay, F.: Synoptical description of the rainy summer 1953. *Beszámolók*, 1955. pp. 91—96. 6 figs.

The rainy summer of 1953 is described from the synoptical point of view. The period rich in precipitation lasted from May 27 till June 28 and consisted of sharply separate cycles. The first cycle was of monsoonal origin, in the second cycle it have been the very unstable air-masses advancing from SW, in the third those advancing from NE which caused the unusual rainfalls.

Mrs. Otta, E.: Formation of a stationary front above Hungary on August 27, 1953. *Beszámolók*, 1954. pp. 231—234. 3 figs.

The synoptical history of wide-spread rain on August 27, 1953 is discussed and the reasons are given for the failure of a published forecast.

Mrs. Kallós, I.: Wind storm at Lake Balaton. *Beszámolók*, 1954. pp. 224—230. 6 figs.

Weather conditions of the wind storm that occurred at Lake Balaton on September 10, 1953 are dealt with. A cold front passing over the country has caused the storm that grow extraordinarily severe as a local cyclone has developed at sea-level in consequence of the orographic modification of air flow in the basin.

Németh, T.: Fluctuation in the precipitation at Budapest. *Beszámolók*, 1955. pp. 214—219. 2 figs. 3 tables.

In the last ten years appeared a period of 8,5 months in the precipitation series of Budapest. The first part of the paper is dealing with the steadiness and intensity of the period, the second part wants to find out in which future decade this period will appear again. As a result it is pointed out that the appearance of this period is connected to the cycle of solar activity and the temporary manifestation of mediterranean climatic features in the climate of Hungary.

BODOLAI, I. : Influence of the atmospheric friction layer on the formation and distribution of precipitation. *Beszámolók*, 1955. pp. 239—284. 1 fig.

Methods are discussed for the qualitative and quantitative characterization of meteorological factors involved in the formation of precipitation. The determination of advective and non-advective variations of temperature, humidity and air-pressure is studied in detail. In the second part the influence of the friction layer on the intensity and regional distribution of precipitation is examined. In connection herewith the methods of A. N. Mercalov and A. F. Djubjuk for the computation of up-draft are dealt with.

TARDOS, B. : On thermal up-drafts. *Időjárás*, 58. 5. 1954. pp. 283—288. 4 figs.

Starting from the law of conservation of energy, a formula is derived for the value of the adiabatic gradient in which the kinetic energy is taken into account as well. In order to record and to survey the fluctuations of air density near the soil that are preceding the development of upcurrents, a densimeter has been constructed indicating 1 gr/m^3 of fluctuation of density by 1 mm of deviation on the diagram. This instrument is at the same time suitable for measuring turbulence, too.

KOZMA, B. & RAJKAY, Ö. : Prevision of wind-path and wind-pressure values. *Időjárás*, 59. 3. 1955. pp. 129—138. 4 figs.

Illustrated by concrete examples, the practical application of formulae is dealt with, which have been deduced for the forecasting of numerical values of wind-path and wind-pressure from theoretical considerations due to B. Kozma (see literature). The two first parts of the study are specifying the conditions and rules to be considered when applying the formulas. The third part is containing descriptions of actual cases serving as examples.

BODOLAI, I. & MRS. BODOLAI, E. JAKUS: Some remarks on the forecasting of absolute contour lines. *Időjárás*, 60. 3. 1956. pp. 150—158. 8 figs.

Practical problems of forecasting absolute contour lines are dealt with on the basis of a theorem of V. D. Uspenskij. As a result it is shown that eddies are playing a decisive part in the local change of the absolute geopotential of isobaric surfaces. By the method of Uspenskij best results have been achieved in the forecasting of the 700 mb. surface.

AUJESZKY, L.: Studies on the synoptics of quasi-stationary fronts in Hungary (V/b situations). *Beszámolók*, 1955. pp. 230—238.

A system of neccesary and sufficient synoptical conditions for the development of a V/b situation is proposed in this paper. This consists in the following ten conditions : 1. Presence of a strong meridional circulation. 2. Particular location of a high-level frontal through above Central Europe. 3. Prevailing air flow in the middle troposphere from a southerly direction. 4. Advancing side by side of air-masses of extreme characteristics in the lower layers of the troposphere. 5. Lack of upper-air advection of cold air in the region of development of the V/b front. 6. Warm air masses present above the Mediterranean. 7. The 5,4 days period of atlantic cyclones and the 7,2 days cycle of the sudden advance of the pressure at the Azores should meet so that the phase of the 7,2 days cycle is somewhat preceding that of the 5,4 days period. 8. Gradual decrease in the velocity of an advancing western cold front accompanied by fall of pressure when approaching the eastern border of the Alps. 9. Fulfilment of Maletzka's condition of development of a Genova cyclone preceding the situation V/b. 10. Blocking of the Dévény pass by a cold air-mass advancing from the West.

AUJESZKY, L. : Forecasting of dew-formation. *Időjárás*, 60. 1. 1956. pp. 26—35. 11 figs.

It is pointed out that in spite of the known micrometeorological differences in dew formation it is possible to forecast in a general way whether there will be dew in the course of the following night, and even the quantity and duration of dew-formation may be foreseen.

OZORAI, Z. : Orographical occlusions in the Carpathian-Basin. *Időjárás*, 60. 6. 1956. pp. 329—341. 10 figs. 6 tables.

After the inrush of strong northern cold fronts an orographical occlusion is forming in the Carpathian-Basin. In order to study this process, synoptical conditions between February 16 and 23, 1954 have been thoroughly examined. The mechanism of formation of an orographical occlusion has been clarified from different points of view, e. g. sea-level charts, upper air data, the general climatic features of this country, the annual distribution of occurrence of the phenomenon. The final conclusions are enabling a more reliable estimation of some weather situations and leading to more elaborate forecasting procedures.

AUJESZKY, L. : Synoptical aspects of a planned regular forecasting service in medical meteorology. *Időjárás*, 60. 6. 1956. pp. 365—375.

The synophtical foundations for a planned regular forecasting service for medical meteorology are dealt with.

DÉSI, F. : On virtual temperatures. *Időjárás*, 60. 2. 1956. pp. 114—115.

Two formulae of virtual temperature are generally used. One is giving virtual temperature as a function of common temperature, atmospheric pressure and vapour pressure, the other as a function of specific humidity. The mathematical relation between these two formulae is analysed.

DÉSI, F. : Pressure distribution and vertical motion. *Beszámolók*, 1953. pp. 237—240.

The values of vertical gradient of momentum are derived from the continuity equation and the equations of movement of Guldberg-Mohn, and Ertel, respectively. The importance of the regional determination of the friction coefficient is emphasized, particularly as for Hungary. This factor is very important in forecasting thunder-storms and for studying the alledged influence of shelter belts on the amount of precipitation.

V. Aerology

Aerological activity of the Meteorological Institute in the decades before World War II was chiefly consisting of upper wind measurements once or perhaps twice a day with pilot balloons, and of the survey of atmospheric conditions carried out during the international days by means of balloon sounding. In spite of the adventure of systematic radio-sounding in other countries during World War II, it was — in consequence of economical and other difficulties following the war — only at the end of 1949 that the Hungarian meteorological service became able to join in this cooperation. Radio soundings were carried out every second day between December 1949 and September 1950, and daily during 1951—1952, whereas the soundings twice a day, recommended by the Meteorological World Organization, could be implemented since February 1953.

One of the chief aims of aerological research has been in the past three years to carry out high-altitude atmospheric observations by means of balloon pilot measurements and radio soundings ; another aim consisted in the study of individual weather situations.

According to this program, aerological ascents have been transferred from the Meteorological Institute, situated in the interior of the city, to a newly built Aerological Observatory which — being more favourably sited outside the urban area — is now carrying out the measurements.

Thus, in the past years two radio soundings have been executed daily from the Aerological Observatory at the internationally determined times of 3,00 and 15,00 GMT, and, according to international agreement, at 00,00 and

12,00 GMT as from April 1, 1957. A mean altitude of 11,4 (1951), 10,8 (1952) and 9,8 (1953) km has been reached in the first years with sounding instruments and rubber balloons, both made in Hungary, whereas the average height of soundings rose in the last three years to 13,7 (1954), 12,9 (1955) and 13,5 (1956) km. A similar rise is appearing in the number of soundings reaching higher altitudes.

Although a definite improvement as to the height of soundings has been statistically shown in the course of late years, the heights attained are, however, not yet satisfactory, especially if taking into consideration the tasks and increased claims in connection with the International Geophysical Year.

The number of upper-wind measurements has, in late years, changed as well significantly, according to international obligations and the exigencies of scientific research. Whilst upper-wind measurements were made, after the war, two or three times a day, there have been carried out in late years, with the development of the demands of scientific research, 8 to 10 pilot measurements a day. The number of pilot measurements rose therefore in the course of the five years between 1951 and 1955 from 1500 to 3100 a year. In December 1955 we started — according to the synoptical observation times — to carry out upper-wind observations regularly every three hours, i. e. eight times a day; the number of these observations became in the following years constantly about 2800.

The particularities of the Carpathian Basin are implying the study of upper-winds on aerological stations the site of which must be determined by orographical conditions. The eight upper-wind measuring stations in the lowlands and mountains of Hungary carrying out twice a day pilot balloon ascents have been chosen in accordance with this requirement. This network is particularly suitable for the study of air flow conditions in the basin surrounded by mountains.

Aerological data are published every year in a separate Yearbook of the Observatory. This publication is containing in its aerological part all soundings and upper-wind measurements made at Budapest, as well as the pilot observations at the seven country towns. Besides the publication of measured data a great number of summarizing tables is added. The tables summing up the upper-wind data give the average distribution of the velocity and direction of the wind at the different main geometrical levels in the course of the year. These summarizing procedures have been carried out on data of the highest morning-, noon-, evening- and night-ascent of Budapest and on the highest daily pilot-measurements of the other stations. The tables containing summaries of radio-soundings are including monthly and annual average values of geopotential, temperature and dew-point of the principal isobaric surfaces as well as the monthly and annual mean values of pressure, temperature and relative humidity on the chief levels of geopotential.

The following publications of late years deal with the results of research :

Béll, B. : Practical application of the notion of thermal wind. *Beszámolók*, 1952. pp. 214—225. 6 figs.

A formula for practical computation activities is deduced by means of which the distance from each other of relative isohypses drawn at intervals of 40 gpm may be computed from the value of thermal wind component observed over Hungary on a chart with the scale 1 : 20 000 000. The distance from each other of the absolute isohypses drawn at intervals of 40 gpm may be obtained from the effective wind in similar manner. Advection itself is obtained from the simultaneous plotting of relative and absolute isohypses.

Bucsy, J. : Method of construction of vertical cross-sections and their application for computing circulation. *Beszámolók*, 1952. pp. 226—245. 10 figs.

The first part deals with the method of construction of temporal and spatial vertical cross-sections, developed by the Hungarian aerological service. The second part is discussing how the quasi-static part of the acceleration of circulation may be determined out of the number of thermodynamic solenoids on the basis of isoterms drawn on vertical cross-sections ; these are formed by the isolines of air- and equipotential temperature. A table illustrates the value of solenoids limited by the isotherms drawn with different densities.

Mrs. Békeffy, J. : Ascent velocity of a rubber balloon filled with hydrogen. *Beszámolók*, 1952. pp. 246—256. 1 fig.

After having discussed the theory of a balloon rising in the free atmosphere, author is studying the effective ascending velocity on the basis of the launching of 60 radiosondes to an altitude of 14 km. In a figure the mean velocity values are given for different altitudes. Comparing these empirically deduced velocity values to theoretically determined ones, it is found that ascent velocity can be considered as uniform but until the middle of the troposphere, whereas in the upper part of the troposphere and in the stratosphere it is decreasing. The reason for this decrease seems to be found partly in the temperature difference between filling gas and the surrounding air and partly in other effects depending on quality, material and production of the balloon.

Hille, A. : Clouds and flying. *Beszámolók*, 1952. pp. 264—271. 1 fig.

The meteorological physicist, when giving briefing information to the pilot in a weather situation in which low clouds are involved, needs the data on the altitude of the bottom and the top of the cloud-deck, as well as on the possible stratification of the cloud. It is the question how far the data obtained from pilots can be employed for this purpose. Visual observations seem to be absolutely necessary and the help of meteorological flights is in this case indispensable.

Tardos, B. : The influence of the vertical structure of the atmosphere on the efficiency of aircraft. *Beszámolók*, 1952. pp. 278—284.

The structure of the atmopshere is such that the gliding ratio of aeroplanes is decreasing with the increase of height. In using the international standard atmosphere, and by means of daily radiosonde-data it is possible to compute in practice the decrease of gliding ratio in different altitudes. Two numerical examples are given.

Mrs. Békeffy, J. : Lability tests. *Beszámolók*, 1953. pp. 250—262. 6 figs.

Discussing the work done by H. Faust and A. Similä on practical application of the values of lability energy, rainy situations in Hungary between April and September 1953 are examined and it is stated that the lability values of Faust and Similä are leading to far-reaching conclusions in thunder-storm forecasting.

Béll, B. : Computation of thermal advection from upper air charts and by means of upper wind measurements. *Beszámolók*, 1953. pp. 263—269. 6 figs.

The actual numerical value of thermal advection may be found by a thermobaric field representation on upper air charts. Thermal advection may, on the other side, be computed from pilot-balloon ascents as well. A quick method is introduced for the determination of the numerical values of the wind vector and of thermal advection.

BUCSY, J. : Forecasting of the variation of temperature in the forenoon on clear days by using radiosonde ascents made at night. *Beszámolók*, 1953. pp. 270—282. 8 figs.

The following data have been graphically computed on the basis of radiosonde ascents carried out on 92 clear days in the course of the years 1950, 1951 and 1952: representative points in the daily temperature curve, numerical values of the energy available for the process of warming (in Joule/kg units) and the height of convection. The monthly curves thus obtained of temperature variation in the late morning hours are applicable for the purpose of forecasting. The times for reaching given values of energy (50, 100,150, 200 Joule/kg) are indicated. It may be seen as a secondary result that a double wave is characterizing the annual variation of time of occurrence : two minima at spring and in autumn, one chief maximum in winter and one secondary maximum in summer can easily be determined.

HILLE, A. : Reference numbers for atmospherical conditions of airports. *Beszámolók*, 1953. pp. 290—293.

An attempt is made to attach to one single number the frequency values of the elements of one small region ; this number may serve as an index for the suitability of a given territory as the location of an airfield.

TARDOS, B. : Icing of high-speed aeroplanes. *Beszámolók*, 1953. pp. 294—300.

At the extremity of the bow of high-speed aircraft the temperature is found to increase as a consequence of impact pressure. There is no icing at this spot even at very low air temperatures. At a certain air speed, there cannot occur icing at all.

BÉLL, B. : Operative methods for the determination of temperature advection. *Időjárás*, 57. 1953. pp. 350—359.

In the first part a practical method is discussed for the determination of thermal advection on the basis of the thermobar representation on upper-air charts. It is known that the rate of advection is reciprocal to the area of the so-called advection quadrangle defined by the relative isohypses of an air-layer limited by isobaric surfaces and by the absolute isohypses of the isobaric surface that is situated in the middle of the layer. As a unit for this area a square may be applied the side of which is one longitude degree on the generally used chart of the scale 1 : 20 000 000. A diagram is illustrating the variation with geographical latitude of the factor of proportionality (K) serving for the computation of advection expressed in units degree per day. The second part deals with a simple method for the computation of thermal advection by means of upper wind measurements. The proposed graphical equipment is suitable for a quick computation of the termal wind component and advection.

BUCSY, J. : Auxiliary tables for the interpretation of upper wind measurements. *Az Országos Meteorológiai Intézet kisebb kiadványai*, No. 24. Budapest 1953.

After a short historical introduction a new method for the plotting of upper wind observations is proposed which could be described as the single-ruler method combined with use of tables. It can be used rather quickly and reliably for plotting the results of all upper wind observations, for measurements carried out by means of the simple pilot-balloon as well as for those made by rawind equipment having changing ascent velocities. The precision achieved is — by its use of already tabulated numerical values — surpassing the reliability obtainable by earlier graphical methods.

BÉLL, B. : Advective atmospheric changes during frost situations in the month of May. *Beszámolók*, 1954. pp. 16—25.

The advective processes occurring at different altitude levels and causing the formation of great frosts in May 1952 are discussed. This weather situation is found to consist of three different periods. In the first period there has been (beginning with May 9) a process of advective warming until an altitude of 2—3 km above Budapest, whereas the higher layers were showing an advective cooling. The instability thus produced gave rise to abundant thundery rains in Hungary. The second period (May 16—17) is characterized by a cold front rushing in from Greenland. The plotted advective isallotherms are differing from the actually occurring isallotherms. This discrepancy can be explained by a translation effect. The third period (May 17 and 18) is characterized by the inflow of still colder air-masses. Atmospheric humidity is used as a parameter of advective processes. In frost forecasting a special criterion is offered in the advancement of the isogram of 4 g/kg, approximately corresponding to a dew-point of zero degree. Finally, the close relation between atmospheric processes are pointed out, appearing in the influence of temperature advection on the water-balance and of humidity advection on the heat balance.

MRS. BÉKEFFY, J. : Investigations of lability. *Beszámolók*, 1954. pp. 202—219.

Studies of the author on lability are continued in this paper. The theory and practical application of the layer- or convective cell-methods are dealt with, determining stability and instability conditions of the air by means of the acceleration of circulation. Comparing the results obtained by the use of the two methods, the situation of June 30 and July 2, 1954 has been discussed, and finally confronted to results obtained by the elementary particle method.

TARDOS, B. : A new derivation of the value of the dry adiabatic lapse rate. *Beszámolók*, 1954. pp. 220—221.

Starting from the principle of the conservation of energy and considering the kinetical energy term, a new deduction is given of the formula for the dry adiabatic lapse rate. This deduction is simpler than the earlier have been and gives new points of view, besides it is dealing with the dependence of dry adiabatic lapse rate on the velocity of a rising air current.

BÉLL, B. : Climate of the troposphere in Hungary. *Az Országos Meteorolágiai Intézet kisebb kiadványai*, No. 28. Budapest 1954.

Average values of temperature, air-pressure, humidity and wind are given for individual levels of the troposphere, their variations in the course of the year and along the vertical, the dispersion of measured values and the general behaviour of these elements experienced in the troposphere are described on the basis of measurements carried out in Hungary. The upper wind observations of the years 1927—53, respectively, the results of radiosonde ascents made in the years 1950—53 are treated, whereby these latter are considered until the limit of the troposphere. The statistical results are summed up in 37 tables and 45 diagrams.

BÉLL, B. : Stratification of the troposphere. *Beszámolók*, 1955. pp. 250—259.

The stratification of the troposphere is discussed on the ground of radiosonde observations and pilot surveys carried out in Budapest in the years 1950—53. The different strata of the troposphere are dealt with on the basis of a climatological approach. The fundamental layer found by Schneider-Carius is demonstrated in the vertical distribution of lapse rates. It is possible to distinguish from a consideration of the annual amplitude of temperature a radiating layer, characterized by an amplitude decreasing with height, then a layer with the amplitude increasing with height (from 3 to 7 km altitude) ; above this layer there is one with an amplitude decreasing again upward. The stratification is partly depending on circulation, partly on the variations of the stratosphere. The mean values of relative humidity are indicating the most frequent cloud-levels in the lower troposphere. The average difference in wind-velocities at noon and at night is showing in summer the known discrepancy of daily wind variation on the earth surface and in altitude. The summer-type daily variation at the surface is observable until a height of 200—300 m. The change of wind-velocity according to height is permitting to make a distinction between several layers. Above the convective layer reaching until 3—4 km, the velocity of wind is rapidly increasing with height. The maximum wind speed found in an altitude of about 9 to 10 km during the winter and of 14 km in summer is a consequence of the appearance of jet streams.

BUCSY, J. : Upper air study of the rainy season of autumn 1952. *Beszámolók*, 1955. pp. 10—24.

The first part consists of a discussion of the points of view which could be of importance in the aerological treatment of a given rainy period. The scarcity of upper air data does not permit the application of purely aerological methods (method of one station), the second part of the paper is therefore discussing aerosynoptics of the season in question. Part three is proving by means of gradient winds determined for Budapest on the basis of altitude charts that the precipitations in the season in question are occurring with greatest frequency together with a SW-wind at every level until an altitude of 5 km. It is further found that during the advection of warm air-masses there has been a precipitation in 43%, during a cold-advection in 23% of all cases, whereas the percentage of cases of precipitation without advection has been 34.

BÉLL, B.: Participation of Hungary in the meteorological tasks of the International Geophysical Year. *Időjárás*, 60. 2. pp. 97—103. 1956.

The program for meteorology in connection of the International Geophysical Year is discussed on the basis of papers in the Bulletins of the WMO and the CSAGI, particularly those written by J. van Mieghem. The Hungarian program of the International Geophysical Year is dealt with in all details. Charts are giving information on the measurements to be carried out in Hungary in the course of the International Geophysical Year. The legend below the charts is illustrating this program in all its details.

BÉLL. B.: Aerological activity of Gy. Marczell. *Időjárás*, 60. 3. 1956. pp. 137—143.

The Central Meteorological Institute has decided to name the Aerological Observatory of Pestszentlőrinc after György Marczell, the first Hungarian aerologist who organized in 1913 the Hungarian aerological service and was directing this work until his death in 1943. He carried out valuable research in the field of meteorology and geophysics. The paper is discussing his aerological activity on the occasion of the inauguration of the Observatory.

VI. Ionospheric research

The study of the ionosphere as one layer of the atmosphere has been started in 1954 by the Central Meteorological Institute in the present Marczell György Observatory.

An experimental impulse sending and receiving apparatus has been set into operation at the beginning of January 1954. Its range of frequency varied between 2 and 10 MHz, its output between 500 and 800 watt, depending on frequency. Two vertical-level, distorted-rhombic aerials perpendicular to each other served as sending and receiving aerials, respectively.

The determination of the heights of layers was effectuated by an oscilloscope by means of the sine-curves of a reference audiofrequency-generator. The values of frequency could be read with a precision of $< 0{,}1$ MHz from the scale of the receiving apparatus calibrated by means of a laboratory signal-generator.

The equipment for ionospheric research produced by the Electromechanical Enterprise of Budapest has started its operation in February 1955 and is in use to the present day. The electronically connected sending- and receiving apparatus has a frequency-band of 1 to 20 MHz, the output is varying between 5 and 10 kW and the width of impulse is 100 or 200 microsec, respectively. It has two oscillotron indicators, one for the spectator and the other for photographing. The precision of height- and frequency-marks is assured by quartz-control.

In the period between January and May 1954 experimental surveys have been carried out at some round frequencies (3, 4, 6, etc.), afterwards values of frequency yield have been determined. Starting in July 1954, measurements were carried out every hour with the exception of 1, 9, 17 and 23 o'clock (GMT) and data of h'E, h'F_1, h'F_2 and foF_2 have been determined. Altitudes were given with an uncertainty of about 10 km, frequencies with a precision of 0,1 MHz. Results have been published at the start in 10 days' reports. These were containing, beside the above data, the curves illustrating the hourly averages of one as well as of ten days of the limiting frequency for the layers E and F, further some remarks concerning the same interval.

Starting with May 1955, there were published in the monthly reports numerical data and graphs of the hourly limiting frequency of the layers E and F_2, and the text became published *in German*, too. From October of the same year the inception times of storms in the ionosphere have been additionally reported, their intensity having been indicated, for the time being, in a scale of three degrees. In January 1956, percentage indication of storms in the ionosphere according to their sign has been started. Terminal frequencies of the layer E_s were measured and the limiting frequencies of the E and F_2 layers graphically reported by curves of different colours so far for each hour.

After having studied several foreign monthly reports, the Institute discontinued the graphical reproduction of hourly data and from April 1956 there have been only the hourly means of each month of the layers and, for the time being, the daily averages published.

In July 1956 our report has been drawn fully in conformity with international requirements. The following data are given besides a short Hungarian and German description, and the percentage report of storms in the ionosphere, according to their sign : tables of the hourly medians of $h'F_2$, foF_2 ; $h'F_1$ foF_1 ; h'E, foE ; fE_s (and from January 1957 of $M3000/F_2$), and, in further tables, the hourly values of the same data. Uncertainties and remarks to these tables have been marked with the corresponding international letters (according to URSI). There are yet the hourly graph medians for the above data in each month published in the report, as well as — but only in diagrams — the percentage frequencies occurring in the E_s-layer for 3, 5 and 7 MHz.

The monthly report is containing, besides, data of solar activity obtained by the Astronomical Observatory of Budapest, as well as provisional data of horizontal intensity obtained from the Geomagnetical Observatory of Tihany belonging to the Geophysical Institute Roland Eötvös.

Some problems in connection with ionosphere research, instrumentation difficulties and explanations of certain phenomena are dealt with in the following papers :

FLÓRIÁN, E.: Study of experimental ionospheric measurements carried out in 1954. *Beszámolók*, 1956. pp. 274—284.

Uncertainties are discussed which may occur in the measurement of layer heights in the ionosphere when the reflected signals are obtained in "A" indication by means of cathode-ray tubes. It is proved that there is no possibility — particularly in cases of repeated reflections and simultaneous occurrence of several layers, and principally when there exist, furthermore, a magnetical splitting of the waves — to have satisfactory measurements but with "B" indication and with the horizontal simultaneous displacement of the signals with frequency. In this manner it is possible to obtain an almost cross-section-like picture of ionospheric layers.

FLÓRIÁN, E. : Electrical properties and data of the atmosphere and their measurement in Hungary. *Időjárás*, 59. 1. 1955. pp. 34—41.

This account, prepared originally for the Scientific Council of the Central Meteorological Institute, is discussing data and explanations of electrical phenomena, known at present of the lower atmosphere the data on the ionosphere known from foreign literature, and the hypotheses in connection with the structure of the ionosphere. Ionosphere survey methods are outlined, as well as the practical advantages to be expected from meteorological and wave-propagation research.

FLÓRIÁN, E. : What happened in the ionosphere ? *Rádiótechnika* (regular column). 1956.

In every issue of this technical review, one full page is allocated to the more interesting phenomena experienced during the study of the ionosphere as well as to their explanation, with a peculiar emphasis on the propagation conditions of radio-waves.

FLÓRIÁN, E. Propagation of waves. A *Műszaki Könyvkiadó rádiótechnika könyvei sorozat*, No. 17. 1956. pp. 49—80.

The third part of this booklet is discussing the ionosphere, mean height- and limiting frequency data of each layer, their daily and annual variation, and the influences of the variations in solar activity, their application to the propagation of radio-waves. Some methods of the study are introduced. Data and illustrations of the observation method (24 figs.) are already of Hungarian origin.

REPORT ON THE GEOMAGNETIC AND TELLURIC RESEARCHES CARRIED OUT IN HUNGARY DURING THE PERIOD OF 1954—57

GY. BARTA
D. ENG. SC.

Geomagnetic researches are carried out in Hungary by the Geomagnetic Department of the *Geophysical Institute Roland Eötvös*, telluric current investigations by the Electrical Department of the same Institute as well as by the *Geophysical Research Laboratory* in Sopron of the *Hungarian Academy of Sciences*, and ionospheric researches by the Ionosphere Department of the *Hungarian Meteorological Institute*. The results of the ionospheric researches are to be read in the report presented to the Meteorological Association.

Activity of the Geomagnetic Observatory and magnetic measurements

Magnetic observations started in the Observatory of *Budakeszi* in 1948 were continued until October 1955. It was in November 1954 that the final *Observatory in Tihany* started its activity ($\varphi = 46°54{,}0'$ N, $\lambda = 18°53{,}8'$ E Gr). The two Observatories were simultaneously working during a whole year in order to make possible a precise reduction of the corresponding data. The normal-speed recording of the magnetic elements till now will be completed in the course of the geophysical year by high-speed recording of the magnetic elements and telluric currents.

A reconnaissance survey of the Great Hungarian Plain with a station interval of 1,5 km started in 1951 has been finished on the territory between the Danube, the northern highlands, the eastern and southern frontiers. On several places the survey revealed anomalies indicating covered eruptives.

In prospecting for ore we carried out detailed measurements in different areas of the country with 500—200 m, 50—20—10 m or even smaller intervals.

Experiments were made in connection with magnetometers of soft iron core, too.

Additionally the Geophysical Departments of the *University Roland Eötvös* in Budapest and of the *Technical University in Sopron* carried out earth magnetic measurements on a smaller scale.

The Association of Hungarian Geophysicists held conferences in September 23—24, 1955 and September 24—25, 1956 with the participation of foreign researchers in order to discuss earth magnetical problems.

Studies of telluric currents

The *Hungarian Geophysical Institute Roland Eötvös* carried out measurements over gravity anomalies in order to explore the deep structure of the Great Plain. Trial measurements were effected in the vicinity of the Magnetic Observatory in Tihany for the establishment of permanent recording of telluric currents.

The Geophysical Department of the *Technical University in Sopron* as well as the *Geophysical Research Laboratory of the Hungarian Academy of Sciences* is carrying out experimental measurements since 1952, chiefly for practical purposes, for the development and testing of measuring methods and instruments. Meanwhile certain results were obtained in connection with the interrelation of telluric currents and magnetic variation. The instruments constructed were also tested in 1956 on the territory of the People's Democracy of China. The measurements are well fitting in to the results of international researches of similar character.

HUNGARIAN EARTH MAGNETIC LITERATURE IN 1954—57

BARTA, GY.: A 40—50 years period in the secular variation of the geomagnetic field. (English.) Acta Geologica, Tom. IV. Fasc. 1, 1956.

The geophysical Observatory of Tihany. (Hungarian, with an English résumé.) Geofizikai Közlemények. Vol. V., Fasc. 2., 1956.

About the periodic variation of the gravity field. (Hungarian, with an English résumé.) Geofizikai Közlemények, Vol. VI., Fasc. 1., 1957.

About the secular variation of the geomagnetic field. (Hungarian, with an English résumé.) Geofiz. Közl. Vol. VI., Fasc. 2—3., 1957.

Variation of the geomagnetic field in the Carpathian Basin. (Hungarian, with an English résumé.) Geofizikai Közlemények. Vol. VI., Fasc. 2—3., 1957.

Geomagnetism. (A textbook Hungarian.) Akadémiai Kiadó, 1957. 17 sheets, 192 p.

EGYED, L.: A new theory of the internal constitution of the Earth and its geological-geophysical consequences. (Hungarian, with Russian and English résumé.) Földtani Közlöny, Vol. LXXXV., Fasc. 3., 1955.

EGYED, L.: The magnetic field and the internal structure of the earth. (English.) Acta Geologica, Tom. IV., Fasc. 2., 1956.

HAÁZ, I. B.—BARTA, GY.: Differences in the geomagnetic elements between the observatories of Budakeszi, Pruhonice and Ógyalla. (Hungarian, with Russian and English résumé.) Geofizikai Közlemények, Vol. III., Fasc. 11., 1954.

HAÁZ, I. B.: Effect of temperature in BMZ-measurements. (Hungarian, with Russian and French résumé.) Geofizikai Közlemények, Vol. IV., Fasc. 1., 1955.

HAÁZ, I. B.: Determination of the dip, density and susceptibility of an infinite inclined dike from its gravity and magnetic effects. (Hungarian, with Russian and English résumé.) Geofizikai Közlemények, Vol. IV., Fasc. 2., 1955.

Geomagnetic measurements in the area Felsőcsatár. Geomagnetic measurements in the Velence-mountains. Geomagnetic measurements in the area Uppony, Rudabánya and in the Bódva-valley. (Hungarian.) Geofizika az ásványi nyersanyagkutatás szolgálatában. (Geophysics in the prospection for minerals.) 1955.

TELLURIC LITERATURE IN 1954—57

ÁDÁM, A.: Ein neues tellurisches Messinstrument. (German.) Soproni Egyetem Közleményei, 1956.

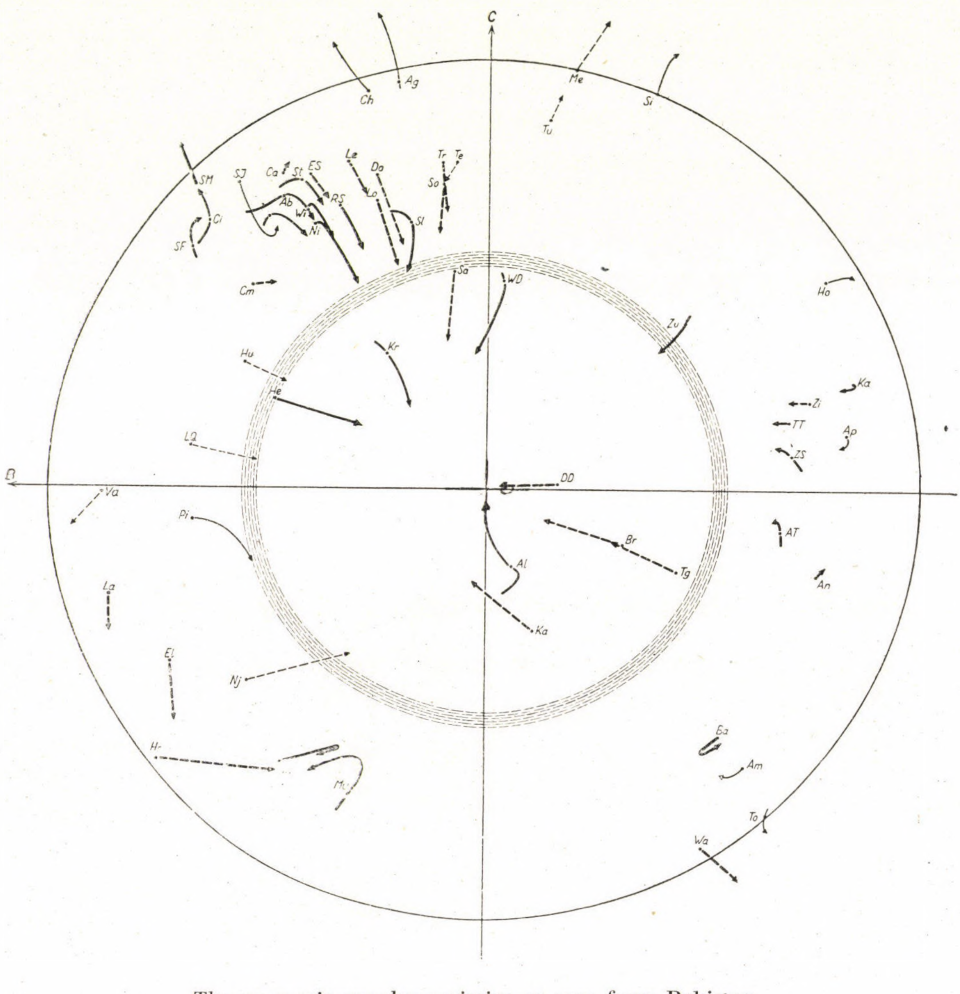
ÁDÁM, A.—EGERSZEGI, P. : Telluric currents and their practical application. (Hungarian.) Természet és Társadalom. CXV. Fasc. 9.
ANNAU, E.—ERKEL, A.—SZABADVÁRI, L. : Rapid variations of the Earth's magnetic field and their relations with telluric currents. (Hungarian.) Bányászati Lapok, 1954. Fasc. 10.
EGERSZEGI, P.—TAKÁCS, E. : Practical execution of telluric researches. (Hungarian.) Bányászati Lapok, No. 11. 1954.
KÁNTÁS, K. : Geoelectrical prospecting in Hungary. MTA Műszaki Tudományok Osztálya Közleményei. (In Hungarian.) Vol. V., Fasc. 1—2.
KÁNTÁS, K. : Results and perspectives of the Hungarian telluric researches. (Hungarian.) Bányászati Lapok, No. 12., 1954.
Results of the simultaneous measurements of telluric currents between Peking (China) and Sopron (Hungary) executed from 9th to 14th January 1956. (English.) Soproni Egyetem Közleményei, 1956.
Development in the newest geophysical research method : in the magneto-telluric. (English.) Soproni Egyetem Közleményei, 1956.
SEBESTYÉN, K. : Telluric current recording apparatus. (Hungarian, with an English résumé.) Geofizikai Közlemények, Vol. V., Fasc. 1., 1956.

Summary of the theoretical researches

G. Barta continued his researches on the secular variation of the geomagnetic field, after having determined that in the secular course at most observatories a superposed wave of a period of 40—50 years is detectable by means of approximation with power-polynomes, in all the three magnetic elements.

The representation with vector diagrams gave a deeper view of the structure of the phenomenon and showed that the space curve described by the end point of the magnetic field-vector is helically enveloping the approximating power curve as a result of the superposed wave (transversal effect); it also appears that the actual change as compared with the adjusted one is more or less late or fast, respectively (longitudinal effect). These results make obvious that the secular variation is — in spite of the many local characteristics appearing on isopor maps — a general process concerning the whole Earth.

A very clear picture of the phenomenon is obtained by means of converting the vectors representing the secular variation into a uniform coordinate system one axis of which is the axis of rotation of the Earth, whereas the two other axes are directed towards the points 291° E and 21° E Gr. of the Equator. The vectors orthogonally projected to the planes of this coordinate system show some regularities indicating that the symmetry center of this phenomenon is around Pakistan. Rotating now our coordinate system so that the center of the projected picture be in Pakistan, it can be proved that the vectors around the center of the picture are pointing to each other, while at the edges of the picture they are directing outwards. As a matter of course, the picture as well as the respective lateral views indicate an assumption that around Pakistan as a center a circuit is flowing which has a radius of about 3000 km in a depth of about 3000 km; the direction of this circuit is clockwise, as seen from Pakistan, its intensity being about 10^7—10^8 ampere. The secular variation is due to the change in time of the position and intensity of the circuit.



The magnetic secular variation as seen from Pakistan

– – – – the assumed eddy,
○ the magnetic center of the Earth.

(The course of observatories situated from the view-point is represented by a thick line, that of observatories situated opposite by a thin line and the courses of short-series observatories extrapolated to 50 years by a dotted line)

It is known that the magnetic center of the Earth lies excentrically towards the Marshall-Islands and its surface projection is moving towards N-NW with a velocity of 10 km/year. If we assume that the Earth's core is bearing the magnetism of the Earth, then this variation is equivalent to a motion of the Earth's core. This movement causes an increase of pressure and spreading out of material around a spot below Pakistan. If the moving mass is electrically charged, the resulting convection current may cause the secular variation of the magnetic field.

From the velocity of motion we infer that the magnetic center of the Earth revolves around the axis of rotation of the Earth in 4000 years which estimation is not in accord with the secular period of about 500 years of the long declination-series at London. But we may presume that the movement of the Earth's core is oscillatory with a period of 4—500 years. The precession of the axis of the eddy may cause the superposed wave, and the helical course observed in the secular variation. In order to unravel this complex of problems, further researches are in course.

G. Barta pointed out in a recent paper that the 50 years period found in the velocity of rotation of the Earth (Brouwer, 1952) may be attributed to the movement of the Earth's core in the interior of the Earth while the core is, according to Vestine, also bearing the cause of earth magnetism. A further consequence of the supposed re-arrangement of the masses is that the gravity field should have a variation with the same period. It is further obvious to assume that the main period of the secular magnetic variation itself is the result of a motion in the core with an according period and thus this variation has to appear in the variation of the velocity of rotation of the Earth as well as in the secular variation of the gravity field.

The writer proposes to examine the variations of the level surface of the gravity force in order to avoid technical difficulties in measuring the gravity field. Namely, the level surface may be determined and its variation followed even in the past with the help of the annual mean sea-level data measured at the thalattograph-stations.

The writer is simultaneously pointing out that in case of very accurate measurements attention must be paid to the gravity effect of the re-arrangements of masses connected with atmospheric processes.

L. Egyed developped a new dynamic theory of the internal constitution of the Earth. The theory has the basic assumption that the material in the core is in a degenerated state, where the nuclei forming the core and their electron-shells become independent from each other. Supposing that the elementary particles are arranged according to the direction of moment and summing up their magnetic moments, we may obtain a quantitative interpretation of the magnetic field of the Earth.

I. B. Haáz developped a method for calculating the position, dimensions and density or susceptibility of covered masses (inclined layers with gravity or magnetic effect) on the basis of the abscissae of the extreme values of measured anomalies Z and H, or on the basis of the extreme values of the anomalies.

He also worked out a simple evaluation technique of the temperature corrections for BMZ instruments.

K. KÁNTÁS theoretically investigated the potentialities of the introduction of a new branch of applied geophysics, the modified magnetotellurics, on the basis of the connections between telluric and magnetic field. Verification of the results of these investigations with model-experiments and field-surveys are in course.

HYDROLOGICAL RESEARCH IN HUNGARY

COMPILED FROM REPORTS OF THE HUNGARIAN RESEARCH INSTITUTES FOR THE 1957 TORONTO CONGRESS OF THE INTERNATIONAL GEODETIC AND GEOPHYSICAL UNION

Prof. E. NÉMETH
D. ENG. SC.

Struggle for existence has induced humanity to interfere with the order of Nature. Due to this, the accessible phases of the hydrological cycle were at first modified by isolated, local establishments, later on by large-scale, contiguous projects of ever widening scope. With regard to the reaction of these operations upon the evolution of Society two conclusions can be reached at. Firstly that hydrological organizations being charged with tasks of increasing number and difficulty, the latter may be satisfactorily solved, regarding the close and manifold interrelation of the problems, only by large-scale *water economy planning*. Secondly, it is found that water economy plays a highly important part in the economical and social life of every country. It follows readily therefrom that in operations of this kind and scale the dual principle of security and economy must prevail to a full extent.

Interference with the order of Nature thus involves a huge amount of responsibility and that is why, in the course of water economy planning, it is necessary to get acquainted with the meteorological and hydrological circumstances of the county, country or countries involved, so as to project successfully the necessary establishment, its dimensions and expectable reactions. For this purpose, a large number of reliable meteorological and hydrological data, encompassing longer intervals of time will be necessary, because hydrology fails to be governed by formulae or precepts applicable in any case : on the contrary, there are only general principles that must not be applied except after careful consideration of local circumstances. *Every river, every water reservoir or subterranean aquiferous layer has a strong individuality of its own, the present condition of which is the result of a past we can fathom only after thorough investigation. In lack of knowledge about this past, it is impossible to predict the future and least in all the reactions to artificially induced changes.*

It is clear that in the course of evolution from isolated local waterworks to large-scale hydrological operations, the mode of accumulating the data characterizing the hydrological cycle will also change, and the development of sporadic observation posts into a country-wide network has to take place. On the other hand, the organization of suitable scientific institutions for the evaluation of data will be necessary. *The development of the network of observation posts and scientific institutions is clearly a function of the social and economic evolution of the country, so that beside the effects of the geographic environment historical forces will also be acting.*

The general considerations described above have been valid in full measure during the evolution of Hungarian hydrologic activity. Regrettable historical circumstances have brought about a series of national catastrophes, every one of which has caused serious setbacks in the thriving of our country. It is sufficient in this relation to point out the devastation by the Tartars in 1240—41 and the subjugation by the Turks of 150 years' duration. In the periods of peace the Hungarian people has exerted tremendous efforts to reach a new blossoming of the country, thus giving evidence of an all-resistant vitality. This is valid also for the realm of water economy, where our country has several times made her way to the foremost ranks of countries living in peace and sometimes initiated ideas much in advance of their time. The great economic reformer of Hungary, Count I. SZÉCHENYI has borne in mind around 1840 a water economy plan the same or even greater in dimensions than those realized in the last decades by the most advanced great countries : the genius of Széchenyi has a century before delineated a general hydroeconomic programme of the Carpathian Basin that can be even at present regarded up-to-date. Although the Hungarian people could not, after the defeat in the War of Independence of 1848—49, realize this plan, but after half a century our country is found again in the vanguard of flood protection and drainage work.

It was in the year 1914 that the logically first task of water economy, the defense against flood and stagnant water damage was completed to its greatest part, so that it became possible to commence preparations for water utilization (irrigation, water-power). The compilation of hydrological data was well under way and the preliminary plans were already drawn, when the outbreak of World War I has torn the possibility of realizing this enormous plan out of the hands of the Hungarian people.

Thirty years later the building of extended irrigation work was buried under the ruins of World War II. After clearing away the ruins, and even meanwhile the Socialist state exerted efforts surpassing all former ones in all branches of hydrology, and a perspectivic general water economy plan of great scope was also prepared after the careful hydrological evaluation of data yielded by an up-to-date observatory network. It is the fervent wish of our peace-loving people to be able to realize this plan at last.

In the following we will endeavor to describe the past and present of Hungarian hydrologic activity according to the phases of evolution delineated above. The work of the last three years will be separately dealt with in accordance with the three-year cycles of the U. G. G. I.

I. Evolution of hydrographic research up to World War I

1. The beginnings of hydrographic researches

The most ancient description of Hungarian waters is found in the Latin chronicle of the anonymous Clerk of King Béla III, entitled *Gesta Hungarorum*, written in 1160 to 1180. The chronicle contains beside the history of the Conquest of Hungary also the most ancient geography of the country. Even people far richer in historical documents cannot boast richer hydrogeographic material in a text almost one thousand years old. The chronicle gives the list and sometimes also more detailed descriptions of the boundaries, defended frontier regions, woods, mountains, rivers, lakes, swamps, fords and settlements of ancient Hungary. Richest of all is the hydrographic material, containing the description of more than 50 rivers, 9 lakes, some swamps and a great number of fords. The names of rivers and lakes are in most cases identical with, in others scarcely different from, the ones used to-day. Beside the great rivers Danube, Tisza, Drava, Save, smaller ones, even some quite insignificant creeks, are listed. Lake Balaton is described as a river. Mention is made of some swamps that have been drained long since.

After some centuries, the discovery and exploration of the scientific results of antiquity and their further development in the Renaissance has led to a blooming of natural science in all Europe, including our country. Science was mostly cultivated in the schools ; some of the most ancient of them were the University of Pozsony, opened in 1467, the Sárospatak College, founded in 1531 and the Gyulafehérvár and other colleges in Transsylvany. The map of Transsylvany was constructed around 1540 by Honterus, the author of a number of books on natural history, physical and descriptive geography, all in Latin. As is common in Europe, the first independent books and detailed descriptions on physical geography appear with the XVII. century also in Hungary. One of such books is the "Medulla Geographiae Practicae..." by D. Frölich around 1640. These geographical descriptions invariably contain more or less hydrographical elements.

An abstract of all sciences was first offered by the "Hungarian Encyclopaedia" by J. Apácai Cseri in 1653. (Hungarian Encyclopaedia, or the Neat System of all True and Useful Wisdom edited in the Hungarian Tongue by J. Apátcai Tsere. Utrecht, the Workshop of Johannes Waesberg, 1653). The scientific statements of this work are based upon the most advanced ideas of the time, those of Descartes. Thus e. g. the phenomena of the hydrosphere are explained on the hand of the Cartesian atomic theory. It is remarkable that Apácai does not regard the surface of the Earth from the static point of view : on the contrary, he speaks of the evolution of the same and attributes a certain part of surface development to the erosional effect of waterflows. ("Thereafter new mountains were formed out of the tremors of the Earth, which have lifted up the same most intensely, and even from large outbreaks of the waters which hawe devoured and taken away some parts of the Earth." (Part 7., II/7.) The polymathic physical geography of M. Szentiványi (Curiosora et selectiora variarum scientiarum Miscellanea, Nagyszombat 1687) contains a chapter entitled Hydrography. It points out the rise and fall of the sea level, the streams directed from the poles towards the Equator, correctly explains the colour of the Red Sea and states that the same is influenced by wind intensity.

In the first half of the XVIII. century physical geography took further advances in Hungary. However, as it was the case in the XVII. century, foreign influence remained intense and specifically Hungarian ideas were scarce. Geography was read in a random manner at colleges and universities, in most cases together with natural history, e g. at the University of Nagyszombat. Of the multitude of names that of J. A. Segner is to be mentioned. The noted natural scientist, the inventor of the Segner-wheel first taught in *Debrecen*, then in *Jena*, *Göttingen* and *Weimar*. He has also published several books on physical geography, in Latin. — The lectures of *M. Bél* inspired by a scientific way of thinking and by the idea of evolution.

The first physical geography in Hungarian was written by J. Molnár : "On the Phenomena of Nature after Newton. Six Books. Pozsony and Kassa, 1777". In 1771, J. Horváth points out correctly that precipitation has to be firstly considered when enquiring into the origin of springs. Of the Latin manuals that of Tomka and Száky is the most widely used throughout a long time.

At the end of the XVIII. century we note an important change, namely that Hungarian physical geography becomes, through the application of the ever widening material of related disciplines, a pragmatic science with new, positive ways of thought. This new progress is also observed in the work of two excellent geographers at the beginning of the XIX. century, Varga and Katona, who published, among others, also a great number of independent hydrological observations and ideas.

Although M. Varga and M. Katona have been the first to represent integral (hologaeic) geographic science, even prior to the work of Humboldt, their names have remained unknown before the world, as their works were published in Hungarian only. Both of them are regarded as ranking among the best Hungarian geographers of all times, being the founders of specifically Hungarian physical geography.

The book of M. VARGA was published in 1808 in Nagyvárad. According to its author the surface of the Earth's stable crust is moulded by the scouring activity of rivers, weathering by frost and insolation, and the erosive work of rain, snow, wind and waves. Thus he pointed out among the first in the world the activity of exogeneous forces.

His work exerted a great influence upon his contemporary, M. KATONA, whose posthumous book entitled "Common physical geography" appeared in Pest, in 1824, 24 years prior to Humboldt's book "Kosmos". The author expounds in detail that the changes of the terrestrial surface are results of the composite action of internal and external forces. Springs are classified as permanent and temporary ones and the volcanic origin of geysers is pointed out. Springs and waterflows are said to derive from precipitation. The subterranean waterways postulated by Descartes and Varenius are refuted.

M. VARGA and M. KATONA can be regarded as the pioneers of the idea of fluvial erosion. They had propounded the erosional origin of river valleys 50 years before RÜTIMEYER and BEETE JUKES and taught this in a time when neptunists regarded valleys as the imprints of the deluge, plutonists, on the other hand, as breaks of the terrestrial crust.

Katona has written in 1824 on fluvial erosion as follows : "the watercourses, as long as they flow between hills, adapt themselves to the windings of the same, whereas on the plains they dig their beds themselves. They dig into the earth deep and wide, as long as their forces become equal to the resistance. Hence the manifold snakelike wind of watercourses"... "Lower terrains are filled up by stream water." Consequently, Katona was avare of the erosive and filling activity of rivers as well as of incisive and lateral erosion. On karstic erosion he wrote : "The inner parts of the Earth contain many holes and cavities, most of them being found in limestone mountains, as parts of the latter are most readily dissolved by water."

KATONA taught that the strength of stream water depends a) on the "muchness", b) on the velocity of the same. Velocity he considered to depend on the slope and the pressure of water· Therefore, the same effect may be attributed to a river of smaller discharge flowing down a more inclined slope and to an abundant river down a slighter slope. He also stated that "the velocity of rivers is commonly greater at the middle than at the shores". He considered valley gorges the results of torrential erosion.

With Katona ended the period of hydrography based solely upon geographic description and in the XIX. century the first hydraulic engineers appeared who looked at the hydrographic properties of the Hungarian country with active interference in mind. The first purpose of their activity was to improve the water economy of the Great Hungarian Basin.

The *Great Hungarian Basin* in the centre of the Carpathian Chain is a plain of roughly 100 000 sq. km, formerly systematically inundated by floods. The area lorded by the floods of the Danube, Tisza and other larger rivers can be estimated to round 38 7000 sq. km, and 22 900 sq. km of this area was covered by *permanent* swamps. Under such circumstances the basic condition for the development of agricultural production, for the evolution of an up-to-date transportation network : in short, for prosperity both cultural and economical was the creation of works of defence against water damage ; the building of flood prevention dams along the rivers of the plains, the drainage of swamps, river regulation to facilitate the downflow of floods and winter ice, the construction of channels to drain excess stagnant water of parts of the plain and the construction of pump stations, etc.

However, as the country was for several centuries an eastern outpost of Western culture against Osmanli imperialism, waging at the same time a series of wars against Habsburg oppression, thus being the scene of almost continuous battles, the great swamps were advantageous to some extent as bulwarks of defence. Therefore drainage work of greater extension was only commenced in the XVIII. century. The hydrological activity, one of the largest-scale ones in the world, of course necessitated the collection of hydrographic data. This is the reason why Hungarian hydrographic research can look back to such a rich past. The beginning in 1782 of the systematic education of engineers at the *Institutum Geometric-Hydrotechnicum* [1] has also contributed to this evolution. — It was the merit of the excellent Professor of the University, K. HADALY (1743—1834) to have written the first Hungarian book on hydrology [2].

To commence with great hydraulic works, a systematic hydrographic survey was first of all necessary. As a matter of fact, a detailed map of the Danube has been prepared much earlier (1699—1726) by the General FERDINAND A. MARSIGLI entitled "Mappa generalis in que Danubii Fl. Caetium Montem inter et Bulgariae Flumen Jantram intercepti Tractus integer in subsequentibus XVIII. sectionibus divisim specialissime exhibendus representatur". — However, this map, although showing the detailed ground plan of the river before regulation, was constructed for military purposes and lacked some important information as regards river regulation. There were also maps prepared for civilian purposes, such as the one of S. Mikoviny on the Csallóköz and on part of the river between Pest and Baja, made in 1735 to 1750, further the map of the engineers Ruttkay and Balla from 1766 on the river beach between Pomáz and Szentendre. These did not, however, comprise the entire Hungarian section of the Danube and therefore could not serve as bases for a comprehensive plan of regulation. On the other hand, maps of the Tisza and other rivers were completely lacking. Therefore, in the course of the "Danuba Mappation", enacted by law in 1814, comprising 900 kms of the course of the river, not only situation plans were drawn (2535 map segments to scales 1 : 3 600 and 1 : 7 200) but also cross- and longitudinal sections (determined) (362 and 119 drawings, respectively) and, moreover, efforts were made to delineate the regimen of the stream. The first water gauges were established from 1823 on in connection with this work; the observers had to note beside water stages also ice conditions in winter-time. Upon this time fell the first measurements of water discharge with the Woltmann propeller as well as the determination of the first water discharge curves. It was in the course of this work that the rope-suspended Woltmann propeller was used first in the world, and on the hand of these results could P. Vásárhelyi express in 1845 the opinion that the velocity distribution along verticals may be represented by a vertical-axis parabola [3]. The widely known measurements of Humphrey and Abbott on the Mississippi were published only 16 years later, in 1861 [4].

The survey of the Tisza river was carried out between 1833—46 with similar thoroughness (1026 map sections to scale 1 : 7 200, 1896 cross- and detailed longitudinal sections).

For the sake of completeness we mention the monograph of Professor Arenstein on the ice conditions of the Danube between 1847 and 1850, which served as an example for the collection of ice data decreed for the entire Habsburg monarchy in 1850 [5]. The first observations on ground water were made in 1864 [6]. The first series of water temperature measurements date from 1866 [7], the most ancient analyses on the chemical composition and suspended load of Danube water from 1872 [8].

As regards hydrometry, it has to be pointed out that the bifilar suspension of the Woltmann propeller [9] as well as the integrating measurement along verticals were first used by the Hungarian J. Révy in the course of the hydrographic survey of the Paranà River in 1870—71 ; and further that I. Horváth, Professor of the Technical University of Budapest, was the first to use an electric registration apparatus in his flood velocity measurements on the Danube, March 1876 [11]. We have to record finally, that J. Kvassay, the organizer and head of Hungarian hydraulic engineering service also contributed to the development of hydrometry with a theoretical paper published in 1877 [12].

2. *The activity of the Hydrographic Department (Vízrajzi Osztály)*

The hydrographic work and observations described in the chapter above were partly carried out by the river conservancy service, partly by individual workers most of them professors of the Budapest University. It may be stated especially concerning the latter category that although some of it was doubtlessly highly important pioneer work, it gave no more than fragments of information as to the hydrography of the country and by no means could substitute systematic and organized hydrographic survey.

It was by the 1879 and 1881 floods of the Tisza River that attention was called to the necessity of such organized hydrographic work. The first of the floods swept away the great town of Szeged, the latter one inundated 225 000 hectars of land. The government resolved to establish a central bureau of hydrography to further the work of river regulation. This bureau commenced work in 1886 as the Department of Hydrography of the Ministry of Traffic and Public Works.*

*Its name was changed in 1891 to "Department of Hydrography of the Ministry of Agriculture", and later, in 1931, to "*Institute of Hydrography*". This name remained until 1952.

The purpose of the institution was "to collect the data necessary for river regulation, flood prevention, water utilization and shipping, to measure lacking hydrographic data and to evaluate and publish above named", and further "to determine all of those factors which influence the alteration of river beds, as well as their interrelations, so as to supply complete information about the nature and functions of our rivers and the laws to which they are subject" [13].

Hydrographic institutions of the same scope and scientific programme were exceedingly scarce at that time. The first hydrographic organization of the world, the Service Hydrométrique du Bassin de la Seine (1854) was restricted to the study of a single drainage area. There were no more than four countries possessing all-comprising hydrographic institutions, namely Switzerland (1870), Russia (1874), Bohemia (1875) and the Grand Duchy of Baden (1883).

At the time of organization of the new institute there were 140 gauges observing water level conditions. One of the first things to be done was to organize a more close-spaced network of water level and precipitation observation posts together with the telegraphic reporting of observations (1889). Telegraphic reporting comprised beside the data of more important water gauges also ombrometric data and the values of air temperature at the time of the spring snowmelts [14]. Data were published up to 1898 in tabulated form, thence daily on lithographed maps. The "Daily Water-level Map" is a special bulletin, the 64. volume of which is under publication at present. It shows in map form the morning water stage conditions of the Danube and its tributaries as well as the precipitation of the last 24 hours, the thickness of snow cover and the ice condition of rivers in the winter and air temperatures in the spring ; it gives the data of shipping waterways (water depth at fords, bridge clearances, etc.), the meteorological and hydrometric forecasts and — for the sake of comparison — the highest and lowest water levels hitherto observed at the individual water gauges. The map is constructed on the hand of telegraphic information arriving in the morning, mimeographed around noon and delivered to the interested agencies in Budapest in the early afternoon. The organizations in the country obtain the map per post. (In 1920 to 22 the maps prepared by the Hungarian Hydrographic Service were edited with French captions by the Allied, later International Danube Commission. The Yugoslav and Roumanian Hydrographic Services edit entirely similar maps since they have been established around the twenties. In 1944 the Hungarian example was also followed for some time by the Viennese Directorate of Waterways).

Another important task was the realization of flood forecasting. In order to establish the necessary references, the water stages observed in the last 10 years on all water geuges in the country were transformed into the metric system and published in print. This has been done every year since and thus the complete observation material of the Hungarian water gauges is accessible in print since 1876 : this is another feature not many of the European countries can boast of. The method of flood forecasting was elaborated by the first Head of the Hydrographic Department, J. Péch [15]. In 1889 the prediction of the crest of floods one to eight days in advance has begun on the basis of telegraphed reports. In the 'nineties forecasts for 24 to 48 hours were regulary published for 20 of the Danube gauges and studies were under way concerning long-distance forecasting. Thus the relation between winter precipitation and the spring floods of the Tisza were investigated by Ö. Bogdánfy. The same author has written the first Hungarian monograph on hydrology and also a handbook on the hydraulic investigation of natural streams [16].

It was also in 1889 that the developing of a network of levelling bases for the Hydrological Department has begun. To determine the altitudes of 613 first-order level bases along the main streams 4016 kms of high-precision levelling were carried out up to 1896. The average error per kilometer was computed to be $\pm$ 0,56 mm [17]. This network was completed by the secondoder levelling of the pairs of so-called profile stones, designating the localities of reference cross-sections of the rivers. The points described above serve as bases for the detailed re-surveying of the rivers, carried out at repeated intervals by the Hydrographic Service.

The detailed map of the Tisza River with 1 : 25 000 scale situation plans, 1 : 20 000/1 : 100 longitudinal and 1:1 000/1:100 cross sections, containing besides the data of the mapping of 1889 to 1891 those of the first detailed survey of 1834 to 1841, was published from 1898 to 1902 in a multicolored edition. (A second edition, corrected after the data of the 1929/31 survey, was given in 1935). The detailed 1 : 25 000 and 1 : 5 000 ground plans and cross and longitudinal sections of the Danube were edited 1905 to 1915 by the Hydrographic Service, on the basis of the 1899—1908 survey. A 1 : 150 000 bathymetric chart of Lake Balaton was prepared in 1894/95. Of course there is a much richer manuscript material of continnously corrected river-bed records, comprising also the main tributaries of Danube and Tisza. This material also contains the results of periodically repeated fixations of flood and small water stages. Time and again detailed descriptions of the repeatedly resurveyed levelling base net are published by the Hydrological Service.

In the realm of water discharge and velocity measurement the work covering more than three decades of S. Hajós is of international significance. Beside the velocity-measuring propeller named after him — adopted in the period before World War I., by the Hydrological Service of Russia, among others — he has designed a number of other instruments (a pneumatic bed section tracer, self-registrating gauges of several types, a so-called integrating float for low-velocity measurements, etc.) It was he who developed the method of detailed measurement — a perfected version of the integrating method along verticals — for which he constructed an electric device recording the rate of lowering of the propeller by the rope of a winch [18]. His ingenious device for calibrating propellers is also of interest.

To try out and compare new instruments and methods a great number of experimental measurements were carried out by the Hydrographic Department. Of the results the checking of propeller velocity measurements by immediate volume determination on a tank filled with the propeller in the opening has to be emphasized, besides the establishing of effects of water-level change upon water discharge. The "flood loop" determined with a series of measurements at Tiszapüspöki at the time of the 1895 spring flood of the Tisza River became a classical example in world literature.

S. Hajós kept in close touch with all significant hydrographers of his time and also published a number of papers in foreign journals [19]. In 1906 he summarized the rich harvest of his experimental and research work in a handbook entitled *Hydrometry* [20]. The acknowledgement of international professional circles was brought to him by his election to Vice-President of the Assembly of the heads of Central European hydrographic institutions, on the threshold of World War I [21]. In the two-volume Hydrometry [22] of Professor Kolupaila, Hajós is mentioned as one of the greatest of his profession, with his portrait and a number of drawings of his instruments.

The valuable hydrometric treatise of Professor J. Weissmahr on the sources of error in hydrometric velocity determination was published in the last year of World War I [23].

As regards bed-load determination, the survey of the bed material of the Tisza River comprising the entire length of the stream has to be mentioned. It was carried out in connection with the rived-bed topography survey of 1891. Suspended load of the river was investigated in 1901 on water samples collected every five days in four profiles.

Mention has to be made of the detailed investigation into the water household of four different plain, hilly and mountainous drainage areas selected for this purpose, carried out by the Hydrographic Department between 1901 and 1905.

Of the studies immediately connected with practical applications of water economy the detailed surveying of the water power resources of the country is of special interest. This work fell between 1897 and 1903 and comprised more than 200 watercourses. In this connection longitudinal profiles of valleys were constructed in the length of 10 600 kilometers and more than 1600 special water discharge measurements were made in 463 profiles. This was the first country-wide water power capacity survey in Europe, encompassing an area of 180 000 sq. km [25]. The problem of irrigation water consumption was also subjected to detailed studies (1897—1901). The activity described above was completed by a number of statistical studies on floods and flood protection works, a set of maps serving purposes of shipping, river regulation and hydrological research, as well as measurements, studies and expert opinions on an enormous diversity of water problems.

3. *Hydrological activity of other institutions*

The huge field of work of hydrology was cultivated — at least in some respects — beside the Department of Hydrology by a number of other institutions.

In the first place the *Hungarian Meteorological Institute*, founded in 1870, has to be named. The work of this institute was preceded by some systematic meteorological observations made as early as the beginning of the XVIII. century, Budapest having been the Eastern outpost of the first European observation network of 37 stations, founded by the *Societas Meteorologica Palatina* in 1779. It was also in Budapest that precipitation measurements have been commenced in 1782. However, it is only since 1871, the founding of the Meteorological Institute, that a country-wide observation network can be spoken of. The first precipitation map, dated from 1885, was primitive enough, but ombrometry took a quite rapid development after 1886 with the material and scientific assistance of the Hydrographic Department. Thus, the precipitation map of A. ANDERKÓ could be based upon the series of the thirty-year span 1871—1900. The two-volume Climatology (1907—1909) of Zs. RÓNA, giving a detalied monography of all meteorological elements, was a preferred handbook throughout a long time.*

The subsurface waters, especially the artesian ones, explored by a large number of drillings, were studied by the *State Geological Institute*, established in 1869 ; of course, a great deal of information was also collected at the geological institutes of the Universities. The main sources of geological data concerning Hungary are the Yearbooks and other editions of the Geological Institute and the Geological Bulletin (Földtani Közlöny), started in 1872 ; the Mining and Metallurgical Journal (Bányászati és Kohászati Lapok) since 1868. The first geological map of the country was drawn by L. LÓCZY sen. (1 : 900 000) ; the hydrological map of Ö. BOGDÁNFFY, showing superficial permeability values, was constructed on the basis of Lóczy's map (1901).

Hydrology was intensely cultivated also by Hungarian geographers, the more since the Geographical Institute of the Budapest University was led through several decades by scientists whose basic training had been in engineering, namely L. LÓCZY sen. and J. CHOLNOKY. The first one of them was led chiefly by geological principles in his work, although his contributions to hydrology have also been great [26]. To Cholnoky, who was held by his contemporaries to be the most active Hungarian geographer of the first part of the XX. century, we will come back later, as his activity was continued also in the period between the two World Wars.

The *Hungarian Geographical Society*, founded in 1872, served hydrology partly by its journal (Földrajzi Közlemények, Geographical Journal) and partly by special editions. Most eminent of the latter is the 22-volume monograph entitled "*The results of the scientific study of Lake Balaton*", containing a whole volume on hydrography (water household, level oscillations, ice conditions, etc.).

Limnological problems have been studied at the *Hungarian Experimental Institute for Ichthyobiology and Sewage Control* (1906).

Hydrology being the borderland of a number of different disciplines, it is natural that there should be a great number of other scientific institutions whose work has had some bearing on the hydrology of our country. It is almost impossible to give a complete list of all these achievements and thus in the following we will name only the social organizations and journals not mentioned above. The first one of them is the *Hungarian Academy of Sciences* founded in 1825 and the *Society for the Cultivation of Natural Sciences*, which has grown out of the former in 1841 and edited the *Journal of Science* (Természettudományi Közlöny), since 1869, then the *Hungarian Geological Society* (1950) and its *Division of Hydrology*, the predecessor of the *Hydrological Society*, whose *Journal of Hydrology* (Hidrológiai Közlöny) has just celebrated its fortieth anniversary ; the *Society of Hungarian Engineers and Architects* (1867) and its *Journal*, etc. Last but not least we mention the official periodical of the *Hydrological Service*, the *Vízügyi Közlemények* (Hydraulic Proceedings) which has published most of the results of engineering hydrology.

II. The cultivation of hydrology in the period between the World Wars

The peace treaties of Paris in 1920 brought about important alterations in the course of our frontiers and caused a crucial change in the country's life, the consequences of which thoroughly influenced hydrological research.

The problems of water power utilization, in the focus of interest for the last quarter century, had to be put off because Hungary became a flatland country.

Because of the lost war, the relatively slowly paying hydraulic investments were abandoned. Hydrological research thus lost for a time one of its driving forces. Reiterated economic crises also added their share to cause a stagnation lasting several years.

The first event worth of notice was the organization of the International Hydrographic Service in the Danube Basin (1924) [27], followed in 1929 by the initiation of wireless hydrographic reporting. This excellently functioning organization can serve as an example for hydrological co-operation in flood prevention and shipping on any big international waterway.

Problems arisen in connection with floods postulated the improvement of the collection and evaluation of hydrographic data. In a paper [29], prepared in connection with the exceptional flood of the Danube, 1927, after a thorough study of hydrological factors influencing

*See also the issue from B. BÉLL in this periodical.

flood water discharge and their interrelations, J. BENEDEK developed a theory which gave complete explanation of the origin and deployment of this flood. The paper mentioned can be regarded as the predecessor of the method of "unit hydrographs", which has become widely used since that time. — Concerning problem of gauge correlation, important from the point of view of flood protection, valuable research was carried out by P. BENEDEK [28].

The exceptional winter of 1928—29 gave a definitive impulse to the cultivation of cryology. Prompted by the pioneering dissertation of W. LÁSZLÓFFY, the systematic study of ice conditions on our rivers was begun [30], and measurement of snow cover thickness was extended by the Meteorological Service to the entire ombrometric network.

In search for a way out of economic crisis attention became focused upon the Great Hungarian Plain, economically rather backward at that time. It became obvious that the basin can be helped only by the development of intensive water economy. The main problems connected with hydrology were the regulation of stagnant water, irrigation and of forestation. All these problems involved the determination of the position and oscillations of ground water table as well as some intense research on hydraulic properties of soils, precipitation conditions, modes of water-storage, and the quality of waters available for irrigation. All this was begun in 1923 by the workers of forestry research, in 68 drinkwater wells. A further network of 150 pipe wells was laid 1929 to 1934 between Danube and Tisza on the intention of ROHRINGER, Professor of the Technical University. This network was extended from 1933 on to the entire basin by the Hydrographic Service, so as to record ground water conditions prior to the large-scale irrigation schemes [31]. At the outbreak of World War II observation was going on in 400 pipe wells made especially for this purpose. Forestry research has also carried on important work in determining the interaction of forests and ground water. Valuable results widely known in international circles were reached by E. IJJÁSZ [32], who evaluated the data of more than one hundred observation posts.

The purpose of more intensive agriculture and irrigation was served, among others, also by country-wide pedologic mapping to 1 : 25.000 scale, which yielded a lot of important hydrological information under the leadership of L. KREYBIG of the State Geological Institute.

To promote irrigation farming, the twin journal of Vízügyi Közlemények, the *Öntözésügyi Közlemények* (Journal of Irrigation) was started in 1939 under the editorship of E. NÉMETH. The six volumes of this journal have devoted ample space to hydrological publications beside the extended field of irrigation. Especially valuable were from the hydrological point of wiew the papers of L. MADOS on water storage and the quality of ground waters [33], the results of G. REPP-NOWOSAD about the water household of vegetation-covered soils [34] ; and the hydrographical investigation of the *Bureau of Irrigation* into problems of water supply of the Tiszalök irrigation system, especially the computations of E. MOSONYI to determine back water surface alterations to be effected by the Tisza weirs [35]. To further preparations for more intensive water exploitation the scope of the Hydrographic Yearbook (Vízrajzi Évkönyv) was gradually increased since 1930. Up to that time it contained only water stages, since then frequency and duration curves were added beside bed profiles at the gauge stations, discharge graphe and hydrometeorologic information. — The Meteorological Institute prepared, in compliance with international agreements, climatic tables and maps for the years 1930 to 33, as well as precipitation and drought studies in connection with irrigation schemes [36]. All these data were evaluated by F. HAJÓSY. It was on the basis of these data that E. NÉMETH could proceed to determine the specific water requirement of irrigations in the Hungarian Basin [36].

The interactions between transport capacity and of the transported sediment further between the bed and bed-load were problems important from the points of view of both irrigation and river regulation. This set of problems was tackled by the pioneering work of the excellent geographer mentioned above, J. CHOLNOKY. It was he who pointed out first the widely differing dynamics of upper, middle- and lower-sections of normal-slope rivers and who gave a simple and instructive physical interpretation of the differences.

In his deductions he indicated the ratio of river energy and the work of load transport to be the parameter characterizing the dynamics of a river. If this parameter exceeds unity, as usual in upper river sections, the river will attack its bed with its surplus energy, using the bed-load as a tool to effect vertical erosion. Such river has upper-section character. If the parameter is around unity, the river is just able to carry its load in a state of dynamic equilibrum, unable to deepen its bed, but forms meanders by a combination of lateral erosion and sediment deposition. Such a river is of middle-section character. At values of the characteristic parameter less than unity the river must deposit part of its bed-load, inducing the formation of shoals and alluvial fans : this river of lower section character is characterized by silting up. The longitudinal profile of the rivers consists of an alternating series of reaches of gentle and of steep slope, thus the character of the section repeats itselfs ; at least, there arises the possibility of such repetition.

Cholnoky has also pointed out why the meandering "bastard" branch of the river, which branches out from the river branching on its alluvial fan and rejoins it at the foot of the latter, should be of middle-section character [37]. The value of the pioneering statements of Cholnoky is not in the least impaired by the fact that prefixes upper, middle and lower are in some contradiction with the actual sequence, wherefore Hungarian hydraulic engineers prefer to use the terms *incised*, *meandering* and *branching* sections.

Experiments to determine bed-load transport data back to 1933, although systematic measurements were only begun after the development of the new bed-load trap type, constructed entirely without wire-mesh. The hydrodynamically correct dimensions of this so-called Győr type bed-load trap were determined in Laboratory I. of the Technical University. Theoretical investigation on the bed-load movement was made by T. Bogárdy [38].

The heavy water damages of the years 1940 to 42 have induced some thorough studies in connection with the development of a canal network to drain stagnant waters. The problem of the amount of water to be drained by the canals was to be solved by investigating the duration, intensity and frequency of precipitation as well as by correctly choosing the run-off factor and studying the modes of water accumulation.

In this respect remarkable results were reached at as early as the end of World War I by J. Korbély [39], whose work was further developed by B. Kenessy [40], E Németh, and with especially good results, by J. Bogárdi [41] whose studies extended well past World War II.

In the period between the two World Wars the water quality survey of dug and drilled drink-water wells was carried out by the *Hungarian Institute of Public Health*. Systematic hydrological investigation was begun on our thermal and mineral springs (influence of weather (and — in Budapest — of the regimen of the Danube) upon yield, studies on correlated parameters, etc.). For this work a *group of spring investigation*, headed by F. Papp, was organized at the Geo-Mineralogical Institute of the Budapest Technical University. The Professor of this same Institute, A. Vendl [42], has been engaged since several decades in studying the formation of sulphatic ground waters and the possibilities of preventing concrete corrosion. His first publication on this topic appeared in 1930, wherein he explained the origin of ground waters of exceptionally high sulphate content in the SW of Budapest. He stated that sulphate was formed out of finely dispersed pyrite occurring in lower Oligocene clay, decomposing into sulphuric acid in the presence of oxygen and water, and forming gypsum and sulphate of magnesia when interacting with dolomite particles in the clay. Sulphuric acid also attacks the feldspar grains of the clay, giving rise to the formation of sodium sulphate. Sodium and magnesium sulphate remain dissolved, whereas gypsum is precipitated within the clay.

Prof. Vendl has solved the problem of preventing concrete corrosion by applying active biological desulphurants. It was shown by laboratory tests that sulphate-reducing bacteria decomposing the sulphate ion under anaerobic circumstances will thrive on organic matter such as grass, sawdust, peat and chaff. Even at present investigations are being conducted into the hitherto uncleared reaction mechanism of this process. It could be established that no hydrogen sulphide is formed on decomposition : it is most probable that sulphur derived from the sulphate ions is incorporated into the organisms of the bacteria. The process was also tried out in the field and the reaction was found to go on with unimpaired intensity through quite a long time. At present we have the results of successful field experiments of two years duration at hand. Packing concrete with organic substances to prevent sulphate damage was already applied in practice. Field experiments were carried out by the research department of the *Bureau of Geodetic Survey and Soil Investigation* under the direction of E. Vécsey.

The *Institute of Ichthyobiology and Sewage Research* also carried out successful work between the Wars, under the leadership of M. Korbuly and then of R. Maucha. Limnologic problems of rivers and lakes as well as of the artificial fisheries of about 12 000 hectars' extension were attended to by E. Unger, A. Lindmeyer and especially by R. Maucha, whose work is of pioneering significance and well-known in international circles. For some time he was President of the »Internationale Vereinigung für theoretische und angewandte Limnologie«. He summarized his methods of water analysis, developed at his Institute out of internationally used methods inaugurated by the Hungarian Prof. of Chemistry L. Winkler, in a treatise entitled »Hydrochemische Methoden in der Limnologie«, which appeared in the 12. volume (Stuttgart, 1932) of the series »Binnengewässer«, edited by A. Thienemann.

In the same period, viz. at the end of the thirties, hydrological research on water storage in mountainous regions was begun. Investigations in connection with the possible construction of several large-capacity storage basins in the Carpathian Basin were led by E. Mosonyi. These studies were partly directed to determine the hydrographic nature of the upland waters of Hungary, partly to predict seepiage and evaporation losses expected in storage basins [43].

III. Hydrological research in the first ten years of the People's Democracy

In Hungary, World War II wrought terrible destruction. Scientific institutions were reduced to ruins, all laboratory equipment was destroyed and a great number of promising young scientists dead. So e. g. the equipment of the laboratories of both Institutes of Hydraulic construction of the Technical University was gone, the Hydrographic Institute at Nagymaros on the Danube ruined: the First Assistant of Institute I and the Directing Professor of Institute II were killed in action. So was L. MADOS, to the enormous detriment of Hungarian soil hydrological research. Everything had to be commenced anew.

The resurrection of scientific research could be effected only by the utmost efforts, by the unselfish cooperation of all parties involved. The help of the government consisted in careful reorganization of the scientific life of the country, backed by enormous material aid. Thanks to this, all the branches of hydrological research could make a new start.

Research is directed on top level by the *Hungarian Academy of Sciences* and promoted on a social basis by the *Hungarian Hydrological Society*. Hydrological research is also directed by the Academy, by way of its *High Council of Hydrology*. Besides immediate control and frequent discussion of research tasks in the special sections of the High Council, reports of scientists and institutions on the state of hydrological research are often heard at hydrological congresses and symposia, where further topics of importance for the people's economy are delineated and new directions of research pointed out. A great number of problems was brought nearer to solution by the working committees of the Hydrological Society. Scientific work thus coordinated is characterized by collective efforts and important bearing on practical life. Participants of this work are all research institutes cultivating any branch of hydrology. In the following we will subdivide our report according to fields of research. However, in the introduction we will try and delineate the complex activity of the Hydrological Department, reorganized under the name *Research Institute for Water Resources.*

The Hydrographic Department and the Research Institute for Water Resources

The social reform and new economic order gave, after the repair of war damages, a new possibility for an enormous development of the hydrographic service. This development was to be felt mostly by the restoration and extension of the hydrographic observation network as well as by the increase of the number and scope of bed-load and water discharge measurements.

The hydrographic observation network of the country, consisting of 137 gauge stations in 1937, was doubled to the end of the first Five-Years Plan (1954). 273 further water gauges were established on smaller watercourses, so as to facilitate the exceedingly important assessment of agricultural and industrial water reserves. Beside the two self-registering gauges of former times 19 new ones were erected ; the first teleregistering gauge is under construction in Budapest. However, this is but the first step in the field of water gauge automation and further intense evolution in this field will be necessary to facilitate the solution of the problems of engineering hydrology. Moreover, the hydrological phenomena of smaller watercourses are of very swift deployment so that their description is only possible by self-registering gauges.

The hydrological study of surface waters was enriched in 1945 by the commencement of systematic water temperature measurements by the Hydrographic Service. In spite of technical difficulties, we possess at present good initial data for round 50 stations.

Country-wide and international hydrometric reporting also took a significant development as compared to pre-war conditions. To-day the Hungarian hydrographic service obtains the data of 63 stations at home and 45 abroad, as related to 39 and 24 stations, respectively, in 1938.

With the increasing demands on water economy the need for a sudden development of water discharge measurements as well as for the extension of these measurements to smaller watercourses and springs has arisen. In the 'fifties there is already an annual average of 2200—2500 measurements on 200 watercourses. It was on the basis of these data that the discharge statistics of surface waters, yielding up to now reliable data for as many as 50 stations could be established.

A similarly urgent need of the people's economy was the recording and systematic study of spring waters, as the date on the yield and duration of springs formerly obtained were rather sporadic. Although it has been impossible up to now to extend spring registration and recording to springs of the smallest sort, the data of 700 registered and 140 systematically observed wells are sufficient for practical and certain scientific purposes. The register does not contain as yet springs of less than 20 litres p. m. output, whereas the discharge and other physical and chemical properties of springs over 1000 litres p. m. are generally determined each month.

Bed-load determination of rivers shows a similarly rapid development. Whereas only some isolated experimental measurements were carried out before the war, the suspended and bed-load and the bed material composition of the rivers were determined by systematic measurement series made at standard localities after 1945. Up to 1954, measurements were made at 32 standard localities on 10 rivers. The number of samples exceeded 12 000 per annum.

As compared to the recording of data on surface waters, the registration of ground water conditions is quite young. The establishment of ground water wells for observation purposes was commenced in 1930. These wells were laid out by several different organizations (Department of Hydrology, Geological Institute, Hydraulic Construction Institute of the University, Bureau of Irrigation, Forestry Research Institute). In 1944, when these random wells were concentrated into a country-wide observation network, the number of observation wells already ranged around 300. After 1945 this network had to be intensely developed, as postulated by different aspects of water economy (drainage of stagnant waters, irrigation, canalization, water reserves, etc.). This development was so rapid that, at the end of 1945, 2068 wells were kept on record by the Hydrographic Service. Some of these were of local importance, serving manifold purposes of research. It was therefore necessary to classify wells into a national network and those serving for research. At the same time the perspectivic plan of a general ground-water observation well-network was perfected, providing for 1400 wells in the entire country. Of these, some 944 were established until 1955. The number of research wells amounted to 1124.

The quantitative changes in hydrographic apparatus, which can be called with good reason revolutionary ones, were also reflected by the publication of hydrological data. Since the new regim of the country, recorded and evaluated data on water stages, temperature, ice conditions, water discharge and ground-water stage, forming the basis of hydrological planning and research, are published in far greater volume and far more rapidly than previously. Since November, 1948, hydrographic and meteorological data covering one month are published in the next one under the heading "Vízrajzi adatok" (Hydrographic data), together with long-range averages for comparison. The "Vízrajzi évkönyv" (Hydrological Yearbook), containing the sum of one year's data, is published within 9 months from the end of the year, always in advance of similar publications by neighbouring states along the DanubeValley.

The sudden increase of the number of hydrological and especially discharge data indicates the assumption of a new course in hydrological research. Whereas water level is only qualitatively characteristic of the regimen of water discharge is a quantitative parameter on which may rest the husbandry of water as a raw material on the one hand and scientific hydrological research on the other.

This large-scale development of hydrographic activity is supported by the appreciation of the importance of hydrology on the part of the government. It is to be ascribed to this fact that the latter did not content itself with a simple qualitative extension of hydrografic service, but sponsored the establishment in 1952 of a *Research Institute for Water Resources* to secure the continuation and systematic development of hydrological research.

The first and most important task of hydrological research on surface waters was to take stock of exploitable water reserves. This was to be solved partly by discharge statistics based

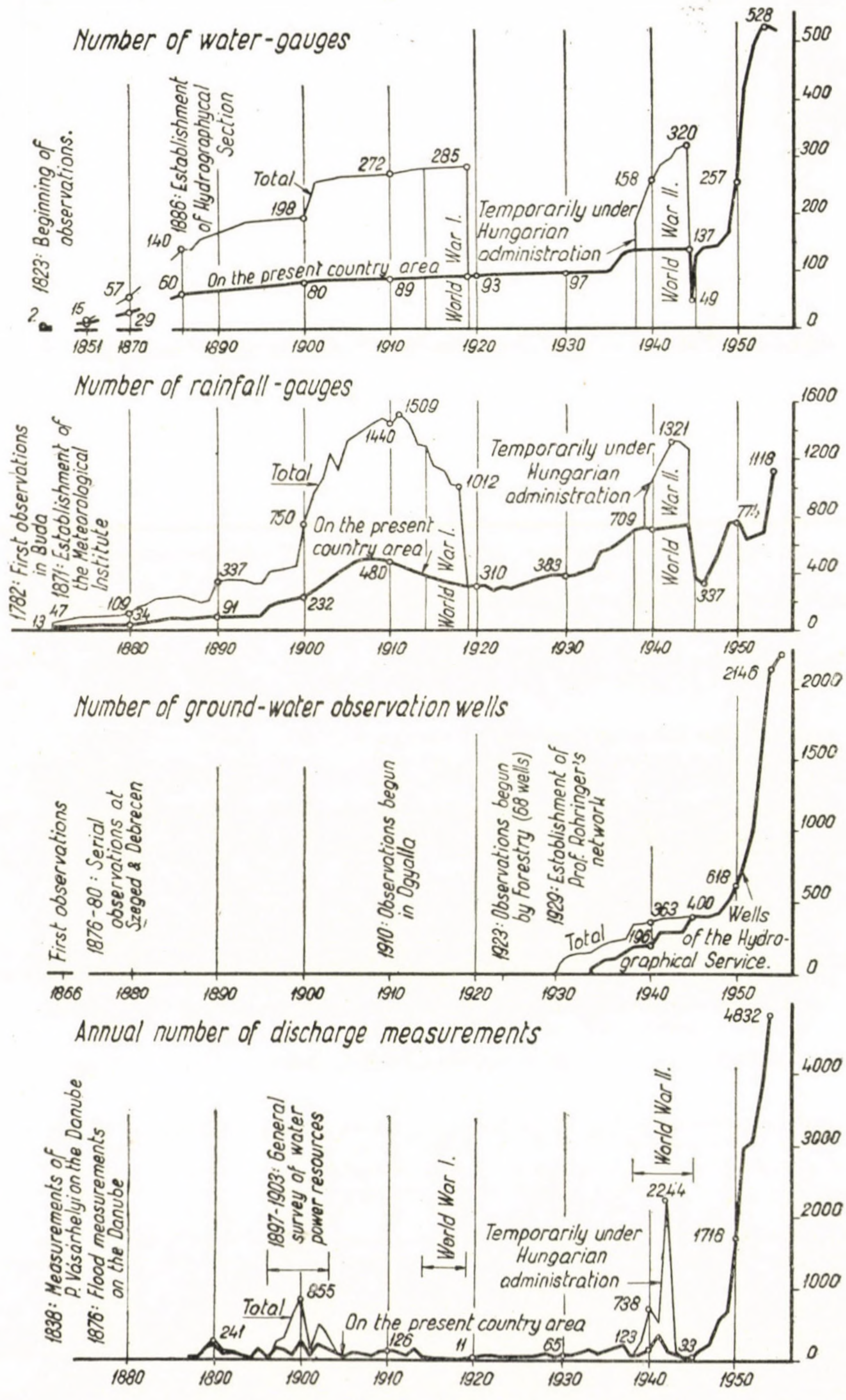


Fig. 1. Development of water-observations

upon immediate measurement, and partly by determining from these the relationships governing the hydrological cycle under the conditions prevailing in the country. From these we could deduce average and extreme water supply values for any moment at any point of any river.

The solution of this problem necessitated the clear statement of scientific difficulties. The methodologic directives for the recording of superdicial waters were based on a study of Hungarian experiences and Soviet and other hydrological methods. These directives were applied in preparing and recording water discharge statistics. This work was followed by the study of the run-off properties and methods for their determination in hydrologically hitherto unstudied regions and watercourses.

The starting point of investigation was the water budget equation, which was established abroad with no respect to Hungarian data. Because of this we could not de without foreign guidance. On these grounds the chart indicating the specific water yield, i. e. the long-distance average run-off of the drainage areas of Hungarian rivers, were prepared and the hydrological longitudinal section of our more significant rivers determined after the method initiated by W. LÁSZLÓFFY.

Another important problem was the investigation of load conditions and load transport in our rivers. Before 1945 there was no research worth mentioning done on river load. However, the first phase of research, completed in the immediate past, yielded some internationally significant results in the field of hydrological theory as well as in the cognizance of load conditions of our larger rivers.

Concerning the transport of suspended load, the interrelations of load concentration and suspended load weight with water stage, discharge and medium velocity were determined at some profiles of some rivers. The inportance of the hydraulic relations established by J. BOGÁRDI concerning suspended load transport has grown well out of the boundaries of the country [44]i.

Studies were also extended to the theory of suspended load transport. A number of experiments was carried out to compare the validity of the theory of diffusion, Velikanov's and gravitational theory. Latest experiments encompass the variation of suspended load transport along the rivers.

As to bed-load transport, the interrelations of load weight to water stage, discharge and medium velocity were determined. The bed-load trap developed by Z. KÁROLYI and the Institute of Hydraulic Construction No. I [45] was found to be the most reliable instrument of the internationally proposed types. Studies were made to develop an instrument for listening to bed-load noise. In the laboratory of the Institute of Hydraulic Construction No. I experiments were carried out to determine the critical medium and bottom velocity causing start of the bed-load movement. At the present, investigations into the variations of bed-load transport along the river are under way.

Beside the theoretical results of research the manifold practical applications of these results are of interest. Such applications were the solution of the silting problem of the Tiszalök Weir and of related problems of water-power exploitation on the Danube. Research on load transport has greatly facilitated correct and economic designing of water regulation works.

The basis of water husbandry is water economy planning, guaranteeing the equilibrium of water supply and demand in a country-wide sense as well as for each individual drainage area. The first problem is tackled by a national water economy plan, the latter one by a set of regional plans. Both kinds of planning are based upon large-scale scientific and methodologic research. The enormous system of the Water Economy Plan of the country was evolved on the ground of the methodologic investigations and scientific statements of E. MOSONYI, Corresponding Member of the Academy of Sciences, and his co-workers. On this basis water economy plans were made also for our more important industrial regions. Furthermore, the estimation of our exploitable water-powers has been made, too [46].

An important step regarding the collection and systematic treatment of hydrological data was the edition of the Hydrological Atlas Series by the Research Institute for Water Resources. The first series of the Atlas contains the detailed charts of drainage areas and a summarizing illustration of factors influencing hydrographic conditions. The further two series give a summary of observation material covering several decades, dispersed hitherto in hydrological and meteorological yearbooks as well as individual publications and manuscripts. These data also present a basis for the extended application of hydrological analogies.

Also to be mentioned are flood studies, having important bearing on the designing of waterworks [47]. Part of these studies is occupied with methodologic problems, analyzing the experiences of probability methods standardized in Soviet practice, while another part seeks to determine the probability of occurrence of flood stages on our larger rivers. Filling a gap of long standing is the systematic collection of data as to the deployment of floods on small rivers and the determination of flood formulae applicable under our circumstances to the flood discharge of smaller watercourses.

Because of the flood protection works of large extension one of the crucial problems of Hungarian water economy is the correct planning of the drainage of stagnant waters. This work could be carried out on new and more reliable lines according to the results and directives of P. SALAMIN [48]. In evolving these directives, valuable help was given by the members of the Council for Surface Drainage. The determination of specific water transport, governing the design of drainage network, was started some years ago ; however, because of the size of the area involved it was completed only for some parts of the areas of stagnant inland waters. Evaluation comprised the 50-year precipitation records of 70 meteorological stations.

Investigations into the ice conditions of our rivers are significant because of the winter floods on the Danube and lately also for river canalization works. The statements of W. LÁSZLÓFFY concerning the formation of the ice cover and the phenomena of the passage of ice are widely known.

Concerning the field of underground hydrology, one of the young disciplines in this country is ground water research. As it was seen above, the observation of the ground water table was commenced, at least in the Great Plain, some 20 to 25 years ago ; however, scientific work has begun only in the last decade, when the determination of ground water table changes and ground water supplies gained on significance from the point of view of water economy.

After some previous surveys and evaluations of ground water data, ground water mapping of the country was commenced under the auspices of the State Geological Institute, resulting in isobath maps illustrating the position of the ground water table. It must be stated, however, that it was impossible to finish this task over the entire country during the tenyear period treated here. In establishing the relationships governing subsurface water notion, significant additions were made by designing firms (Bureau of Hydraulic Design, Civil Engineering Design, Bureau of Geodetic Survey and Soil Investigation).

The statistical interpretation and evaluation of ground water observations have much facilitated the tackling of problems of agricultural production, drainage work and even of civil engineering and foundation design.

Initial evaluation of data was soon followed by studies on the variations of ground water level with meteorological factors especially precipitation and temperature. In this field internationally important results were obtained by the aid of the correlation method [49]. Studies were carried out to determine the effect of surface watercourse upon ground water, so as to clear the reaction of ground water to river stage variation caused by backup expected from proposed river canalizations.

A further step was done by investigating the infiltration of precipitation. The path of infiltrated precipitation was followed down to the ground water table ; in this way it became possible to determine the amount of stored ground water. Methodologic investigations have shown that in analyzing ground water table changes it is expedient to resolve these changes in space-dependent and time-dependent ones.

Theoretical studies on ground water reserves have led to more advanced ways of ground water exploitation and thus often influenced the solution of important practical problems. Such problems were the solution of the forecasting of ground water rise in a number of cases, the study of the effects of the Tiszalök, Szeged and Visegrád dams on the ground water table and the exploration of ground water conditions in the Nagyberek swamp adjacent to Lake Balaton.

Even younger than ground water investigation is the study of Karstic water, important from the point if view of drink- and industrial water supply of settlements lying far off larger rivers. Up to 1949 there were no measurements or theoretical methodes which could served for characterizing the properties of karst springs with sufficient reliability for economic planning.

It was proven by spring registration and systematic research commenced in 1949 that all springs are fed exclusively by precipitation and that the discharge of the springs is governed to some extent by petrological and tectonical circumstances. It could be established that karst springs in limestone and dolomite will respond differently to a given amount of precipitation. The classification of the springs according to dependability has become possible as well as the definition of a dependability index comprising the stability of flow, temperature and chemical composition [50].

On the ground of these results the following parameters could be determined :

1. the long-range average amount of infiltrating water, recharging the Karstic aquifer, and the amount of Karst water to be exploited in the long range without overthrowing hydrological equilibrium ;

2. the size of the drainage area of any Karst spring, even after discharge measurement series of no more than 1 to 2 years duration,

3. the discharge diagrams of Karst springs on the basis of 1 to 2 years measurements and ong-range series of precipitation data, substituting within the limit of precision demanded by lpractice the measurement series of several decades. and finally.

4. The equilibrium of exploited and recharged water amounts in karstic areas.

The processes and methods connected with this work and the results thereby obtained are entirely new. Systematic spring investigations covering an entire country and statements deducted therefrom are unknown in foreign literature.

On the basis of the results of karst water research a series of successful prospectings for artificial and natural Karst water wells could be effected. The artificially opened up Karst water wells yield a total of 27,500 cubic metres per day in si different localities. To our knowledge, artificial Karst water development of this order of magnitude is unique in all the world.

Forestry research related to the field of hydrology

Research was extended to a variety of hydrological properties of forests and barren lands. The interests of forestry required the exact knowledge of climatical parameters [51] and of the effects of forest cultivation upon climate [52]. A definite relation was established between the oscillations of the ground water table and the periods of forest growth.

The common field of research of the hydrologist and forestry expert is the study of erosional phenomena. In this respect the workers of forestry research and especially I. HÉDER have been notably active. The latter found out by pedological and microclimatic phytocoenological investigations that a barren hillside is by no means homogeneous from the point of view of afforestation: on the contrary, it is divided according to different properties into a set of barren land types situated one above another. Erosional agencies (water and wind) will act differently upon these differentiated types of differing altitude, so that differing kinds of soil preparation and amelioration have to be applied to check erosion prior to afforestation, which should also be done in several subsequent steps with different species of trees and shrubs. The studies of I. HÉDER [54] also pointed out that barren lands on different base rock, possessing different cultivation properties, have to be separated from the point of view of erosion control as well as of afforestation. He defined on a geomorphological basis the types of barren land according to differences in exposition and altitude for five types of base rock. He also delineated directives for checking erosion, for the modes of soil preparation and afforestation, concerning the tree and shrub types to be used and the agrotechnics of their plantation. On the basis of measurements he pointed out the importance of artificial microrelief development for snow retention, inhibition of erosion and improvement of water husbandry.

Hydrometeorological research

The determination of the distribution of normal precipitation values for Hungary according to the months and seasons of the year by evaluating precipitation data covering the four decades 1901—1940 by F. HAJÓSY [55] was of fundamental importance. Z. BERKES found a remarkable relationship connecting the state of humidity of the soil surface with the rainfall of certain weather fronts [56]. M. KÉRI was occupied with methodological problems of snow cover climatology and with the evaluation of data on snow conditions in Hungary [57]. The frequency of occurrence of different amounts of precipitation was calculated by L. KULIN [58] on the hand of data for the half-century 1901—1950.

The treatment of a large number of hydroclimatological and hydrometeorological problems is incorporated in the handbook of Agrometeorology by L. AUJESZKY D. BERÉNYI and B. BÉLL, edited by the Hungarian Academy of Sciences. Special mention has to be made of the part of the book treating the climate of Hungary, by D. BERÉNYI, this being the most instructive and at the the same time most concise description of the climate of this country among all treatises written thereon [58].

The book of B. BÉLL entitled "From the soil to the limits of the atmopshere" (A talajtól a légkör határáig, Budapest, 1953, pp. 210) has the object of summarizing the latest achievements of meteorology, inclusive of high-atmosphere research by balloons, rockets and wireless methods.

Hydrogeological research

Hydrogeological studies may be subdivided into general and regional ones. Of the former' the ones containirg new results based upon original investigations in the fields of hydrogeological mapping theory, of the relations of hydrogeology to geomechanics, of the problems of Karst waters, cave waters springs, mineral and medicinal waters are of importance.

It was decided in 1950 by the State Geological Institute to perform a complete ground water survey by means of a network of wells covering the entire country and especially the Great Plain. In the course of this work 1,2 million wells were surveyed and a continous ground water isobath map of the Great Plain prepared. The data of this one great survey were convert to uniform level by the aid of records of permanent ground water observation wells of 15—20 years, standing.

Ground water mapping has yielded some valuable data on the geology of the regions of the Great Plain. Even the outlines of the basement structure appear on the ground water map. The work executed gave beside the location of the ground water table (in the depth of 1 to 20 metres in the Great Plain) also references for the fluctuations of ground water level.

The Bureau of Geodetic Survey and Soil Investigation can also record achievements connected with ground water research. The physical, chemical and biological processes eventually occurring in the soil and ground water were studied throughout the country. The annual and seasonal oscillations of the ground water table were also studied. The evaluation of these results forms the basis of development of engineering hydrology, whose services are of increasing benefit to design and execution. It was within the scope of this Bureau that the registry of the Ministry of Construction for soil mechanical and hydrological records was established. This registry executes the systematic collection and evaluation of soil drillings of all firms and institutions. The complex of evaluated data serves as a basis for hydrological information and advice for official and private agencies.

Protection measures against aggressive waters were elaborated with the cooperation of the Special Council on Corrosion of the Academy of Sciences, by considering the experiences of several decades in the field of concrete corrosion and the properties of our cement brands as well as related foreign specifications and literature. The proposals thus elaborated comprise almost the entire field of anti-corrosion work, even as regards defence against industrial sewage. Heavy corrosive damage was done by the waste water of sulphuric acid and other factories in regions with high ground water table. Thus the surveying of the extent and direction of ground water contamination and the preparation of other kinds of maps indicating chemical properties of ground water were commenced.

The chemical, isotropic and electrical methods of the study of ground water flow were developed and furthered. The evaluation of several hundred reports on this problem from scientific as well as practical points of view is under way.

The Hydrological Division of the Civil Engineering Construction Firm, engaged chiefly in prospecting for water supplies and the drainage of trenches and pits as well as in the solution of seepage problems of irrigation canals and flood levees, is not directly interested in scientific research. However, in the course of practical designing problems, a lot of investigations were carried out as to the nature and efficiency of exploring and examining tools and methods of evaulation. Thus, important work was done in developing a method of geoelectric tracing of subsurface cables and pipes and in initiating a new system of test pumping.

The observation, especially in Artesian wells, of the waters of deeper aquifers was carried out by the Hydrological Division of the State Geological Institute. Temperature, pressure and hydrochemical parameters are under evaluation. The Division also studied the problem of recharge and proceeded to registrate underground water reserves. The relationships governing the connection of hydrological and geomechanical conditions were studied in detail by E. R. Schmidt of this Division [60]. Especially remarkable is the series of investigations into Karstic water exploration in mining, as the richest coal and bauxite deposits of Hungary occur in regions imperilled by karst water inundation, strongly impairing present production as well as production increase planned for the future. It was shown on a geomechanical basis by Schmidt that there is a causal relation between the direction of Alpine-Carpathian mountain building forces and the fault systems of the regions involved, and further that of the two systems of faults nearly at right angle to each other the one striking NW-SE is of dilatative nature and thus more dangerous from the point of view of Karstic inundation and more productive from the point of view of karst spring flow. The pattern of the superficial drainage net is also controlled by this tectonical structure.

Beside his activity described, Schmidt gave a concise description of Hungarian hydrogeologic regions and pointed out some problems of the Artesian basins of Hungary, explored up to now by nearly 2000 Artesian wells.

Because of the utmost importance of Karst water for both water utilization and mining, the Karst water problem in all its aspects was subjected to intense study and the results discussed in symposia and literature [61].

After 1950 there were important achievements in the field of exploration of caves and their waters. Especially noteworthy are the water-dyeing experiments of L. Jakucs, throwing light on the interconnections of Karst caves and springs. One of these experiments has led to the discovery of Béke Cave. During the investigation of this underground cave of almost 10 km length a number of problems concerning the role of erosion and corrosion in cavity forming was cleared.

The solution experiments of T. MÁNDY on dolomite and limestone have pointed out that in certain cases dolomite is dissolved more readily than limestone. In studying the chemical composition of cave waters, F. HOLLY and R. MAUCHA have established a relationship between the size of cavities and the concentration of dissolved material.

In the Geo-Mineralogical Institute of the Technical University investigations were carried out to determine relations between spring types and the geological features of the adjacent rock. Proposal has been made of a spring classification system based upon this relation [61].

There was also a great number of regional and detail studies, comprising the hydrogeological properties of individual morphotechnic units (Bükk Mountains, Mecsek Mountains, the area between the Danube and Tisza Rivers, etc) [63—66].

The studies of E. R. SCHMIDT, of great importance from the point of view of mining, have cleared much of the geomechanical relations of karst water occurrences around Ajka, Eplény, Gánt Dorog, Tatabánya and in the Mecsek Mountains [67].

Hydrochemical research

The attention of Hungarian scientists was called long ago to problems of water examination and the improvement of water supply. Several results of international standing were attained in these fields of research. It is sufficient to refer to the equivalent percentage notation in computing the analysis results of mineral and medicinal waters proposed by K. THAN, Professor of Chemistry of the Budapest University of Sciences. It was by this method that it became possible to express correctly the relative amount of individual ions in the water and the chemical characteristics of mineral and medicinal water instead of the former arbitrary calculation of salts formed. The methods for the determination of the oxygen and iodine content of waters developed by another Professor of the same University, L. WINKLER, have been up to now in permanent use all over the world. The method for determining total hardness by WARTHA and PFEIFFER, Professors of the Technical University, and the reagent for nitrous compounds of GRIESS and ILOSVAY are similarly known in all civilized countries. Water analysis was so much advanced in Hungary at the beginning of the century that L. WINKLER, Professor of the Budapest University was requested to write the chapter on water analysis for the widely used technical analytical handbook of LUNGE and BERL.

Water analysis

In the following period there were also many scientists bent on the development of water analysis, especially the professors E. SCHULEK and R. MAUCHA, disciples of Professor Winkler. E. SCHULEK developed together with P. RÓZSA a method for the simultaneous determination of sulphide, thiosulphate and carbonyl sulphide ions.

R. Maucha [69] has compiled a series of semi-microanalytical methods of water analysis for field use. In 1949 he inaugurated a semi-micro correction method for the field determination of the dissolved oxygen-content of water. His new method for determining biochemical oxygen demand reduced the time of measurement from 5 days to 24 hours. The essence of the method consists in determining the constant of reaction velocity during the first 24 hours and calculating therefrom the biochemical oxygen demand for five days. By the method of MAUCHA for illustrating the composition of water by a graph indicating equivalent percentages of the eight most important ions, the comparation of different waters is much simplified.

In the State Geological Institute the complexonometric method of determining total hardness and calcium and magnesium ion content was adjusted to field requirements. A process for the half-micro field determination of the sulphate ion content of water was also developed. The principle of the method consists in titrating back the unprecipitated rest of a known amount of excess baryum chloride with complexone III. in the presence of a mixed indicator. The mixed indicator is prepared by thoroughly grinding together 400 mgs of phtaleine complexone, 80 mgs of methyl red and 100 mgs of diazin green and dissolving 10 mgs of the preparate in the mixture of 4 ccm of distilled water, one drop of cc ammonium hydroxide and 2 ccm of 96 per cent ethanol. The palmitate process is similar in principle, inasmuch as the excess baryum chloride is titrated back with potassium palmitate in the presence of a phenolphtaleine indicator. The determination is carried out on previously softened water samples.

In the Research Institute for Balneology the alteration of carbonyl sulphide was studied. It was established that no method except the basic iodometric one is satisfactory for the determination of the total amount of carbonyl sulphide.

In the Institute of Public Health an efficient zircon-haemotoxyline method was developed for the determination of fluorine. In the same institute a method of assaying minute quantities of fluorine was developed lately, based upon the fact that aluminium determination by the aid of aluminone is disturbed by the presence of fluorine. It is made possible by this new principle to avoid tedious distillation [71]. The Institute of Public Health also developed a method for determining small amounts of silver, in water disinfected by the catadyne process, with a paradimethylaminobenzilidene rhodanide reagent.

The catalytic effect of iodine was utilized by DEMETZKY [72] to determine iodine content indirectly by measuring the speed of the arsenous acid-cerium sulphate oxidation reaction in the presence of a ferroine indicator.

Aggressive waters

The aggressive properties of waters and the defence against concrete corrosion were much attended to by the Institute of Public Health. Within the scope of this problem the computation of the agressive and bound carbonic acid content of water in calcium vs. carbonic acid equilibrium was carried out [73]. New correction coefficients for the determination of the free carbonic acid content of water were also computed [74], beside designing a modified process for the precise determination of free carbonic acid in water. The occurrences of water containing calcium-aggressive carbonic acid in Hungary were established. A formula based upon theoretical assumptions was derived for computing the *p*H value with a degree of precision exceeding that of former methods from the data of free and fixed carbonic acid content. The values thus determined are in perfect agreement with the ones actually measured [75]. — A method for computing the amount of carbonic acid agressive with respect to concrete was also published.

Investigation tools. The object of improving water sampling has led workers of the Institute of Public Health to develop a new sampling apparatus capable of collecting samples without gas loss even from drilled wells. The apparatus is designed so as to secure the sixfold exchange of water in the sampling container. An up-to-date sampling apparatus, of advantage in limnologic work, was described by R. MAUCHA of the Research Institute of Fish Breeding. The Institute of Public Health has designed some 20 years ago an automatic pipette series, making possible the simultaneous lifting of 20 samples on a single suction, with the automatic regulation of zero and end level. Automatic pipettes have been used in the Institute of Publich Health for the dosage of reagents, so as to eliminate errors arising in series analyses from using pipettes of differing calibration. A cockless fluid feeder for the dosing of concentrated sulphuric acid was also developed which was found satisfactory through some years in practical application.

Amelioration of drinking and industrial water. In this field rather valuable results were attained at the Institute of Public Health by the processing of the filtering substance Fermago [76]. The substance serves for the elimination of acids, manganese and iron from drinking and industrial water. The process and the substance is used in a number of municipal waterworks in Hungary. Successful applications of the filtering substance were reported from Austria, Czehoslovakia and Rumania.

Corrosion checking. In this field excellent results were arrived at by A. VENDL, Professor of the Geo-Mineralogical Institute of the Technical University, who has studied since several decades the formation of, and protection against, concrete-corrosive sulphatic groundwaters. His first publication on the topic appeared in 1930, clearing the formation sulphatic ground water of very high-concentration in the environs of Lágymányos and Örsöd, Budapest [77]. Professor VENDL solved the checking of sulphatic corrosion by applying active biological desulphurants. It was shown by laboratory experiments that bacteria reducing sulphates exist on organic materials such as grass, sawdust, peat, etc. capable of decomposing the sulphate ion under anaerobic circumstances. It was established up to now that no hydrogen sulphide is formed on decomposition, as the bacteria most probably incorporate sulphur into their organisms. Packing with organic substances was already applied in practice with satisfying results [78].

Of great practical importance is the process of corrosion checking developed at the Institute of Public Health on the initiative of A. JENDRASSIK [79], improved and applied in a number of cases by SZ. PAPP. The process succeeds in keeping expensive deep drillings from speedy ruin at relatively low costs, with the simultaneous elimination from the well water, of iron dissolved from the well casing. The process consists essentially in substituting the dissolved oxygen necessary for the formation of a natural protective film by artificially induced chemicals as long as the film has been formed.

Waters of public baths. The investigation of this topic was commenced in Hungary only in the last few years. Studies were carried out in several directions by the Institute of Public Health [81]. The oxygen consumption, the increase of total nitrogen and chloride content in the bath water discharge was used to define a so-called Bolberitz index of contamination, characterizing the bacterial contamination of bath water as well as the inorganic one. The definition of this index of contamination allowed the determination of maximum permissible population of bathing pools. By determining in a number of experiments the amount of pollution caused by one bathing individual in the common pool a formula was deduced yielding the number of admissible bathers in the case of a given rate of water exchange or the rate of water exchange necessary in the case of a given number of guests [82].

Drink water control. Important activity was deployed in the Institute of Public Health in improving drink water supply in the country. The control organization of village public wells and communal and municipal waterworks was developed together with the construction of wells yielding high-grade drink water. The water supply of soda water factories, dairies, bakeries, food plants and factories and of mineral wells stands under constant sanitary supervision. The data of water analyses of the last 30 years, numbering about 150 000 and the technical data of the wells are listed in a card file, according to geographical location, yielding exceedingly valuable information for a variety of scientific and practical problems. It was e. g. established by the aid of statistical evaluation [83] that the coexistence of several objectionable ingredients in water is far more characteristic of the contamination of well water than greater amounts of any single contaminating substance. It was proved similarly by statistical investigations that contamination of well water in Hungary occurs to the most part within the wells themselves, so that drinking water supply could be significantly ameliorated by prescribing well types of adequate construction.

For the protection of the purity of ducted water the establishment of protective zones was decreed in 1954 by the Ministry of Public Health. The decree is far more detailed than similar ones abroad, as it contains beside general prescriptions also a delimination of the dimensions of the protection zone according to the technique of water obtainment. An entirely new feature of the decree is the prescription of protective zones around water mains.

Surface waters. The sudden industrialization of the country in the last years has brought about the large-scale increase of industrial sewage, causing the gradual contamination of natural waters acting as recipients. To protect the purity of surface waters, the research institutes connected with hydrology have increased their research activity on these waters. Thus the Research Institute of Fish Breeding has carried out the complete study of three watercourses.

As the contamination of surface waters imperilled the purity of municipal drink water wells situated on the banks of the former, detailed chemical and bacteriological control of surface waters was commenced in 1951 by the Institute of Public Health. Ever since, the analysis of 118 waterways and lakes has been carried out at average intervals of one quarter year. In summarizing the results of these analyses a file of surface water quality was established and continuous quality control of superficial waters inaugurated. Scientific personnel of the Institute gave account of their investigations into the contaminations of the Sajó and Tisza Rivers.

Mineral and medicinal waters. The detailed chemical analysis of the Sóshartyán, Szécsény, Nógrádszakáll, Tótkomlós and Pesterzsébet mineral and medicinal waters was carried out by the State Geological Institute.

The quality control of mineral and medicinal springs is the duty of the Institute of Public Health. In this connection the analyses of a number of recently explored mineral and medicinal waters were executed beside several hundred routine control analyses. On the hand of analysis results, mineral and medicinal waters were relegated into 10 groups [84] and a file of mineral water quality established.

An up-to-date survey of the radium content of our mineral and medicinal waters was also carried out by the Institute of Public Health. Radioactive mineral waters were classified according to these results into 5 groups. The lower limit for a well to be classed as radioactive was established at 1 mμ C/l.

Medicinal mud. The studies of the Geological Institute concerning the occurrences of medicinal mud are great value. The mud of the Hajdúszoboszló, Héviz [86] and Harkányfürdő mineral waters and of the Velence and Balaton lakes were subjected to up-to-date investigations.

At the Geological Institute the chemical composition of the water squeezed out of some muds was also examined [87]. It was established that only squeeze waters containing larger amounts of organic material were medically beneficient, in probable connection with the hydrogen sulphide formed out of, and the oestrogene hormones contained in, organic colloides.

Sewage. In this field special mention has to be made of the theoretical paper entitled "Sewage and river water", by R. MAUCHA of the Research Institute of Fish Breeding, opening up new lines of thought in the theory of the sewage receptivity of recipients.

The Institute of Public Health also controls the functioning of household and industrial sewage purifying apparatuses, with special regard to hospital sewers. A file of purifying plans and apparatuses has also been established. Of the industrial waste waters those of slaughterhouses have been attended to lately.

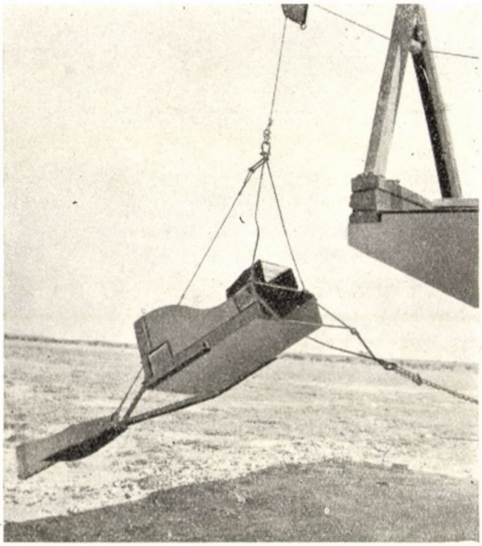


Fig. 2 — Bed-load trap

Hydrobiology. Closely connected with hydrochemical research is the study of production biology, considering the variations of dissolved oxygen, exploitable carbonic acid, concentration of hydrocarbonate and carbonate ions, and the changes in illumination. Of the studies on this topic those concerned with the determination of the productive capacity of waters have to be emphasized [89]. Of special interest is the treatise on the energetical and productive biological explanation of hydrochemical variations of the Velence lake, giving simultaneously the amount of organic material produced [90].

Water economy. It was only in the last few years that attention was called in Hungary upon industrial water exploitation. The studies of the Institute of Public Health are connected with the qualitative and quantitative aspects of the correct water economy of industrial plants [91].

The preparation of graphs indicating the quantity, quality and temperature relations of water input and sewage output was proposed to facilitate the control of correct industrial water utilization.

Of the activity of the *Institute of Rheumatism and Balneology*, directed by the DR. Ö. SCHULHOF, the investigations of Mrs. A. R. LIGETI concerning the technology of semi-artificial bath water preparation at the Parád waterings place are to be mentioned, beside the study of B. BÁNYAI on the alteration of carbonyl sulphide into alkalic sulphide in basic environment, and that of J. LORENZ R., on the methods for the simultaneous determination of sulphur in different bonds in Hungarian medicinal waters.

Hydrometric research. Routine hydrological activity occurs, beside the hydrometric group of the Research Institute of Water Resources, also at the individual District Water Boards. In the solution of problems arisen in the course of measurements, help is given to the above institutions by the Hydraulic Construction Institute No I of the Technical University, directed by Professor E. NÉMETH. This Institute is responsible for the instruction of hydrology and hydrometry, whereas hydrometric practice is carried on at the Nagymaros hydrometric station of this Institute. In the course of practice students learn cross-section surveying, velocity determination, surface slope measurement, determination of suspended and bed, load, while at the opposite shore, in the neighborhood of the village Visegrád, the surveying of the cross, and longitudinal sections of a smaller creek and the determination of its discharge by the salting procedure is on programme.

In the course of research in the Budapest Laboratory of the Institute a number of problems has attained theoretical as well as practical solution, in some cases on the hand of experiences collected during measuring practice at Nagymaros. However, there vere several problems postulating hydraulic laboratory experiments. The workshop of the Institute also played an important part in improving instruments, discovery of sources of error, and in the development and sometimes manufacture of new research tools.

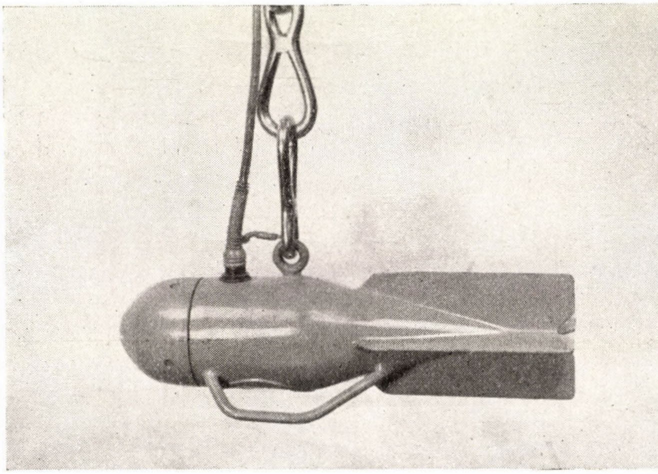


Fig. 3 — Bed-load noise detector

The bed-load trap of Z. KÁROLYI's design was investigated by the Institute as early as the end of World War II, whereby the most advantageous shape of this instrument was experimentally established [93]. (Fig. 2)

It was in connection with this same problem that the first bed-load noise detector of Hungarian design was prepared on an assignment by the Győr Conservancy Board, in the workshop of the Institute, according to a proposal by Z. KÁROLYI, under the direction of Professor E. NÉMETH, after the plans of L. IVICSICS and with the co-operation of Lecturer J. BOROS and mechanic K. ASZTALOS. A number of experimental measurements were carried out with the instrument before it was given its final shape and delivered. Since that time the apparatus yields satisfactory results in tracing zones of most intense bed-load movement along cross-sections [94]. (Fig. 3)

As it is widely known, the determination of slope on rivers is subject to a source of error due to the rippling of water, inhibiting correct establishment of water level altitude. This source of error was successfully eliminated in the course of practice in Nagymaros by the ripple damping apparatus developed at the Institute.

To determine irrigation water consumption, E. NÉMETH carried out laboratory experiments with a venturiflume of linear calibration. On the hand of results on three models to different scales he determined the constants of the linear relation and the head loss occurring on measurement with this type of meter. It was shown by experiments that the calibration of the meter can also be carried out experimentally if using at least three models of different scale [95].

Hydraulic experiments with linear-scale weirs and circular orifices were also performed at the Institute.

At the Research Institute for Water Resources a "Hydrographic Manual" was prepared on the basis of the enormous amount of experience accumulated at that institution. Hydrometric activity was furthered by the improvement of a number of instruments (the Berényi wing for velocity measurements, the baton float system of Tarnóczky, etc.).

IV. Hydrological research in the years 1954—56

The activity of this period stood under the influence of two important circumstances. One of them was the fact that the Research Institute for Water Resources (abbreviated VITUKI), successor of the Hydrological Department, attained around 1954 full efficiency for coping with the tasks imposed upon it by its enormous field of work. The second circumstance consisted in the centralization of the state control of water economy under the National Water Board. Since that time the VITUKI, the research organ of that institution, obtains therefrom directives for the practical directions of hydrological research, whereas scientific research, essential for the solution of long-range problems, is directed by the Hungarian Academy of Sciences, more precisely by the High Council of Hydrology, headed by A. Vendl, Member of the Academy.

In the sense of the above said the activity of the Research Institute may be classed as follows :

1. Collection, evaluation and publication of hydrological information, forming the basis of water economy research and planning.

2. Scientific investigations into the principles of hydrology and hydraulics.

3. Research on the solution of practical water economy problems.

4. Documentation work, serving water economy research, planning and construction.

The full-scale activity of the VITUKI has also brought about significant changes in the distribution of research activity amongst State institutions and social organizations. On a social level, as it was stated above, research is concentrated in the Hungarian Hydrological Society.

Under the leadership of E. Mosonyi, President of the Society, Corresponding Member of the Academy, the Society tackled with success a number of problems connected with the rapid establishment of unique water economy. The problems of the working committees, the topics of lectures and symposia were selected so as to possess beside scientific interest also a bearing on the question of planned water economy.

With the establishment of new institutions and with the increase of scope of the old ones, the field of work of the Society was also altered in 1954. While in 1952 there were three sections with no more than 700 to 800 members, the number of the latter increased to 1300 until the beginning of 1953. In the Budapest branches si sections were at work and there were four further branches in the country (in Szeged, Pécs, Miskolc and Győr) in which there developed a seething life after some initial difficulties. Beside scientific questions the most urgent problems of agriculture, water supply, sewage treatment, irrigation, modernization of surface water husbandry, canalization of the Tisza River were furthered and revised.

In 1953 the strengthening of the organization of water economy was already to be felt. Therefore, less problems were left to the sections of the Society, as an increasing number of problems was attended to by official organs. Nevertheless, lectures on manifold industrial problems, continued and symposia gradually tended towards practical questions.

Beside a series of symposia hydrological congress was held in September, 1955, by the Hydrological Society, on the 70th anniversary of the Hungarian Hydrographical Service, with Soviet, Austrian, Czech, Yugoslav, Polish, Bulgarian, German and Roumanian participants. Main themes of the congress were the hydrological aspects of shipping, river regulation, flood protection, drainage, irrigation and river canalization.

In the same year a commemoration festivity was held by the Society on the 160th birthday of P. VÁSÁRHELYI.

At the conferences of the High Council of Hydrology and the Special Councils of Irrigation, Drainage, Water Supply and Sewage Disposal, scientific problems having important bearing upon practical problems were discussed. In order to correctly coordinate scientific efforts the High Council has revised the programmes of scientific institutions, and in the case of wide-scope problems it even gave directives for the ways of solution to be taken. The High Council also paid special attention to the national water economy plan, of great importance from the point of view of water economic activity.

Corresponding to the principle of coordination, the activity of individual research institutes is much interrelated. Most of the work lies in the field of the Research Institute for Water Resources (surface waters, subsurface waters, water quality control, hydraulic model experiments), and is carried out in the pertinent division of that Institute. This vork is supplemented by the specific activity of other research institutes (Meteorological Institute, Geological Institute, Forestry Research Institute, Research Institute of Ichthyobiology, Institution of Public Health, Hydraulic Construction Institutes Nos I and II Geo-Mineralogical Institute of the Technical University).

In our report we have to mention beside the fields above-named also those of erosion control and hydrometry.

Surface waters. Of the activity of the pertinent division of the VITUKI, standing under the direction of W. LÁSZLÓFFY, we will note the following :

The basis of water economy planning being the knowledge of available surface water reserves, the activity of the division was begun by preparing the discharge statistics of surface waters. This work, encompassing at present

159 water gauge profiles, had to be preceded by well-founded methodological studies, as the stage-discharge relation is by no means unequivocal or time-independent in most of the profiles. It had to be considered furthermore that discharge statistics being the basis of all further hydrological research, it had to be manipulated with the utmost possible precision. The first assessment of exploitable water reserves of the country was made on the basis of discharge statistics. In the course of this work the specific run-off maps of the drainage areas of Hungarian rivers as well as the hydrological longitudinal profiles of main streams were prepared.

One of the objects of the division is the systematic exploration of the hydrology of our country, and the scientific systematizing and publication of the valuable observation material accumulated during the last twenty years' activity of the Hydrographic Service. Beside the discharge statistics above-mentioned, forming the basis of hydrological research, the preparation of the Hydrological Atlas of Hungary has to be mentioned. The volumes of the Atlas, appearing at random intervals in three series. The first one is entitled "Drainage areas of our rivers" and contains the summary of the most important geographic and observation network data. These volumes contain beside the description of the general build-up and water network of the drainage area the detailed area data of the drainage areas of confluent rivers, the concise illustration of relief features, forest coverage, precipitation and temperature relations, the summary of hydrological data and geological, geographic, meteorological and hydrological literature on the area. Six volumes of this series have been published up to now. The second series is entitled "Hydrometeorological data", the third one "Hydrography of our rivers". The first volumes hitherto published summarize the precipitation distribution and the characteristic water levels of the country.

Among the items of fundamental research may be listed the water economy investigations on certain selected drainage areas, illustrating the relations of precipitation, run-off and evaporation on the basis of the monthly water balance. The first result of immediate applicability in practice was the construction of reliable references for the determination of the evaporation of water surfaces and entire drainage areas by K. Szesztay [96].

Similarly of great practical interest is the huge field of hydrological forecasting [97]. After the development of methods suitable for use in our country, forecasting aids were prepared for the following purposes :

forecasting of flood crests on the Danube and on the section of the Tisza above Tokaj, on the hand of peak values observed at points situated farther upstream,

the same, considering the amount of rain fallen upon the drainage area, the continuous forecasting of water stages expectable at the main water gauges of the Danube.

This is the place to mention further investigations connected with floods : thus e. g. the determination of design flood stages for the construction of flood protection works for our more important rivers [98], the connected investigation of the silting up of the stream bed of the Upper Danube and — last but not least — the development of the calculation method for approximate determi- nation of the probability of any value of flood discharge on streams lacking adequate hydrological investigation, filling in a very urgent gap of designing practice.

In connection with floods also a series of hydrotechnical problems had to be investigated. In this connection seepage phenomena occurring on flood levees and in the soil at flood times were intensely studied by both the Institute of Hydraulic Construction No I and the VITUKI. The former did the laboratory and theoretical work, while the latter investigated selected parties of the Danube, Tisza and Körös levees.

Similarly led by hydrotechnical points of view were the hydrological studies of the Bureau of Hydraulic Design directed by Professor E. MOSONYI, connected with the canalization of the Tisza River, the foundation problem of Danube hydro power stations, and the effects of planned backup upon adjacent ground water. Institute of Hydraulic Construction No II carried out model experiments imitating the Visegrád section of the Danube. The experimentally determined streamlines were checked by photographing at night from adjacent hilltops the tracks of flares floating down the Danube]99]. (Fig. 4.)

Fig. 4. Streamlines of the Danube photographed at night

In former times, there was almost a total lack of interest as to the load transport of our rivers. This branch of science was developed in our country to the most part in the later years, although prior to the establishment of the VITUKI. Our scientists have attained significant theoretical and practical results and it may be stated that a period of river sediment research was ended. after five years' work with the publication by the Academy of Sciences of the book by the DR. J. BOGÁRDI summarizing this large investigation complex [100]

The accumulation of surface water had to be attended to from the point of view of economic development of stagnant-water drainage. Research was focused upon five points : intensity of precipitation, run-off factor, specific discharge, water household equation and the role of precipitation accumulated as snow and ice in the formation of drainless pools. Studies on precipitation intensity will be dealt with below.

In connection with the determination of the run-off factor studies were chiefly concerned with the effects of previous precipitation and the water household properties of soils, pointing out simultaneously the lines of development of more efficient research methods. We succeeded in determining specific discharge for the entire area of the Great Plain ; at present, values of specific discharge most adequate for planning purposes under the present economic circumstances are available for all areas of inland water accumulation ; there are also specific discharge values ordered according to power functions to facilitate more detailed calculations on rentability.

For the determination of specific discharge, maps were prepared to illustrate this parameter or one of its partial factors for the entire country and for the entire Carpathian Basin [101]. Intense studies concerning the physical classification of drainage areas in the Great and Little Hungarian Plain were made by P. SALAMIN, the results of which give valuable help in planning further research [102]. At the same time, SALAMIN has proposed a method of designing flatland drainage systems, considering to a greater degree the modes of apparition of surface waters and the non-permanent nature of their movements. The role of snow and ice was cleared to an increasing extent by latest studies, indicating the lines of approach to determining the temporal and spatial distribution of the run-off from snow melts.

It was possible to define in the possession of several thousand observation data the variation of the water content of snow cover with altitude above sea-level, as well as the effects of vegetation upon the water content, thickness and bulk density of snow [103]. These studies of superficial water accumulation were partly made by the Institute of Hydraulic Construction No. I, partly by the VITUKI and the Bureau of Hydraulic Designing.

In 1956 a model experiment to determine the hydraulics of water accumulation was commenced under the direction of E. NÉMETH. At the Nagymaros experimental station of the Institute of Hydraulic Construction No I. an 1 : 35

scale undistorted model of the sample drainage area, investigated in the Mátra Mountains by the Institute of Forestry Research, was prepared together with an artificial rain machine. The model is equipped with adequately reduced rain-gauges and recording discharge meters. At present preliminary experiments are under way. It is desired to determine the relationships governing the hydraulics of accumulation by comparing experimental results with parameters of the life-size drainage area.

Subsurface waters. Research was concentrated upon the location and motion of ground water, the quantity and qualityof Karst water and seepage problems important from the point of view of irrigation and drink water supply.

Of the studies on relations governing ground water stage fluctuation we note some of those carried out by the Division of the VITUKI directed by Gy. Szilágyi. To secure the accumulation of experimental and observation data concerning the laws of ground water stage fluctuation and the interrelations of meteorological factors and ground water, the former ground water observation network was much developed by the Division, so that now it consists of 2 200 observation wells. In the region between Danube and Tisza, at Kecskemét the so-called *Ground Water Research Plant* was developed and equipped beside a climatic station and several ground water wells also with a big-size infiltration meter. The research plant served mostly to establish and gradually develop the methods of investigation of ground water stage variation.

By evaluating the data of 175 ground water observation wells of sufficiently long observation series the relation of ground water rise to the total precipitation of the winter half-year and of the average ground water level to air temperature were established. On the basis of these relations the parameters characterizing average ground water fluctuation, such as the lag of fluctuation with respect to air temperature variation, average periodic oscillation, the percentage of winter half-year's precipitation affecting recharge and the relation of ground water level variation to depth below surface were determined. It was established that in regions uninfluenced by river oscillation the most important factors governing ground water level variation were evaporation loss and infiltration of precipitation. In the field of ground water research excellent results were obtained by K. Ubell, after the pioneering work of the Dr. J. Bogárdi [104].

The relations mentioned above as well as some others deducted in the course of research have made possible the solution under certain circumstances of the water household equation, the forecasting of maximal ground water level in spring and several other practical problems.

In connection with this research, it was stated by E. Németh on the basis of a long-range ground-water-well observation series that there exists an elliptical correlation between ground water depth and the averages of the environment [105].

Research concerning water supply was coordinated with theoretical work, some results of which concerning pipe and antenna wells were attributable to GY. SZILÁGYI [106].

In the Budapest Laboratory of the Institute of Hydraulic Construction No. I. the hydraulics of seepage towards wells was investigated on the hand of model experiments by G. ÖLLŐS, with the simultaneous determination of

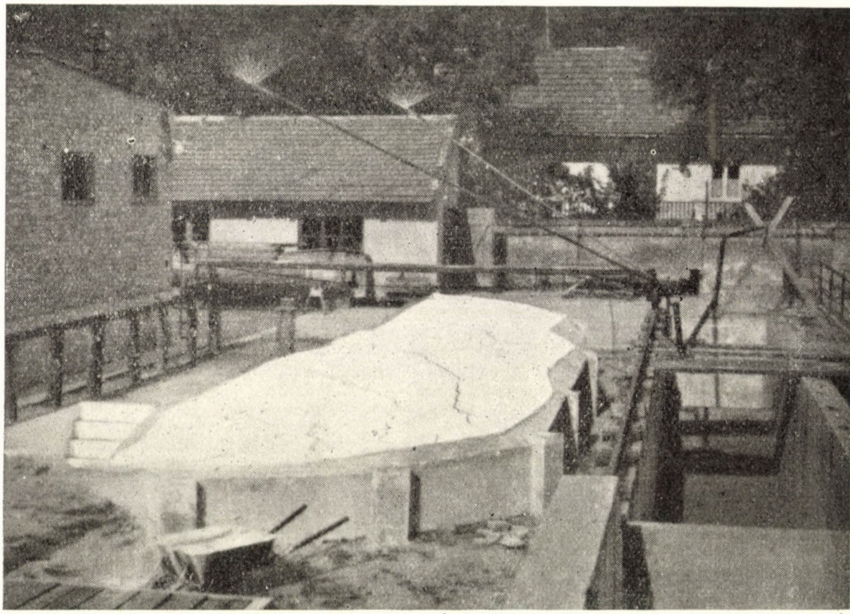


Fig. 5. Model for investigations of wateraccumulation

partial inflow values from individual aquifers in the case of inhomogeneous soil structure. (Fig. 6.) Aspirant L. SZABÓ, appointed as assistant of the Professor, investigated the effect of lateral seepage, whereas SZ. K. BOZÓKY was engaged in studying water motion along slopes in the laboratory and in the experimental plant at Nagymaros [107].

In connection with Karst waters a spring cadaster was established by the VITUKI, registering at present more than 700 springs. 90 per cent. of this total are Karst springs, yielding the water supplies of some of our industrial centres. Springs were characterized by a dependability index (the quotient of maximum and minimum discharge) closely related to geological circumstances. The greatest amount of disadvantageous properties is exhibited within the zone of descendent karst water, by springs surging from limestone whereas dolomite karst springs are somewhat better and springs feeding from the deep carst most reliable. At the some time, directives were developed for the modes of spring catchment.

In addition to this work there were established two areas of karst water observation, with the object of obtaining in a number of Karst water wells of adequate depth the data necessary for the determination of relationships governing Karst water level variation. One of the areas is situated North of Lake Balaton, the other one in the karst around Keszthely. The level fluctuations of stable karst water level, the relation of spring discharge to this variation, the equilibrium of Karst water exploitation and recharge were studied on the hand of data obtained in these two regions and in other karst areas.

In connection with the study of Karst water, the time of infiltration of 80 to 100 millimeters of artificial rain and the related alteration of the chemical composition of Karst water was investigated around the Pálvölgy cave, Budapest and on the Bükk Plateau. Object of these studies was the improvement of reliability of karst water exploration.

It became evident on the hand of karst water studies and the data of spring recording that the wells of Hungary are governed mainly by precipitation and that their discharge depends on the so-called design precipitation percentage, i. e. the ratio of the first four month's precipitation to that of the entire year. The relations established hitherto in connection with karst water level variation are the results of studies by H. KESSLER [108].

The State Geological Institute has finished ground water mapping. The results of this work were dealt with by the head scientist, A. RÓNAY in a monograph containing a number of multicolored maps, soil profiles and water quality data [109].

The Karst Water High Council of the Academy of Sciences headed by M. VENDL co-ordinated karst water research from the geological point of view. At the Karst Water Symposium, held in 1954, the proposal of karst water exploration on a geomechanical basis by R. E. SCHMIDT was discussed.

Hydrometeorology. The scientists of the Meteorological Institute were engaged chiefly in studying the formation of precipitation and extreme precipitation conditions. L. AUJESZKY and F. DÉSI summarized in 1954 for the first time in the a special monograph the topic of artificial rain suscitation and climate influencing and found the theoretic importance of the success of artificial interference verified by the BERGERON—FINDEISEN rain theory [110].

In another paper, AUJESZKY has treated the possibilities of artificial rain production [111]. Theoretical studies on the process of rain formation are under way at the Budapest-Lőrinc Observatory of the Meteorological Institute [112]. F. HAJÓSY has reported on the principles of determining a hydrological sequence of the observation posts of a close-meshed network in a larger drainage area, and on the successful application of these principles [113].

The data collected on the variability and the extremities of precipitation at Budapest were evaluated by J. KULIN [114].

The Institute has subjected the circumstances of the great 1952 summer drought and the consequent great autumn rains to careful study, in their relation to high-altitude atmospheric conditions.

A process for homogenizing long-range precipitation observation series was proposed by K. SZESZTAY of the VITUKI [115]. Aspirant Z. SZIJGYÁRTÓ applied the methods of mathematical statistics to the determination of the distribution and duration of rainless intervals and to the extreme values of precipitation in periods of one month or more [116].

Hydrochemistry. Practically, all the Hungarian streams, 131 in number, were subjected to water quality control by the Water Quality Division of the VITUKI. Samples were taken in some 630 localities, on the average in four subsequent instances, and investigated partly in the field and partly in the laboratory for physical, chemical and biological properties. In this way a clear picture of the chemical composition and of contamination of our waters was obtained [117]. Research was also done to define and introduce a "contamination Index".

In the line of water-chemistry methodics investigations were carried out *a)* to determine the sulphide ion by complexonometry ; *b)* to determine the calcium ion by flame photometry in the presence of abundant contamination ; *c)* to determine the cyanide ion, *d)* to determine minute amounts of phenol, and *e)* concerning the methodical problems and applicability of processes of oxygen consumption determination.

Quality of underground waters. The water quality data of soil water were compiled mostly from the technical point of view, on the hand of investigations by the VITUKI and by related organizations. At present there is a 1 : 50 000 scale map of the entire country, indicating all wells of which chemical analyses, were made and on which isohypses of equal sulphate contents, hardness, and the type of water are marked. The material will be published in all probability to a 1 : 200 000 scale.

Investigation of irrigation waters. The study of the filtrating watersnof alkali soils west of the Tisza is especially important for the defence against soda accumulation in insuffciently irrigated soils. The evaluation of the data of stream analysis from the point of view of irrigation, and comparative studies on irrigated soils are under way [118].

Erosion. At the Forestry Research Institute, G. LÁDY has carried out experiments concerning erosional effects observable on an intensely eroded zone, a zone of average erosion and a zone standing under the protection of a 12 years old wood belt of 4 m breadth perpendicular the slope, all of these being situated in a hilly area with loess soil [119]. The observations have pointed out that

1. As compared to other zones, erosion decreases and humus accumulation increases in the zone protected by the wood belt.

2. $CaCO_3$ content, whose values above a certain limit may lead to rapid exsiccation of the soil, decreases by the effect of the wood belt.

3. The sum of *hy* values, characterizing the water household, will increase in consequence of the wood belt, because of the increasing thickness of fertile soil.

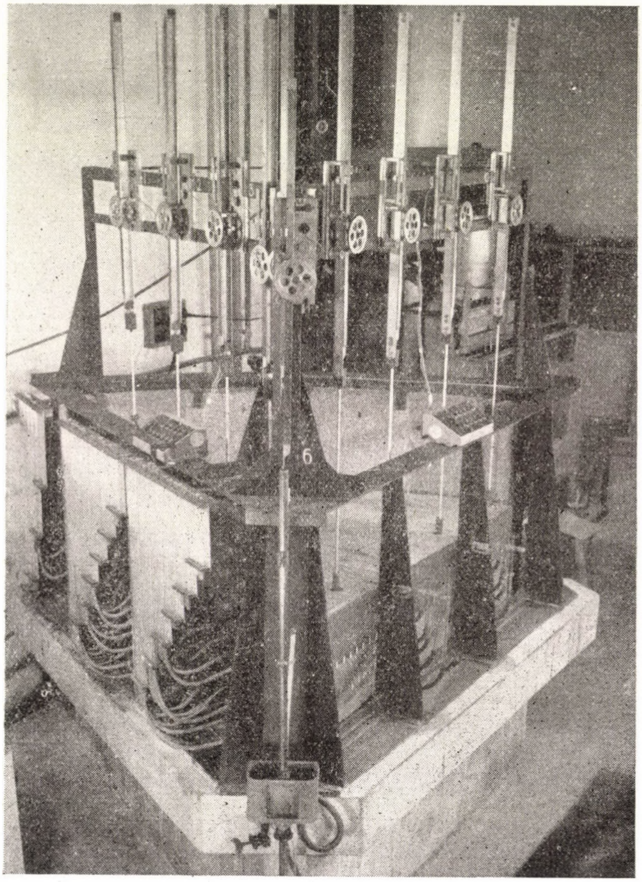


Fig. 6. Model for ground water movement to wells

A standard proposed concerning the afforestation of mountainous and hilly barren lands waps repared by I. HÉDER.

For the purpose of the exact study of erosional phenomena a sample area of about 5 hectars was delimited on a barren pasture of the Mátra Mountains. The area is part of the drainage area of a small periodic creek. The accumulated water discharge and its detritus content is measured by an adequate apparatus at a favourable place. The object of these studies is the determination of the processes of erosion by water, the study of the factors influencig erosion, the determination of the order of magnitude of these factors for badlands in different stages of erosion at different points of the grazing areas of hilly and mountainous regions on andesite, rhyolite, their tuffs and the superimposed clays, claystones and soils.

It was attempted to determine by these observations, 1. the influence of the quality and the broken or fissured state of the basement rock below shallow cover of inadequate water supply upon the percentage of runoff, 2. the influence of the compactness of topsoil upon the velocity of run-off and the intensity of erosion, 3. the effects of the presence and quality (swelling, non-swelling) of argillaceous colloids, 4. the effects of wind intensity and direction, with special respect on the deviation of precipitation.

Hydrometry. A great importance was attributed by the VITUKI to the solution of the measurement problem of irrigation water. Thus the adequacy of some discharge meters was checked by laboratory tests. The laboratory has investigated the applicability in case of water carrying detritus of shunt-connect discharge meters mounted on pipes and of reduced-length Pikalov discharge meters to be built in two open channels.

K. Fazekas was engaged in the improvement of several hydrometric instruments : it was he who developed the prototype of the recording water gauge [120]. B. Weimann gives account on bed surveyings made with echograph [120].

In the Institute of Hydraulics No. I of the Technical University, E. Varrók has made laboratory tests on instruments measuring small water velocities [122]. Theoretical studies concerning the determination of creek discharge by salting were carried out by I. Vágás [123].

In the workshop of the Institute float-type discharge meters were prepared for observations in ground water wells on the request of the Civil Engineering Firm. The hydrometric instrumentation of the erosion sample area of then Forestry Research Institute was also prepared at the workshop of the Institute.

BIBLIOGRAPHY

1. Fodor F. : Az Institutum Geometricum, az egyetem bölcsészeti karán 1782-től 1850-ig fennállott mérnöki intézet. (The Institutum Geometricum, the Institute of Engineering, existing between 1782 and 1850 at the Faculty of Sciences of the University.) Budapest, 1955. With French, German and Russian summary.
2. Hadaly K. : Elementa hydrotechnicae . . . 1783.
3. Vásárhelyi Pál : A sebesség fokozatáról folyóvizeknél, felvilágosítva egy a Dunán mért keresztmetszés és abban talált sebességek által, továbbá a Duna vízemésztéséről különböző vízállásoknál. (On the degrees of velocity in streams, as illuminated by a cross section measured across the Danube and the velocities found thereby, and further on the water consumption of the Danube at different level heights.) A Magyar Tudós Társaság évkönyve, 1845.
4. Humphreys A. A. — Abbot H. L. : Report upon the physics and hydraulics of the Mississippi river . . . Philadelphia, 1861.

5. Arenstein J.: Eisverhältnisse der Donau, beobachtet in Pesth in den Jahren 1847/48 und 1848/49. Sitzungsberichte der k. Akademie d. Wissenschaften, Bd. V., Wien, 1849. — Idem pro 1849/50. Bd. VI.
6. Suess E.: Über das Grundwasser der Donau. Österr. Revue, 1866.
7. Greguss Gy.: A Dunavíz hőmérséklete. (The temperature of Danube water.) Mathematikai és Természettudományi Közlemények vonatkozólag a hazai viszonyokra. Vol. IV. Bp. 1866.
— *Idem:* Temperature of the water of the Danube, ibid.
8. Balló M.: A Duna folyam vegyi viszonyairól Buda-Pest mellett. (On the chemical relations of the Duna River around Budapest.) Math. és Termtud. Közlemények, Vol. XI. Bp. 1873.
9. Révy J. J.: Hydraulics of Great Rivers. The Paránà, the Uruguay and the La Plata Estuary. London, E. F. N. Spon, New York, 1874.
10. Harlacher A. R.: Die Messungen in der Elbe und Donau und die hydrometrischen Apparate und Methoden des Verfassers. Leipzig, A. Felix, 1888.
11. Hajós S.: Hidrometria. (Hydrometry.) Budapest, 1906.
12. Kvassay E.: Note sur le moulinet de Voltmann. Annales des Ponts et Chaussées, 1877. 1ère semèstre, p. 236.
13. Péch J.: Die Hydrographische Section, ihre Entstehung, Inaugurierung, Aufgabe und die Ergebnisse ihrer bisherigen Tätigkeit. Budapest, 1897.
14. Ministère R. Hongrois de l'Àgriculture: Organisation du Service National Hydrométrique en Hongrie. Budapest, 1899.
Péch J.: Le Service National Hydrométrique en Hongrie, Bp. 1900.
Hydrometrischer Dienst in Ungarn. Budapest, 1900.
15. Péch J.: Prévision des crues. Budapest, Min. de l'Agriculture, 1897. Wasserstandsprognose. Studie über die Voraussagung der zu erwartenden Wasserstände. Bd. Bp. Ackerbauminist. 1895.
16. Bogdánffy Ö.: A téli csapadék és a Tisza tavaszi árvizei. (Winter precipitation and the spring floods of the Tisza.) Vízrajzi Évkönyv, Vol. IX. Bp. 1900.
— Hidrológia. (Hydrology.) Magyar Mérnök- és Építész-Egylet kiadványa, 1901.
— Természetes vízfolyások hidraulikája. (Hydraulics of natural stream flow. — Two volumes.)
17. Szilágyi B.: Nivellements de haute précision de 1895 à 1899 de la Section Hydrographique de la Direction Nationale du Service des Eaux, Budapest, 1900.
18. Hajós S.: Neues Verfahren bei Strommessungen mit dem Woltmann'schen Flügel und Vorrichtungen zu demselben. Detaillier Methode. Budapest, Calderoni und Comp. 1902. L'état actuel des jaugeages en Hongrie, Bp. 1900.
19. Hajós S.: Jaugeauges en Hongrie. Annales des Ponts et Chaussées, 1898 Beiträge zur Frage über die Umlaufwerte Woltmann'scher Flügel. Verbands-Schriften d. Deutsch-Österr.—Ungarischen Verbandes f. Binnenschiffahrt, Budapest, 1901.
20. Protokoll über die erste Zusammenkunft der Vorstände der hydrographischen Aemter von Deutschland, Frankreich, Italien, Österreich, Ungarn und der Schweiz am 30/31 Juli, 1914.
21. Kolupila, Steponas: Hidrometrija. I—II. Kaunas, 1939—40.
22. Weissmahr J.: Vízsebességméréseink hibái és csökkentésükre vagy kiküszöbölésükre szolgáló módszerek és eszközök. (Error sources of our water velocity measurements and methods and devices for their control and elimination.) Vízügyi Közlemények, 1918. I. No. 3.
23. Viczián, E.: Rapport entre les précipitations atmosphériques et le débit de drains ou des canaux. — Studien betreffend das Verhältniss des gefallenen Niederschläge zu den abfliessenden Wassermenge. VIIIe Congrés International d'Agriculture, Vienne, 1907. Section V., Rapport 4.
24. Viczián, E.: Magyarország vízerői. Általános felvétel. (Water powers of Hungary. General survey.) Budapest, 1905. Second edition, 1913.
25. Lóczy L. id.: A folyóknak mint geológiai tényezőknek munkája. (The work of rivers as geologic factors.) Magyar Mérnök- és Építész-Egylet kiadványa XV.
26. Commission Technique Permanente du Régime des Eaux du Danube: Protocoles des séances tenues à Tercianské Teplice en mai 1929. Roma, 1930. — pp. 25—42.
27. Németh E.: Vízmérceállások és vízmennyiségek összefüggése. (On the stage-discharge relation.) Vízügyi Közlemények, 1929.
28. Lászlóffy Woldemár: A hidrológiai kutatás különös tekintettel a hidrográfiai adatszolgáltatás mai állására. (Hydrological research, with special respect to the present state of hydrographic information.) Vízügyi Közlemények, 1930.

29. Ministère R. Hongrois de l'Agriculture : Institut hydrographique: Compte rendu de l'étude de la crue du Danube en 1926 dans le secteur prés de l'embouchure de la Drave. Bpest, 1929.
30. Commission du Régime des Eaux du Danube : Études sur le régime des glaces du Danube. Milan, U. Hoepli, 1934.
LÁSZLÓFFY W. : A folyók jégviszonyai, különös tekintettel a magyar Dunára. (Ice conditions of the rivers, with special respect to the Hungarian section of the Danube). — Vízügyi Közlemények, 1934.
IHRIG D. : Az 1935. évi februári mohácsi jeges árvíz. (The Mohács ice flood of February, 1935.) Vízügyi Közlemények, 1935.
31. LÁSZLÓFFY, W. : Note sur l'observation des Eaux phréatiques en Hongrie. — Die Grundwasserbeobachtungen in Ungarn. Rapport présenté au IX[e] Congrès de l'Union Internationale des Institute de Recherches Forestières, Budapest, 1936.
32. IJJÁSZ, E. : Grundwasser und Baumvegetation. „Erdészeti kutatások" 1938—39.
33. MADOS, L. : Talajismeretek hasznosítása a belvízrendezés terén. (The utilization of pedologic knowledge in drainage work.) Öntözésügyi Közlemények, 1940.
A Tisza, Hármaskörös, Hortobágy folyók és a hortobágyi tározómedence vizének vizsgálata. (Study of the waters of the Rivers Tisza, Hármaskörös and Maros and of the Hortobágy reservoir.) Öntözésügyi Közlemények, 1941.
34. REPP-NOWOSAD, G. : Kultúrnövények élete szikes talajon. (The growth of plant cultures on soda soils.) Öntözésügyi Közlemények, 1944.
35. LAMPL, H. : Az országos Öntözésügyi Hivatal 1941. évi jelentése. (Report of the Hungarian Bureau of Irrigation, 1941.) Öntözésügyi Közlemények, 1942.
36. HAJÓSI, F. : A csapadék havi középértékei Magyarországon. (Monthly averages of precipitation in Hungary.) Vízügyi Közlemények, 1934.
NÉMETH, E. : Az öntözés előfeltételei és lehetőségei. — A Tiszántúl öntözése. (Conditions for and possibilities of irrigation. — Irrigation East of the Tisza River.) — M. K. Földművelésügyi Minisztérium, 1937. No. 6. p. 57.
37. CHOLNOKY J. : Magyarország földrajza. (The Geography of Hungary.) Pécs, Danubia, 1929.
— Folyók szakaszjellegének összefüggése a szabályozással és az öntözéssel. (The variation of the phase characteristics of rivers with regulation and irrigation.) Vízügyi Közlemények, 1934.
38. BOGÁRDI J. : Hordalékmozgás a folyószabályozásban. (Load movement in irrigation.) Vízügyi Közlemények, 1942.
39. KORBÉLY, J. : Az árvizekről. (On floods.) Vízügyi Közlemények, 1915.
40. KENESSEY B. : Az árvizek számítása csapadékból. (Computation of floods from precipitation.) Vízügyi Közlemények, 1928.
NÉMETH E. : Olasz módszerek a lecsapoló csatornákban vezetendő vízmennyiségeknek csapadékból való számítására. (Italian methods for computing water to be drained by canals from precipitation data.) Vízügyi Közlemények, 1934.
NÉMETH E. : A korszerű mezőgazdaság vízi feladatai. (Hydrologic problems of modern agriculture.) Bpest, 1941. A Mérnöki Továbbképző Intézet kiadása.
41. BOGÁRDI J. : A lefolyási tényező és a levezetendő belvízmennyiség. (The run-off factor and the amount of stagnant water to be drained.) Vízügyi Közlemények, 1944.
42. VENDL A. : Über die Bildung des Budner Bitterwasser. Hidrológiai Közlöny. 1933.
Budapest gyógyforrásai közös védőterületének tervezete. (A plan for a common preservation zone of the Budapest medicinal springs.) Hidrológiai Közlöny, XXIV. 1944, 1—3.
43. MOSONYI E. : A hegyvidéki víztározás jelentősége a tiszavölgy öntözéses gazdálkodásában. (The significance of mountainland water storage for irrigation in the Tisza Valley.) Öntözésügyi Közlemények, Budapest, 1943/1.
— A visóvölgyi víztározó medence. (The Visó Valley reservoir.) A Magyar Mérnök- és Építész-Egylet Közlönye. Bpest, 1944/9.
MOSONYI E. : Hegyvidéki nagyobb víztározó medencék hidrogeológiai méretezése. (Hydrogeologic designing of greater mountainland reservoirs.) Vízügyi Közlemények, Budapest, 1947/1—4, 1948/1.
44. BOGÁRDI, J. : Mesure du débit solide des rivières en Hongrie. La Houille Blanche, 1951. Mars—avril, No. 2.
45. KÁROLYI, Z. : Mesures se rapportant au débit solide du Haut-Danube Hongrois. — International Association for Hydraulic Structure Research. Third meeting. 1949.
NÉMETH E. : Hidrológia és hidrometria. (Hydrology and hydrometry.) Tankönyvkiadó. Bpest, 1954.

46. MOSONYI E. : Les Forces Hydrauliques de la Hongrie. La Houille Blanche, Grenoble. 1947/5.
47. CSERMÁK B. : Kisvízfolyások árvízi hozamának számítása. (Computation of flood discharge of small streams.) VITUKI beszámoló, 1954.
PUSKÁS T. : A tiszai árvízszámítás néhány tapasztalata. (Some experiences of flood computation on the Tisza River.) Vízügyi Közlemények, 1954/2.
GYÖRKE O. : A Hernád magyarországi szakaszán mértékadó árvízszint. (The competent flood level on the Hungarian section of the Hernád River.) VITUKI beszámoló, 1955.
LÁSZLÓFFY W. : A hazai árvízelőrejelzés tökéletesítése. (Improving Hungarian flood forecasting.) Vízügyi Közlemények, 1956/3.
SZESZTAY K. : Az árvízi előrejelzések néhány módszertani kérdése. (Some methodological problems of flood forecasting.) VITUKI beszámoló, 1955.
KÁROLYI Z. : Folyóink mértékadó árvízszintje. (Competent flood levels of our rivers.) Magyar Tudományos Akadémia Műszaki Tudományok Osztálya Közleményei, XIX/4.
IHRIG D. : A hidrológiai előrejelzések feladatköre és módszerei. (Scope and methods of hydrological forecasting.) Mérnöki Továbbképző Intézet kiadványa. 2771/1954.
SZILÁGYI J. : Az Átalér és a Váli víz rendkívüli árvize 1953-ban. (Exceptional floods on Váli-víz and Átalér in 1953.) Vízügyi Közlemények 1954/2.
LÁSZLÓFFY W. : A hídnyílások és vízépítési műtárgyak hidrotechnikai méretezéséről. (On the hydrotechnical designing of bridge clearances and hydrological structures.) Mélyépítési Tudományi Szemle 1951/6—7.
KARKUS PÁL : Néhány vízfolyásunk különböző valószínűségi árvízi hozamai. (Probability of different flood levels on some of our streems.) Vízügyi Közlemények, 1953/1.
48. SALAMIN P. : Vízháztartási vizsgálatok. (Water household studies.) Mérnöki Továbbképző Intézet, Bpest, 1954. No. 2169.
Belvízgazdálkodás. (Inland water economy.) Építőipari Műszaki Egyetem Tudományos Közleményei, Bpest, 1955. Vol. I. No. 3. p. 3.
49. BOGÁRDI J. : Korrelációszámítás és alkalmazása a hidrológiában. (Correlation analysis and its application in hydrology.) Budapest, 1952. Akadémiai Kiadó.
— Der Einfluss des Niederschlags und Temperatur auf die Veränderungen des Grundwasserspiegels. Acta Technica Ac. Sci. Hung., Tomus V. Fasc. 2, 1952.
— A várható tavaszi maximális havi közepes talajvízállások előrejelzése az Alföldön. (Forecasting of the maximum monthly average ground water level in the Great Hungarian Basin.) Hidrológiai Közlöny, 1953. No. 11.
— Methodical problems of examining of ground water level in low land area. Acta Technica Ac. Sci. Hung. Tomus VIII. Fasc. 3—4, 1954.
50. KESSLER H. : A karsztvíz feltárása. (Carst water exploration.) Vízügyi Közlemények, 1952.
51. SZÁNTÓ I. : Erdőgazdaságunk éghajlati adottságai. (Climatological conditions of our forest economy.) Erdészeti Kutatások, 1947—49.
52. PAPP L. : Tarvágás hatása az erdő mikroklímájára. (The effects of clear-felling upon the micro-climate of the forest.) Erdészeti Kutatások, 1954.
53. SZŐNYI L. : Az erdei fák vegetációs periódusa és az altalajvíz közti kapcsolatok megállapítása. (Establishment of relations between vegetative periods of forest trees and ground water.) Az Időjárás, 1950.
54. HÉDER I. : Dolomit és mészkő kopárfásítások egyes főbb irányelvei. (Main directives for dolomite and limestone barrenland afforestation.) 1951.
55. HAJÓSY F. : Magyarország csapadékviszonyai 1901—1940. (Precipitation conditions in Hungary, 1901— to 1940.) Meteorológiai Intézet kiadása, Budapest, 1952. p. 157.
56. BERKES Z. : A talajfelszín állapota és a csapadék mennyisége. (The state of soil surface and the quantity of precipitation.) Orsz. Meteorológiai Intézet, beszámoló az 1951-ben végzett tudományos kutatások eredményeiről.
57. KÉRI M. : Problémák a hótakaró éghajlati értékeinek kiszámításával kapcsolatban. (Some problems concerning the computation of the climatological values of snow cover.) Orsz. Meteorológiai Intézet. Beszámoló az 1951-ben végzett tudományos kutatások eredményeiről.
Magyarország hóviszonyai. (Snow conditions of Hungary.) Orsz. Meteorológiai Intézet. Beszámoló az 1951-ben végzett tudományos kutatások eredményeiről.
Hótakaró gyakorisági értékek Magyarországról. (Values of frequency of snow-cover in Hungary.) Orsz. Meteorológiai Intézet. Beszámoló az 1953-ban végzett tudományos kutatások eredményeiről.
58. KULIN I. : Csapadékmennyiségek gyakorisági értékei 50 évi (1901—1950) megfigyelések alapján. (Frequency values of precipitation amounts on the basis of a fifty-year (1901—1950) observation series.)

59. AUJESZKY L., BERÉNYI D. és BÉLL B. : Mezőgazdasági meteorológia. (Agricultural meteorology.) Bpest, 1951.
60. SCHMIDT E. R. : A karsztvízjáratok kialakulásának geomechanikája. (Geomechanics of the formation of carst cavities.) Magyar Tud. Akad. Műszaki Osztályának Közleményei, VIII. 1. 1953.
— Karszt és karsztos hévízforrásaink geomechanikai alapjai. (Geomechanical fundamentals of our Karst and Karstic thermal springs.) Bányászati Lapok, 1953, VIII.
A hidrológia néhány geomechanikai vonatkozásáról. (On some geomechanical relations of hydrology.) Bányászati Lapok, 1953. 12.
Tektonische Studien aus dem ungarischen Zwischengebirge als beispiel zur theoretische und praktischen Anwendung der Geomechanik. Geotektonisches Symposium zu Ehren von Hans. Stille Stuttgart, 1956.
61. ALBER F. : Tanulmány a dorogi bányamező vízelzáró tömörítő fúrásairól és a vízbetörésekről. (Treatise on the inundations and on the water-isolating drillings at the Dorog mine.) Hidr. Közl. 1952.
HORUSITZKY F.: A víz a Föld belsejében (Water in the Interior of the Earth). Hidr. Közl. 1942.
KÁNTÁS K. : A karsztvízkutatás geofizikai lehetőségei. (Geophysical possibilities of karst water research.) M. Tud. Akad. Műsz. és Term. Tud. Oszt. Értesítője, 1950, I.
KASSAI F. : Paleogén szénbányászatunk, a karsztvíz és a védekezés módja. (Paleogene coal mining in Hungary, karst water and the modes of fighting it.) Hidr. Közl. 1948. 1—4.
KESSLER H. : Az aggteleki barlangrendszer hidrográfiája. (Hydrography of the Aggtelek cave system.) Földr. Közl. 1938.
LÁNG S. : Karszttanulmányok a Dunántúli Középhegységben. (Karst studies in the Central Hungarian Mountains.) Hidr. Közl. 1948.
PAPP F. : Dunántúl karsztvizei és a feltárás lehetőségei Budapesten. (The karst waters of Transdanubia and the possibilities of exploring them at Budapest.) Hidrológiai Közlöny, 1941.
PÁVAY-VAJNA F.: A „karsztvíz” és a „karsztvíztérképek”. (On “karst water” and “karst water charts”.) Hidr. Közl. 1950.
PETROVSZKY A. : A dielektromos állandó és a fajlagos ellenállás mérése. (Determination of dielectric constant and specific resistance.) Acad. Sci. Ind. USSR. Petrogr. Traf. Nr. 10. 153.
SZABÓ PÁL Z. : A mecseki karsztvíz. (The karst water in the Mecsek Mountains.) Hidr. Közl. 1940.
SZÁDECZKY-KARDOSS E. : A Dunántúli Középhegység karsztvíztérképe. (The karst water map of the Central Hungarian Mountains.) Hidr. Közl. 1948.
TIHONOV A. N. : A geoelektromos talajvizsgálatok fejlődése a Szovjetunióban a legutóbbi 30 esztendőben. (The evolution of geoelectric soil investigation in the USSR within the last 30 years.) Acad. Sci. USSR. Bull. Geol. 1947. 415.
VADÁSZ E. : A Dunántúl karsztvizei. (Karst waters of Transdanuvia.) Hidr. Közl. 1941.
VENDEL M. : Elektromos triászvízkutatás Dorogon. (Exploration of Triassic Karst water in Dorog by electric methods.) Hidr. Közl. 1941.
VENKOVITS I. : Adatok a dorogi mezozóos alaphegység szerkezetével kapcsolatos üregekhez és vízjáratokhoz. (On the cavities and subterranean watercourses connected with the structure of the Mesozoic basement around Dorog.) Hidr. Közl. 1949.
VITÁLIS S. : A karsztvíz szerepe Budapest szfv. duna-jobbparti részének vízellátásában. (The role of karst water in the water supply of the part of Budapest lying on the right bank of the Danube.) Hidr. Közl. 1937.
SCHRÉTER Z. : A Borsod-Heves vármegyei miocén barnakőszén medencék hidrogeológiai viszonyai. (Hydrogeological relations of the Miocene brown coal basins in the counties Borsod and Heves.) 1950. Bp. Hidr. Közl. Vol. 30. No. 9—10.
AJTAY Z. : A triász-dolomit hidrológiai viszonyai, különös tekintettel a víznyerésre és víz-leadásra. (Hydrological properties of Triassic dolomite, with special respect to water discharge and recharge.) M. Tud. Akad. Műsz. Oszt. Közl. VIII. 1—4.
62. PAPP F. : Ásvány- és gyógyvizeink keletkezése. (The origin of our mineral and medicinal waters.) Bp. 1953.
A források rendszere. Hidr. Közl. 1954.
63. RÓNAI A. : Alföldi talajvíz-problémák. (Ground-water problems in the Great Hungarian Basin.) Bpest, 1953. Alföldi Kongresszus, Akadémiai Kiadó, 41—50.
Újabb adatok a Duna—Tisza közi talajvizekről. (Some new data on ground-water between Danube and Tisza.) 1953, Bp. Hidr. Közl. 33. 5—6.
Talajvíztanulmányok a Duna—Tisza közén. (Studies on ground-water between Danube and Tisza.) 1954. Bpest, M. Áll. Földt. Int. Évi Jel. az 1952. évről.

64. SÜMEGHY J. : Hidrogeológiai adatok a Duna—Tisza közéről. (Hydrogeological data on the region between Danube and Tisza.) 1952, Bp. Földrajzi Értesítő, Vol. 1. No. 2.
Békéscsaba vízellátásának kérdése. (The water supply problem of the town Békéscsaba.) 1952, Bpest, Hidr. Közl. Vol. 32. No. 3—4.
65. WEIN GY. : Hidrológiai adatok a Bükk-hegység K-i részéből. (Hydrological data on the E part of the Bükk Mountains.) Bpest, 1952. Hidr. Közl. Vol. 32. No. 1—2.
SCHRÉTER Z. : A Bükk-hegység régi tömegének földtani és vízföldtani viszonyai. (Geological and hydrogeological features of the ancient massif of the Bükk Mountains.) Bpest, 1954. Vol. 34. No. 78.
66. WEIN GY. : A Mecsek-hegység hidrogeológiája. (Hydrogeology of the Mecsek Mountains.) Bpest, 1952. Földrajzi Értesítő. Vol. 1. No. 2.
SZABÓ P. Z. : A Mecsek karsztvízrendszere. (The karst water system of the Mecsek Mountains.) Bpest, 1953. Hidr. Közl. Vol. 33. No. 7—8.
VENKOVITS I. : Orfü környékének (Mecsek-hegység) vízföldtani viszonyai. (Hydrogeological relations of the environment of Orfü, Mecsek Mountains.) 1954, Bpest. A Magyar Áll. Földt. Int. Évi Jel. 1952. évről.
67. SCHMIDT E. R. : A geomechanikai szemlélet szerepe a karsztvízkutatásban és a karsztvíz elleni védekezésben. (The role of geomechanical thinking in exploration for and defence against karst water.) Bányászati Lapok, 1954, 9.
A karsztvízjáratok kialakulásának geomechanikája. (The geomechanics of the origin of karst water cavities.) M. Tud. Akad. Műsz. Oszt. Közl. VIII. No. 1. 1953.
68. SCHULEK E. : Hidrológiai Közlöny. 1947. Vol. 27. No. 5—8.
69. MAUCHA R. : Hidrochemische halbmicro Feldmethoden. Archiv f. Hydrobiol. 41. Stuttgart.
70. MAUCHA R. : Hidr. Közl. 1954. 34. 1—4.
71. SCHER Á. : Hidr. Közl. 1956. 36. 137.
72. DEMETZKY M. : Doctor of Technical Sciences' Thesis. Bpest, 1943.
73. PAPP SZ. : Gesundheits Ingenieur 1942. 65.
74. PAPP SZ. : Zeitschrift für Analitische Chemie 1943. 125. 9—10. 349—369.
75. PAPP SZ. : Hidr. Közl. 1949. 29. 325—333. Magyar Tud. Akad. Műszaki Oszt. Közleményei. X. 3—4. 473—484.
76. PAPP SZ. : Acta Technica 1952. 437—461. Magyar Tud. Akad. Műszaki Oszt. Közleményei, 1952. 189—204.
77. VENDL A. : Hidr. Közl. 1930. Geologie und Bauwesen 1930. Hydrogeology of Budapest bitter mineral water wells. Proces-verbaux des séances de l'Assemblée générale d'Oslo de l'Union Géodésique et Géophysique Internationale. p. 188. 1948.
ALMÁSY A. : Über sulfathältige Grundwasser. Acta Technica. Tomus V. Fasciculus 2. p. 125.
ALMÁSY A. : Über die Sulfatverminderung der Grundwasser. Acta Technica. Tomus XII. Fasciculi 1—2. p. 139—156.
78. VENDL A.—ALMÁSY A. : Acta Technica, 1952. 125.
79. JENDRASSIK A. : Magyar Mérnök- és Építész-Egylet Közlönye, 1939. 43—44.
80. PAPP SZ. : Acta Technica 1952. V. 457—461. Hidr. Közl. 1953. 33. 129—133.
81. BOLBERITZ K. : Hidr. Közl. 1953. 33. 183.
82. BOLBERITZ K. : Hidr. Közl. 1954. 34. 149.
83. BOLBERITZ K. : Magyar Tud. Akad. Műszaki Oszt. Közleményei, 1953, 497.
84. PAPP SZ. : Manuscript received by the Editor, Hidrológiai Közlöny, 1956.
85. PAPP SZ.—GAÁL L.-NÉ : Hidr. Közl. 1956. 36. 202—207.
86. CSAJÁGHY G. : Hidr. Közl. 1949. 29. 24—27.
87. CSAJÁGHY G. : Hidr. Közl. 1954. 34. 5—7.
88. MAUCHA R. : Vízügyi Közlemények.
89. MAUCHA R. : Magyar Kémikusok Lapja, 1947. 2.
90. DONÁSZY E. : Hidr. Közl. 1953. 33. 286—292.
91. BOLBERITZ K. : Hidr. Közl. 1953. 32. 430.
92. BOLBERITZ K. : Vízügyi Közlemények, 1953. II.
93. KÁROLYI Z. : Mesures se rapportant au débit solde du Haut-Danube Hongrois. — International Association for Hydraulic Structure Research. Third meeting, 1949.
94. IVICSICS L. : A görgetett hordalék zörejének mérése. (Measuring the noise of bed-load.) Mérés és Automatika. I. 1953. 5. 137—138.
A görgetett hordalék zörejének megfigyelése. (Observation of bed-load noise.) Hidr. Közl. 36. 4. 242—247.
95. NÉMETH E. : Az öntözővíz mérésére szolgáló korszerű berendezések, különös tekintettel a Venturi csatornákra. (Up-to-date instruments for measuring irrigation water con-

sumption, with special respect to Venturi meters.) M. Tud. Akadémia Műszaki Tudományok Oszt. Közleményei, No. 4. 1952.

96. SZESZTAY K. : Tapasztalati eljárás a területi párolgás meghatározására. (An empirical method for determining regional evaporation.) Beszámoló a Vízgazdálkodási Tudományos Kutató Intézet 1955. évi munkájáról. Manuscript.

97. LÁSZLÓFFY W. : A hazai árvízelőrejelzés tökéletesítése. (Improving our flood forecasting.) Vízügyi Közlemények, 1956/3.
SZESZTAY K. : Az árvízi előrejelzések néhány módszertani kérdése. (Some methodological problems of flood forecasting.) VITUKI beszámoló, 1955.

98. KÁROLYI Z. : Folyóink mértékadó árvízszíne. (The competent flood level of our rivers.) Magyar Tudományos Akadémia Műszaki Tudományok Osztálya közleményei. XIX/4.

99. ORLÓCI ISTVÁN, BÖZSÖNY DÉNES : A nagymarosi dunaszakasz modell-kísérletének előkészítése. (Preparations for the model experiment on the Nagymaros section of the Danube.) Hidrológiai Közlöny, 1956. No. 4.
SZEPESSY J. : Dunai áramkép-felvételek Visegrádnál. (Stream-line survey on the Danube at Visegrád.) Hidrológiai Közlöny, 1955. No. 11—12.

100. BOGÁRDI J. : A hordalékmozgás elmélete. (The theory of load movement.) Bpest, 1955. Akadémiai Kiadó.
Some characteristic relations concerning suspended sediment transportation. The Port Engineer, Vol. 4. July 1955. No. 3.
Characteristic correlations of bed-load and the Hydraulic factors of natural stream channels. The Port Engineer, Vol. 4. July 1955. No. 3.
Über die Zu- und Abnahme des Schwebestoffgehalts in den Flüssen mit der Änderung des Abflusses. Die Wasserwirtschaft, 47. Jahrgang, Heft 3. Dezember 1956.
Measurements of sediment transportation in Hungary with special reference to their quantitative bearings on erosion. Manuscript.
KÁROLYI Z. : A study into the inconsistencies in bed-load transport on the basis of measurements in Hungary. Manuscript.

101. LÁSZLÓFFY W. : A fajlagos lefolyás sokévi átlaga Magyarországon és a hidrológiai hosszszelvények. (The long-range averages of the annual run-off in Hungary and hydrological cross-sections.) Vízügyi Közl. 1954.

102. SALAMIN P. : Kongress für Bodenkunde, Verlag der ungarischen Akademie der Wissenschaften. Budapest 1956. p. 250.
Belvízrendszerek tervezésének néhány kérdései. (Some problems of designing inland water regulation.) Budapest, 1956. No. 5. p. 342.
Relations entre les irrigations et l'évacuation de l'eau. — Commission Internationale des Irrigations et du Drainage, 3. Congrès, R. 7. Question 10. 10. 117.

103. SALAMIN P. : A hóolvadásból származó belvízmennyiségek. (Inland water amounts derived from melting snow.) Vízügyi Közlemények, 1956. p. 250.
A hóolvadás vizsgálatának kérdései. (Problems of snow-melt investigation.) A Magyar Tudományos Akadémia Műszaki Tudományok Osztályának Közleményei, Budapest, 1956. IX. 1—3. 237.
A hó olvadásának vizsgálata a Bükk-hegységben. (Investigation of snow-melting in the Bükk Mountains.) Időjárás. Budapest, 1956. No. 5. p. 265.

104. UBELL K. : A talajvízállás előrejelzése. (Forecasting ground-water level height.) Beszámoló a VITUKI 1955. évi munkájáról.
Water balance of the sand plateau between the rivers Danube and Tisza. Manuscript.

105. NÉMETH, E. : Recherche graphique sur la correlation entre la fluctuation de la nappe phréatique et celle de la température. Publication n° 37 de l'Association Internationale d'Hydrologie. (Assemblée générale de Rome, tome II.)

106. SZILÁGYI, GY. : La variation du coefficient de filtration dans l'espace de dépression des puits. Symposia Darcy Dijon, 20—29. Septembre 1956.

107. ÖLLŐS G. : A talajrétegződés hatása a kutakkal kapcsolatos talajvízmozgásra. (Influence of soil stratification upon ground water movement in connection with wells.) Hidrológiai Közlöny.
SZABÓ L. : Az oldalszivárgás hatása a felületi öntözések normáira. (Influence of lateral filtration upon superficial irrigation norms.) Hidrológiai Közlöny, 1954.
BOZÓKY SZ. K.—OROSZLÁNY I. : Felületi öntözőrendszerek laboratóriumi vizsgálata. (Laboratory experiments on superficial irrigation systems.) Öntözési és Talajjav. Kutató Intézet, 1951.

108. KESSLER, H. : Estimation of subsurface water resources in karstic regions. Manuscript.

109. Tónai A.: A magyar medencék talajvize. Az országos talajvíztérképező munka eredményei. (The ground waters of the Hungarian basins. Results of the country-wide ground water mapping.) A Magyar Áll. Földt. Int. Évkönyve, Vol. XLVI. No. 1. Bp. 1956.
110. Aujeszky L.—Désy F.: Természetes és mesterséges eső. (Rains artificial and natural.) Meteorológiai Intézet kiadása, Bpest, 1954.
111. Aujeszky L.: A mesterséges esőkeltés újabb fejleményei. (New advances in rain-making.) Hidrológiai Közlöny, 1955.
112. Bodolai K.: A súrlódási réteg hatása a csapadékképződésre és a csapadékok eloszlására. (The influence of the friction layer upon the formation and distribution of precipitation.) Report, 1955.
113. Hajósy F.: A meteorológiai állomások vízrajzi sorrendjéről. (On the hydrological sequence of meteorological stations.) Időjárás.
114. Kulin I.: Budapest csapadékrendkívüliségei. (The vagaries of precipitation at Budapest.) Report, 1954.
115. Szesztay K.: Statisztikai eljárás az inhomogén csapadékok egyneművé tételére. (A statistical method for homogenizing inhomogeneous precipitation.) Időjárás, 1954.
116. Szijgyártó Z.: Statisztikus törvényszerűségek a csapadék évi járásában. (Statistical relationship in the annual distribution of precipitation.) Manuscript.
117. Lesenyei J.: Felszíni vizvizsgálataink. (Investigations on superficial waters.) Report, 1954.
Szebellédy L.-né: Cartes de la Hongrie indiquant la qualité des eaux souterraines. Manuscript.
118. Szebellédy L.-né: A Tisza és a tiszántúli vízfolyások vízminőségi vizsgálata az öntözés szempontjából. (Water quality survey of the Tisza River and streams situated further East from the point of view of irrigation.) Beszámoló a VITUKI 1955. évi munkájáról.
119. Ládi G.: Egy dombvidéki szintirányú erdősáv hatásának vizsgálata. (Study of the effects of a level hillside wood belt.) Erdészeti kutatások, 1956.
120. Fazekas K.: Néhány újabb vízrajzi műszerünk. (Our latest hydrographic instruments.) Beszámoló a VITUKI 1954. évi munkásságáról.
121. Weimann B.: Mederfelvételek echográffal. (River-bed surveys with the Echograph.) Beszámoló a VITUKI 1955. évi munkásságáról.
122. Varrók Endre: Kis vízsebességek mérésére szolgáló műszer laboratóriumi vizsgálata. (The laboratory investigation of a meter for small water velocities.) Hidrológiai Közlöny, 1955.
123. Vágás István: Patakok vízhozamának mérése sózással. (Creek-discharge measurement by salting.) Hidrológiai Közlöny, 1955.

INDEX

A kiadásért felel az Akadémiai Kiadó igazgatója — Műszaki felelős: Farkas Sándor
A kézirat nyomdába érkezett: 1957. VI. 18. — Terjedelem: 18 (A/5) ív, 52 ábra, 1 melléklet

Akadémiai Nyomda Budapest — 42120/57 — Felelős vezető: Bernát György

The Acta Technica publish papers on technical subjects in English, German, French and Russian.

The Acta Technica appear in parts of varying size, making up one volume.

Manuscripts should be addressed to :

Acta Technica, Budapest 62, Postafiók 440.

Correspondence with the editors and publishers should be sent to the same address.

The rate of subscription to the Acta Technica is 110 forints a volume. Orders may be placed with „Kultura" Foreign Trade Company for Books and Newspapers (Budapest VI. Népköztársaság útja 21. Account No. 43-790-057-181) or with representatives abroad.

Les Acta Technica paraissent en français, allemand, anglais et russe et publient des travaux du domaine des sciences techniques.

Les Acta Technica sont publiés sous forme de fascicules qui seront réunis en un volume.

On est prié d'envoyer les manuscrits destinés à la rédaction à l'adresse suivante :

Acta Technica, Budapest 62, Postafiók 440.

Toute correspondance doit être envoyée à cette même adresse.

Le prix de l'abonnement est de 110 forints par volume.

On peut s'abonner à l'Entreprise pour le Commerce Extérieur de Livres et Journaux «Kultura» (Budapest VI. Népköztársaság útja 21. Compte-courant No. 43-790-057-181) ou à l'étranger chez tous les représentants ou dépositaires.

«Acta Technica» публикуют трактаты из области технических наук на русском, немецком, английском и французском языках.

«Acta Technica» выходят отдельными выпусками разного объема. Несколько выпусков составляют один том.

Предназначенные для публикации рукописи следует направлять по адресу :

Acta Technica, Budapest 62, Postafiók 440.

По этому же адресу направлять всякую корреспонденцию для редакции и администрации.

Подписная цена «Acta Technica» — 110 форинтов за том. Заказы принимает предприятие по внешней торговле книг и газет «Kultura» (Budapest VI., Népköztársaság útja 21. Текущий счет № 43-790-057-181) или его заграничные представительства и уполномоченные.

Ára: 52,– Ft

ACTA TECHNICA

ACADEMIAE SCIENTIARUM HUNGARICAE

TOMUS XVIII FASCICULI 3—4

AKADÉMIAI KIADÓ BUDAPEST

1957

ACTA TECHNICA

A MAGYAR TUDOMÁNYOS AKADÉMIA MŰSZAKI TUDOMÁNYOK OSZTÁLYÁNAK KÖZLEMÉNYEI

SZERKESZTŐSÉG ÉS KIADÓHIVATAL: BUDAPEST, V., ALKOTMÁNY U 21

Az Acta Technica német, angol, francia és orosz nyelven közöl értekezéseket a műszaki tudományok köréből.

Az Acta Technica változó terjedelmű füzetekben jelenik meg, több füzet alkot egy kötetet.

A közlésre szánt kéziratok géppel írva, a következő címre küldendők:

Acta Technica
Budapest 62, Postafiók 440.

Ugyanerre a címre küldendő minden szerkesztőségi és kiadóhivatali levelezés.

Az Acta Technica előfizetési ára kötetenként belföldre 80 forint, külföldre 110 forint. Megrendelhető a belföld számára az „Akadémiai Kiadó"-nál (Budapest, V., Alkotmány utca 21. Bankszámla 05-915-111-44), a külföld számára pedig a „Kultúra" Könyv- és Hírlap Külkereskedelmi Vállalatnál (Budapest, VI., Népköztársaság útja 21. Bankszámla: 43-790-057-181), vagy külföldi képviseleteinél és bizományosainál.

Die Acta Technica veröffentlichen Abhandlungen aus dem Bereiche der technischen Wissenschaften in deutscher, englischer, französischer und russischer Sprache.

Die Acta Technica erscheinen in Heften wechselnden Umfanges. Mehrere Hefte bilden einen Band.

Die zur Veröffentlichung bestimmten Manuskripte sind an folgende Adresse zu senden:

Acta Technica
Budapest 62, Postafiók 440.

An die gleiche Anschrift ist auch jede für die Schriftleitung und den Verlag bestimmte Korrespondenz zu richten.

Abonnementspreis pro Band: 110 Forint. Bestellbar bei dem Buch- und Zeitungs-Aussenhandels-Unternehmen »Kultura« (Budapest, VI., Népköztársaság útja 21. Bankkonto Nr.43-790-057-181) oder bei seinen Auslandsvertretungen und Kommissionären.

PRODUCTION OF MANGANOUS SULPHATE SOLUTION FIT FOR ELECTROLYSIS FROM ÚRKÚT WASHERY SLIMES

Prof. Z. HORVÁTH
CAND. OF ENG. SC.
DEPARTMENT FOR NON-FERROUS METALLURGY, UNIVERSITY FOR HEAVY INDUSTRY, MISKOLC

[Manuscript received on 18th Nov. 1954]

Intensive research has been going on for some tens of years, principally at American, Soviet, Italian and German laboratories to find an outlet for products that cannot be processed directly for ferromanganese. From research results elucidates that the manganese content of poor ores can be transformed to valuable products by processes of hot or wet metallurgy.

Hot processes are not dealt with here more in detail; they consist of smelting the ore mixed with coal or with spiegeleisen to produce pig iron and a slag high in manganous oxide. The latter is processed for ferromanganese [1].

Wet processes produce by leaching either manganous sulphate or manganous chloride. From these solutions are produced: by *electrolysis* electrolytic manganese [2] or manganese dioxide [3], by *oxidation* a product rich in manganese dioxide [4], finally by *various processes* manganese salts [5], or ferromanganese [1].

In Hungary manganese ores are found in three places: Úrkút, Epleny and in the region of Eger—Noszvaj—Demjén [6].

The manganese ore at hand contains 19 % Mn, limonite equivalent to 19 % Fe, besides clay, lime, quartz and 5 % humidity. (Here and in the following Mn has been determined by the Volhard-Wolff, Fe by the Zimmermann—Reinhardt method. The undersize of the 44 mesh scree, that is, less than 0,4 mm size, of ores has been treated.

1. Preparation of sulphate electrolyte fit for the production of electrolytic manganese

At this first phase of the investigation a solution was prepared which, according to Bureau of Mines specifications fit for manganese electrolysis, contained 200 g/l ammonium sulphate, 24—35 g/l of Mn in the form of manganous sulphate, nearly neutral and free from impurities. For leaching the final lye of electrolysis is most suitable. This contains according to literary data per l 200 g of ammonium sulphate, 30 g of free sulphuric acid and manganous sulphate corresponding to 3 g Mn. Manganese present as polianite or pyrolusite in such leaching liquor of relatively low acidity is hardly soluble.

Determination of the maximum temperature and duration of reduction

At the first set of experiments a resistance-heated electric muffle furnace was used. The material to be reduced was placed in a glass tube laid parallel to the longer side of the muffle in the middle axis of the latter. The end of the glass tube put into the gas offtake at the back of the furnace was connected to the town gas supply by a rubber hose through the intermediate of a wash bottle.

On the basis of experimental results it was ascertainable that from ores kept for an hour at any temperature between 400 and 500 deg. C and afterwards cooled in reducing atmosphere, diluted sulphuric acid dissolved 95—98 % of the manganese, further that from ore reduced at 400 deg. 30 % of the iron, from ore reduced at 500 deg. 70 % of the iron were lixiviated. Since iron-free lye has to be produced for electrolysis, for this purpose, in order to facilitate de-ironing of the lyes, leaching experiments were pursued on material reduced at 400 deg. C, containing less iron.

Preparation of iron-free lye, at 400 deg. C, from ore reduced during one hour

Experiments aimed at the goal set in the title were conducted in two directions and will be dealt with in two alineas.

a) Variation of the quantity of leaching liquour — and of the duration of leaching

At the use of little leaching liquor, that is of little sulphuric acid, first mainly manganese is dissolved. The experiments have also shown that leaching of short duration, even if there is excess of acid, favours more the dissolution of manganese. A larger amount of iron goes into solution only if previously enough manganese has been dissolved.

From some results may also be concluded that, if the excess of acid is not very great, by the increase of the duration of leaching the iron is separated from the largely neutralized lye, and the sulphuric acid thus liberated dissolves manganese.

One experiment has shown that by the proper choice of the relative amounts of ore and of leaching liquor, and of the duration of leaching, a lye free from iron can be prepared. However, this procedure is not feasible because an iron-free liquor can be prepared only at the expense of the recovery of manganese, and if a high recovery of manganese is aimed at, there will be iron besides the manganese in the solution. That is, the manganese is dissolved satisfactorily only if an excess of acid is used in relation to the theoretically required amount ; in such case no separation of iron is to be reckoned with.

In the preparation of an iron-free neutral lye obtained at one experiment too, more acid was consumed than theoretically necessary for the dissolution of the manganese. This is due to the fact that the limestone content of the ore also consumed sulphuric acid, and the iron dissolved at the begin of leaching is mostly precipitated as basic ferric sulphate and — though not in solution — yet consumes sulphuric acid.

b) Reduction in the presence of water vapour

At these experiments it was aimed at to reach the goal set : production of iron-free solution, by transforming the iron contained in the ore to ferrous-ferric oxyde insoluble in dilute acid, during the reduction of the manganese dioxide to manganous oxide. This can be executed — according to literary data — by two methods.

After EASTMAN the ore containing ferric oxide can be reduced at 400 deg. C by a gas mixture of $CO—CO_2$, containing less than 41 % CO, [7], but also by treating the material containing ferric oxyde at 400 deg. C with a gas-vapour mixture of $H_2—H_2O$ containing less than 88 % H_2 (8).

MATSUBARA worked in the first way, but did not obtain pure Fe_3O_4. HILPERT and BAYER experimented with a gas mixture of $H_2—H_2O$. The succeeded in preparing pure Fe_3O_4 when the gas applied at 400° contained at least 4% of water vapour.

For the experiments town gas containing on the average 43% H_2, 20% CH_4, 10% CO, 3% CO_2, 1% unsaturated hydrocarbons, 1% O_2 and 12% N_2 was at disposal for reduction. Since this contains much hydrogen and substantial amounts of methane splitting up [9] according to the reaction equation $CH_4 = C + 2\ H_2$ its composition is nearer to pure H_2 than to pure CH_4.

Accordingly, reduction was tried under conditions found most favourable by Hilpert and Beyer, that is at 400 deg. C and with gas containing 4 % water vapour.

A glass tube was no more suitable for such experiments. Therefore for further experiments a somewhat modified Schrader aluminium retort, originally fabricated for coal distillation tests [10] was used. The modification consisted in partitioning the inside of the retort by work plates, used for storage of material, mounted on a central tube. The ore to be reduced was placed on the work plates surroundung the perforated tube containing the gas inlet tube projecting down from the plug into the retort. A horizontal tube projecting outward from the retort was connected to one branch of a three-branched glass pipe. Another branch of the three-branched glass pipe was connected to the wash-bottle serving for controlling the gas flow, the third branch of it joined the water feed to the gas. Rubber hoses were used for connection everywhere.

Water was first fed to the gas in the vapour state by connecting one branch of the three-branched glass pipe to the neck of a retort containing water of 30—50 deg. C. A better solution was to feed water in liquid state to the inlet tube of the aluminium retort.

The minimum amount of iron from the material reduced at 400 deg. C is dissolved when material reduced in presence of water vapour is being leached. This was expected so. It is not improbable that through feeding more water the amount of iron dissolved would further decrease, it is even possible that an iron-free solution could be obtained. This way does not appear practicable, however, because though under the effect of water feed less iron goes into the solution, on the other hand, the recovery of manganese becomes worse. (Probably the presence of water prevents the reduction of manganese dioxide.) Therefore these experiments were discontinued, and the procedure described in the next chapter was adopted, which proved successful.

Deironing of iron-containing solution by leaching in counter current

This was planned to be executed by producing an irony solution and deironing it. In selecting a proper deironing method care has to be taken not to introduce undesirable elements with the material introduced for separating the iron. This material should be in good supply and the entire manipulation should be cheap. Considering all these circumstances it was deemed most expedient to use for the separation of the iron the reduced material itself or the MnO contained in it. Experiments executed by variation of the amount of leaching liquor and of the duration of leaching showed that at the neutralization of the lye the iron in solution is precipitated, and the sulphuric acid liberated by the precipitation of iron dissolves manganese. It was shown also that even an iron-free lye could be obtained, but in such case the recovery of manganese is low. This means, in other words, that the total iron is only precipitated if some manganese is still left in the leached ore residue in the form of MnO, that is, if there is excess of MnO in the ore subject to leaching in relation to the acid fed to leaching. From this follows, as has been ascertained too, that the total manganese contained in the reduced material could be leached out from it only by a solution containing acid in excess.

Now if in the interest of good recovery of manganese an excess of acid has to be worked with and, on the other hand, the separation of iron is only successful if there is manganous oxide in excess, it is only too obvious to apply the principle counter current leaching already successfully applied in the hydrometallurgy of zinc and of copper.

In this case, as shown by Fig. 2, the reduced material is first subjected to the so-called neutral, afterwards to acid leaching. The reduced ore is leached by irony nearly neutral lye originating from acid leaching, to which may be some fresh acid is added. In this leaching procedure this lye resulting from acid-leaching and the possibly added fresh acid is entirely neutralized by the manganous oxide present in excess ; the iron content of the lye is precipitated, and an amount of manganese equivalent to the sulphuric acid set free thereby is dissolved. The iron-free lye coming forth from the leaching process called neutral lye is subjected to electrolysis. The solid residue of the first or neutral leaching process still containing manganese is subjected to leaching with fresh acid, called acid leaching. Here there must be as much free acid as is necessary for dissolving the manganese still present in the material already leached once. Of course, besides manganese, some iron is also dissolved. This irony lye passes to the neutral leaching process. The twice-leached material, hardly containing any soluble manganese, is dumped on the spoilheap after washing.

a) *Leaching of Ore Reduced at 400 deg. C for One Hour in the Static State, in Counter-current, with Solution Containing 30 g/l Sulphuric Acid, 200 g/l Ammonium Sulphate and 3 g/l Manganese.*

In connection with these experiments it is noteworthy that in leaching at higher temperature (75 deg. C) aluminium was also dissolved. It appears that at the reduction temperature, that is, at 400 deg. C splitting up of the clay already begins according to the reaction equation [11] :

$$Al_2O_3 \cdot 2\,SiO_2 \cdot 2\,H_2O = Al_2O_3 + 2\,SiO_2 + 2\,H_2O.$$

Probably the alumina thus set free is dissolved at higher temperature in the weak acid.

According to results the lye produceable by counter-current leaching is iron-free, and under suitable conditions the recovery of manganese is also satisfactory.

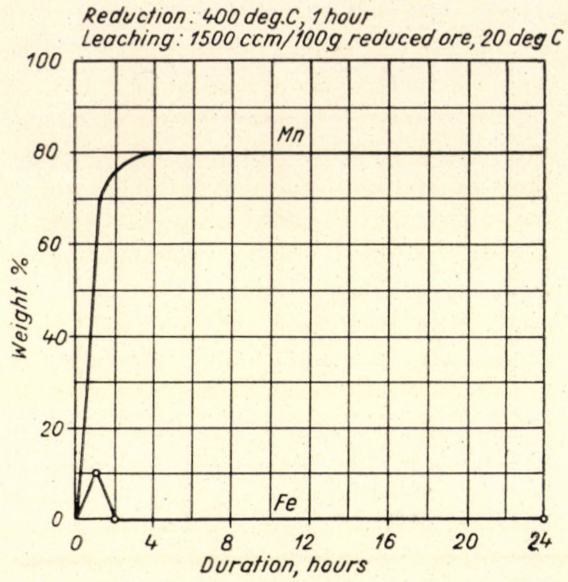

Reduction: 400 deg.C, 1 hour
Leaching: 1500 ccm/100g reduced ore, 20 deg C
100
80
60
40
20
0
Weight %
Mn
Fe
0
4
8
12
16
20
24
Duration, hours

Fig. 1

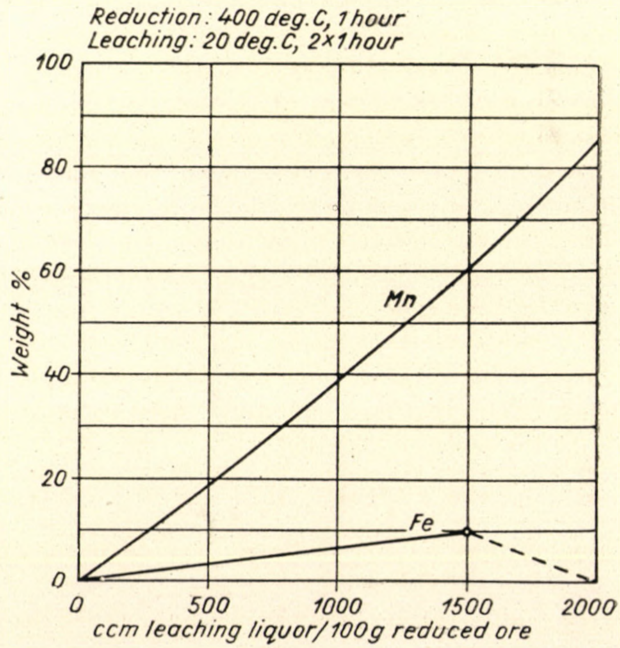

Reduction: 400 deg. C, 1 hour
Leaching: 20 deg. C, 2×1 hour
100
80
60
40
20
0
Weight %
Mn
Fe
0
500
1000
1500
2000
ccm leaching liquor/100g reduced ore

Fig. 2

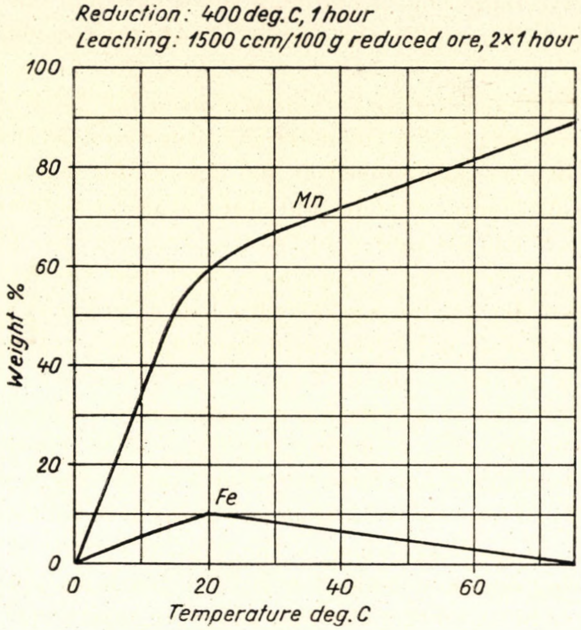

Reduction: 400 deg.C, 1 hour
Leaching: 1500 ccm/100 g reduced ore, 2×1 hour
100
80
60
40
20
0
Weight %
Mn
Fe
0
20
40
60
Temperature deg. C

Fig. 3

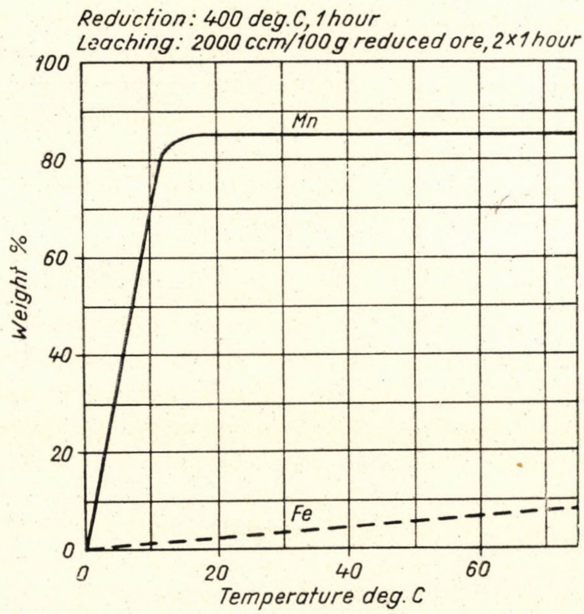

Reduction: 400 deg.C, 1 hour
Leaching: 2000 ccm/100 g reduced ore, 2×1 hour
100
80
60
40
20
0
Weight %
Mn
Fe
0
20
40
60
Temperature deg. C

Fig. 4

The precise determination of optimum conditions had not yet been dealt with here. This was executed in the course of experiments dealt with in the following chapters.

From data of the experiments have been plotted Fig. 1—4. Fig. 1 shows the variation of the percentages of manganese and iron dissolved if the duration of leaching of 100 g of material reduced at 400 deg. C, for one hour is modified, if in acid leaching in counter current and static state at ordinary temperature 1500 cu. cm. of fresh acid are added to 100 g of reduced ore. Fig. 2 illustrates the variation of the percentages of manganese and iron dissolved if to leaching stock reduced at 400 deg. C for one hour leached at ordinary temperature for 2×1 hours (1 hour neutral and 1 hour acid leaching) in counter-current various amounts of leaching liquor are added. Fig. 3 shows the variation of the recovery of manganese and of iron as a function of temperature, when to 100 g of the material, reduced at 400 deg. C during one hour, 1500 ccm of fresh acid are added at the acid leaching of one hour duration. Finally Fig. 4 shows the variation of the quantity of iron and of manganese going into solution as a function of the temperature of leaching, when to the neutral residue of leaching of the stock reduced during one hour 3000 ccm of fresh leaching liquor are added at acid leaching. It is to be noted that the diagrams were constructed from relatively few data by extra- and interpolation. From the figures it is evident that, 1500 ccm of leaching agent added to 100 g of reduced ore, about two hours suffice for either of the acid and of the neutral leaching processes. It is also apparent that at one hour leaching time 3000 ccm of lye to be added to 100 g of reduced ore is the optimum quantity (Fig. 2). It is evident finally that it does not pay to leach at higher temperatures, for the recovery of manganese does not improve — if 2000 ccm of leaching solution are added to 100 g of reduced ore —, while, on the other hand, besides more iron, aluminium is also dissolved, which is undesirable.

b) *Leaching in Counter-current with Stirring of Ore, Reduced during One Hour, with a Solution Containing 30 g/l Sulphuric Acid, 200 g/l Ammonium Sulphate and 3 g/l Manganese in the Form of* $MnSO_4$.

In the following the optimum conditions of countercurrent leaching was tested on ore reduced at 500 deg. C during one hour. Previous experiments had shown that with dilute acid more manganese can be extracted from ore reduced at 500 deg. C, than from stock treated at 400° C. According to data found in literature [12] MnO formed at 500 deg. C resists more to the oxidizing effect of air than the compound developed at lower temperature. On the other hand, since the iron contained in the solution anyway separates at neutral leaching, it is no substantial advantage any more of the reduction executed at 400 deg. C that from the material thus obtained dilute acid dissolved less iron.

For better recovery of manganese counter-current leaching was executed with stirring. For neutral leaching besides the irony solution obtained from acid leaching, fresh acid solution was also added.

By adding to neutral leaching, besides the irony solution originating from acid leaching, fresh acid solution too, with the exception of one experiment, the working procedure adopted in practice [13] was to be approached. Most works applying counter-current leaching namely are operating in a way that they add to the lye obtained from acid leaching, before they pass it to neutral leaching, a certain amount of final electrolyte-lye, that is, a solution enriched in acid. This procedure accelerates the operation and renders it more economical, for it makes possible to meet two requirements of counter-current leaching important from the economic point of view. According to one *only as much MnO has to be fed with the ore into the neutral leaching process as just permits the formation of an iron-free solution ;* according to the other *there must be present in acid leaching only such excess of acid as just suffices to dissolve the manganese present in the tailings of neutral leaching.* Namely if at neutral leaching ore is present in relation to the acid in greater excess than afore-mentioned, tailings containing too much manganese pass to acid leaching, where the manganese is dissolved along with too much iron. Thus more iron and more manganese will be recycled in leaching. If, on the other hand, more acid is added to acid leaching than just necessary to dissolve the manganese contained in the tailings of neutral leaching, this excess acid will dissolve iron, which is undesirable.

From arithmetic means of experimental data were constructed, partly by extrapolation, diagrams of Fig. 5 and 6. The former shows the variation of the percentages of dissolved manganese and iron, if 100 g of material reduced at 500 deg. C for one hour, are leached at ordinary temperature, twice for 1,5 hour, in counter-current, with stirring.

Fig. 6 illustrates the variation of the manganese and iron recovery as function of leaching time, when to 100 g of the material, reduced at 500 deg. C for one hour, a total of 2000 ccm of acid solution is added in acid and neutral leaching.

Optimum results were obtained at one experiment. Then the iron-free lye resulting from neutral leaching contained $\frac{22,8}{2} = 11,4$ g manganese per l (the manganese content of wash-water disregarded), and 94,3 per cent of the manganese went into solution. Although the recovery of manganese is good, and the lye is also free from iron, yet it does not meet requirements of Mn-electrolyses, for its manganese content (11,4 g/l) is only about half of the required one (24—35 g/l).

c) *Leaching in Counter-current, with Stirring, of Ore Reduced at 500 deg. C for One Hour, at Ordinary Temperature with a Solution Containing 60 g/l Sulphuric Acid, 200 g/l Ammonium Sulphate and 3 g/l of Manganese in the Form of* $MnSO_4$.

To obtain for electrolysis a solution containing the required amount of manganese leaching has to be made with a solution that contains about twice the amount of sulphuric acid compared to the liquor, used at former experiments. Therefore in the leaching solution just applied there are 60 g/l of sulphuric acid

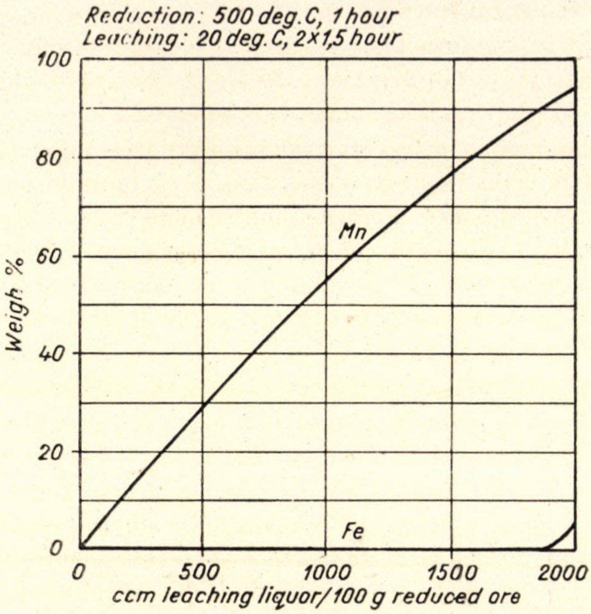

Reduction: 500 deg.C, 1 hour
Leaching: 20 deg.C, 2×1,5 hour
Weigh %
ccm leaching liquor/100 g reduced ore
Mn
Fe
0
20
40
60
80
100
0
500
1000
1500
2000

Fig. 5

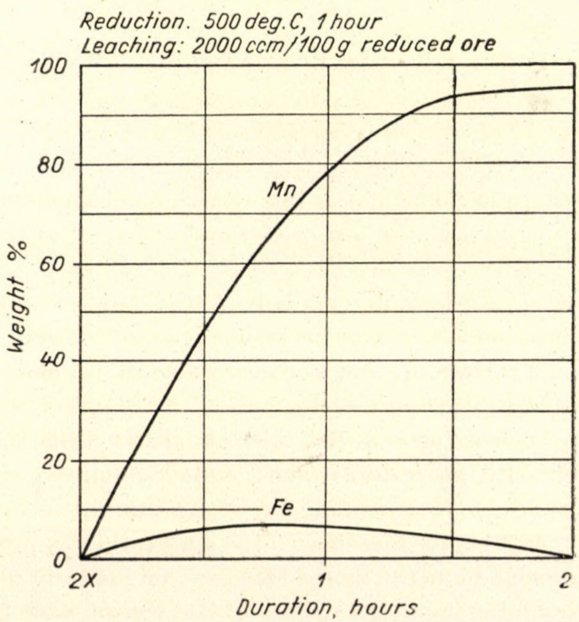

Reduction. 500 deg.C, 1 hour
Leaching: 2000 ccm/100 g reduced ore
Weight %
Duration, hours
Mn
Fe
0
20
40
60
80
100
2X
1
2

Fig. 6

against 30 g/l of the former. From results of former experiments may be concluded, that from this solution richer in sulphuric acid half the volume of the formerly used thinner solution will be necessary for dissolving the same amount of manganese.

The iron-containing initial solution, artificially prepared on the basis of experiments, contained per litre 200 g of ammonium sulphate, 10 g of manganese, 1,4 g of ferric sulphate and 32 g of free sulphuric acid. The further procedure was the same as that adopted at the experiments described in the previous chapter. Fig. 7 shows recoveries of manganese and of iron as functions of the leaching

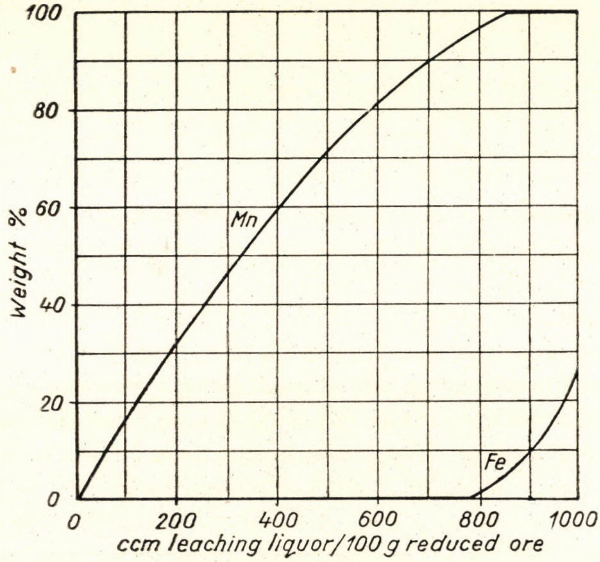


Fig. 7

solution applied to 100 g of reduced ore. The diagram well shows that best results are obtained when to 100 g of reduced ore a total of 750—800 ccm of fresh acid solution are added in both the acid and the neutral leaching process.

After all it may be established that *from Úrkút washery refuse an electrolyte suitable for manganese electrolysis can be produced on laboratory scale* if the ore properly broken (under 0,4 mm size) is treated during one hour in a reducing gas stream at 500 deg. C, cooled in reducing atmosphere, afterwards leached at ordinary temperature, with stirring in counter-current with a lye containing 60 g/l sulphuric acid, 200 g/l of ammonium sulphate and 3 g/l of manganese. In the laboratory good recovery of manganese and iron-free lye are obtained if at the acid leaching of 3 hours duration to 100 g reduced ore 750 or 600 ccm of acid solution are added, and at the neutral leaching of similarly 3 hours duration the solution resulting from the acid leaching or its mixture with 200 ccm of acid solution is applied.

Examination of the leaching processes of material reduced between 400—500 deg. C for 1 hour, in counter-current for 2×3 hours

a) *Composition of Solutions and Solid Residues Resulting from Different Phases of Leaching.*

Aims of this series of experiments was to find what amount of sulphuric acid is lost in leached-out and washed material in order to find the amount of fresh sulphuric acid to be added to the solution, in case of electrolysis.

For these leaching the following solutions were prepared :

	Irony solution	a) *final lye*	b) *final lye*
$(NH_4)_2SO_4$	= 200 g/l	...... 200 g/l	.... 200 g/l
$MnSO_4$	= 33,8 g/l	...... 8,24 g/l	.... 5,5 g/l
$Fe_2(SO_4)_3$	= 5 g/l		
H_2SO_4	= 32 g/l	...... 60 g/l	.... 72 g/l

At two experiments 5 g of reduced ore were leached with 30 ccm of irony solution and 10 ccm of final lye a), during 3 hours, at ordinary temperature, with stirring.

It can be ascertained from the experiments that the catolyte resulting from the first neutral leaching contains iron in all three experiments. At one experiment, the catolyte filtered off at the second neutral leaching is, however, free from iron. It is also striking, that the wash-waters contain relatively much manganese, iron and sulphate (SO_4). The explanation of this is that at filtering following upon neutral leaching two filter papers (one used in filtering after neutral leaching, another in separating the irony solution from the twice leached-out material) retain some liquid. In wash-water obtained by such working method of course there is more manganese, iron and sulphate (SO_4) than can be expected in washings on plant scale. At several tests care was taken to execute filtering, as far as possible, in a way to reduce the metal and SO_4 content of the wash-water to a minimum.

For new experiments pains were taken, however, to prepare an irony solution of approximately the same composition as the irony solution of the system in equilibrium.

This composition was approached by supposing the following :

1. In neutral leaching iron is precipitated in the form of ferric hydroxide,

2. At washing following upon acid leaching no iron is precipitated from the solution because of dilution with water (hydrolysis),

3. The solid residues of both the neutral and of the acid leaching contain after filtering a solution of the same volume, and of equal concentration in relation to SO_4.

Accordingly the SO_4 content of the irony solution must equal the amount of SO_4 in the final lye added to acid leaching ; from this follows also that from the material *leached out once* remains after filtration of the lye as much SO_4 as is found in the wash-water and in the washed-out material together after acid leaching. On the other hand, the quantity of SO_4 contained in the catolyte resulting from neutral leaching must equal the sum of the SO_4 content of the end lye fed to neutral and to acid leaching.

In practice only so much fresh sulphuric acid is to be supplemented to neutral leaching as is carried away by the washed-out material. At these experiments no fresh sulphuric acid was added and the wash-water was not recycled into the leaching process, but the neutral leaching was executed with more final lye.

From the above results that the SO_4 content of the catolyte resulting from the experiment is obtained if from the SO_4 present in the end lye fed to the neutral and to the acid leaching, the amount of SO_4 present in the wash-water and in the washed-out material is deducted.

According to the assumptions there should be 6,279 g of SO_4 in 30 ccm of the irony solution (in the course of analysis 6,265 g were found), the material washed-out once should contain $2,212 + 0,090 = 2,302$ g of SO_4 (according to calculation 2,276 g are in it) and the SO_4 content of the catolyte should be $2,093 + 6,279 — 2,212 — 0,090 = 6,070$ g.

Regarding the distribution of the manganese it may be supposed that the proportion of manganese and of SO_4 present in the wash-water equals the proportion of the manganese and of the SO_4 contents of the *irony solution ;* with other words, this supposes that the wash-water is diluted irony solution. The quantity of manganese contained in the once *(neutrally) leached stock* is obtained, if from the total of the manganese contents of the wash-water, of the washed-out material, and of the irony solution, the manganese present in the final lye fed to acid leaching is deducted. Finally the manganese content of the catolyte must equal the difference between the total manganese brought in with the reduced ore as well as with the final lyes fed to the leachings, and the manganese remaining in the washed-out material.

Accordingly in the case already quoted in the irony solution the ratio $\frac{SO_4}{Mn}$ has to equal $\frac{0,212}{0,220} = 10$ (according to analysis $\frac{6,265}{0,672} = 9,32$); moreover the material leached out once has to contain $0,22 + 0,058 + 0,672 — 0,09 = 0,86$ g of manganese ; finally in the catolyte there must be $1,14 + 0,03 + 0,09 — 0,058 = 1,202$ g of manganese. (There is 0,79 g, but to this has to be added 0,22 g contained in the wash-water not recycled. The total is 1,01 g.)

Examining the iron it is ascertainable that, if the afore-mentioned suppositions hold : 1. The iron contained in the *irony solution* is calculable from the knowledge of the composition of the wash-water and of the manganese and SO_4 content of the irony solution ; 2. *In the material leached-out once* there is as much iron as in the irony solution, in the wash-water and in the ore together, 3. *The material washed-out* must carry away as much iron as is brought in by the reduced ore.

Thus in the irony solution the value of the ratio $\frac{SO_4}{Mn}$ should be $\frac{2,212}{0,070} = 30,3$ (according to analysis $\frac{6,265}{0,228} = 27,5$), in the material leached-out once there must be $0,228 + 0,070 + 0,750 = 1,048$ g of iron, and in the material washed-out 0,75 g of iron.

On the basis of the above line of thought have been drawn Fig. 8, 9 and 10. These display relations only qualitatively, quantitatively they do not fit exactly the conditions of operation.

According to the conclusions of the above argumentation an irony solution was prepared, one litre of which contained 20,5 g of manganese in the form of manganese sulphate, ferric sulphate corresponding to 7,44 g of iron and 9,12 g of free sulphuric acid.

At one experiment only final lye was fed to neutral leaching, no irony solution, at another experiment 5,36 g of ore, at a third one 5 g of ore were subjected to neutral leaching with stirring, using 30 ccm of irony solution and 20 ccm of final lye. The catolyte resulting from neutral leaching was at all experiments free from iron and contained at three experiments following percentages of the manganese present in the ore : $\frac{0,755 - 0,090}{1,252} \; 100 = 53,1$;

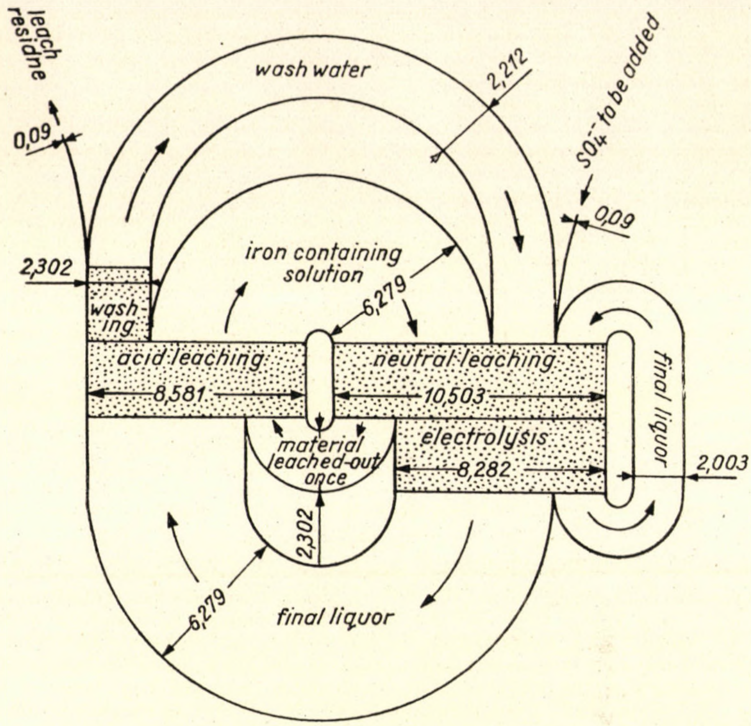

leach residne
0,09
wash water
2,212
SO_4^{--} to be added
0,09
2,302
wash-ing
iron containing solution
6,279
acid leaching
8,581
neutral leaching
10,503
final liquor
material leached-out once
electrolysis
8,282
2,003
2,302
6,279
final liquor

Fig. 8

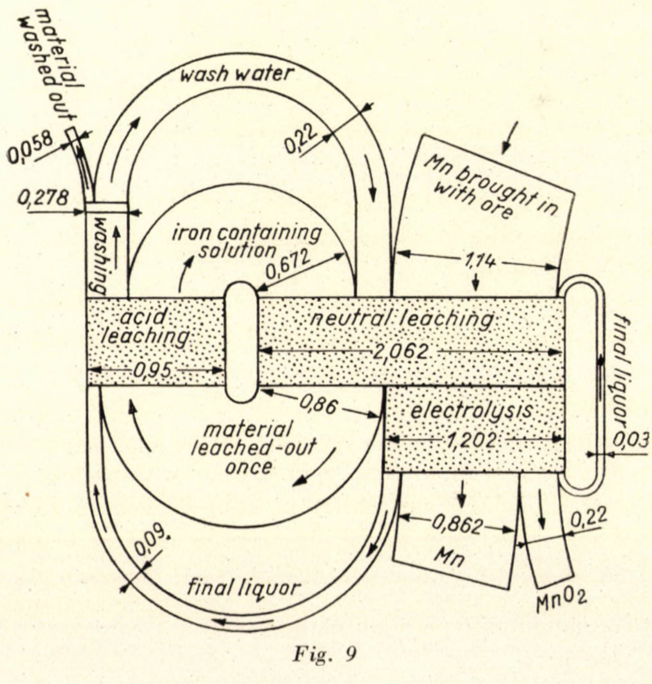

material washed out
0,058
wash water
0,22
Mn brought in with ore
0,278
washing
iron containing solution
0,672
1,14
acid leaching
0,95
neutral leaching
2,062
final liquor
0,86
electrolysis
1,202
0,03
material leached-out once
0,862
0,22
Mn
MnO_2
0,09
final liquor

Fig. 9

$\frac{1,265-0,675}{1,3367}100 = 44,2$ and $\frac{1,250-0,675}{1,250}100 = 46\%$ respectively. (Actually more manganese was dissolved, since the material leached out once and the solution withheld by the filter cup also contain manganese.) Amounts of SO_4 present in the catolyte corresponded to the following percentages of the SO_4 content of the solution fed to neutral leaching : $\frac{5,3}{6,279}100 = 84,5$; $\frac{8,33}{10,465}100 = 79,7$ and $\frac{8,498}{10,565}100 = 81,1\%$ respectively. The material leached-out once, when neutral leaching was executed without adding irony solution, retained according to calculation 0,979 g of SO_4, partly in the solution remaining in it, partly in the form of basic sulphates or calcium sulphate. At the two other experiments these SO_4 amounts were 2,135 and 1,967 g. From this it is evident that, if more iron is precipitated, more SO_4 is contained in the neutrally leached material, which means ; in other words, that the iron goes into the precipitate in the form of basic ferric sulphate. The supposition that the water resulting from washing is an irony solution is fairly well supported by the tabulated results. These experiments attained the aim set, that is, to obtain at the washing with water of the solid residues of leaching solutions containing as little manganese as possible, but much manganese remained in the material washed-out. This is probably due to the fact that acid leaching was done without stirring.

To prove this assumption a further experiment was made the results of which are summed up in Table 1.

Table 1

		Mn, g	Fe, g	SO_4, g
Reduced material	5,36 g	1,4210		
Irony solution	30 ccm	0,6150	0,2230	6,2790
Final lye, a) composition	20 ccm	0,0600	—	4,1860
Catolyte		1,5100	0,1460	9,7000
Material leached once		0,5860		0,7650
Final lye, a) composition	30 ccm	0,0900	—	6,2790
Iron-containing solution		0,5430	0,3650	6,2600
Washed with wash-water		0,0830	0,0526	0,8100
Material washed out		0,0500		0,1280

At this experiment the filtrate was run into a glass filtering beaker, and both leachings were executed with stirring. In the catolyte beside much manganese and SO_4, iron was also found. The amounts of the former two were large probably because of better filtering and of part of the iron remaining in the solution. From the latter circumstance conclusion can be drawn to the fact that for some reason the experiment was not favourable for the formation of basic sulphate. To this may be attributed, just as at the former two experiments, that comparatively little SO_4 remained in the material leached-out once. The recovery of manganese is good:

$$\frac{1{,}421 - 0{,}050}{1{,}421} 100 = 96{,}6\%$$

Best results were attained at the last of the afore-treated three experiments. Let be examined how calculated values agree with results obtained.

The SO_4 content of the filtered irony solution should be 6,279 g according to the assumption, that is, the same as is contained in the initial irony solution (originating from stock). In the material leached-out once would remain according to the former reasoning

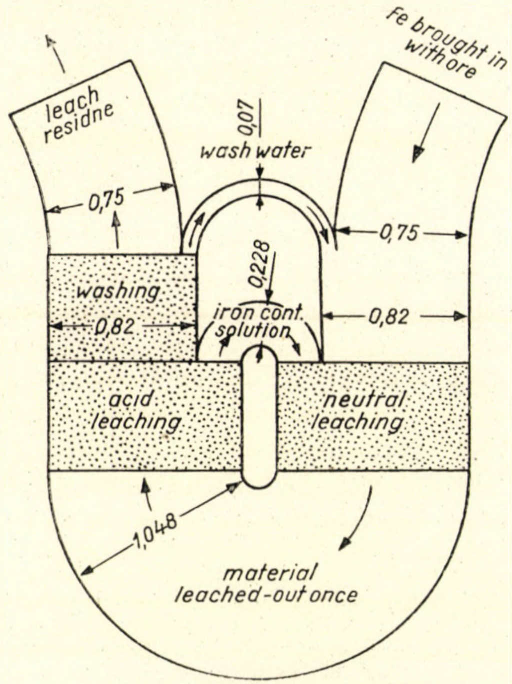


Fig. 10

$1{,}2362 + 0{,}1711 = 1{,}4072$ g SO_4, and were actually found 1,967 g, just therefore in the catolyte there are instead of $4{,}186 + 6{,}279 - 1{,}2362 - 0{,}1710 = 9{,}0578$ g only 8,498 g of SO_4.

In the irony solution should be $6828 \frac{0{,}0725}{1{,}2362} = 0{,}4$ g of manganese and there is 0,62 g of manganese. The material leached-out once contains $0{,}0725 + 0{,}0725 + 0{,}6200 - 0{,}0900 = 0{,}6750$ g of manganese and in the catolyte there is instead of $1{,}25 + 0{,}06 + 0{,}09 - 0{,}0725 = 1{,}3275$ g, 1,25 g of manganese. (If to the 1,25 g is added the manganese content of 0,0725 of the wash-water not recycled, 1,3225 g is obtained as result).

The iron content of the irony solution is according to calculation $6{,}828 \frac{0{,}0527}{1{,}2362} = 0{,}291$ g against 0,321 g found by analyses.

As shown, there are smaller or greater divergences between computed and found values. This is partly due to the fact that the initial irony solution used in neutral leaching does not exactly correspond in composition to the irony solution of the operation in equilibrium, partly to the fact that instead of the

80 ccm of final lye resulting from former experiments 100 ccm of final lye were added, moreover the wash-water was not recycled in neutral leaching, finally the conditions specified at the beginning argumentation do not entirely hold. *Iron* precipitates namely nor in the form of ferric hydroxide but in that of *basic ferric sulphate* at the neutral leaching, and the proportion between the manganese and iron brought out by the wash-water is also not the same as in the irony solution, because in *the course of washing the irony solution contained in the material is diluted, and is hydrolized in consequence of this*, which causes precipitation of iron. The precipitation of iron in the form of basic sulphate modifies the figures of diagram 8. so far that : 1. In the neutrally leached material as much more SO_4 remains against the above computed amount after filtration-off of the lye, as is carried off by the basic iron sulphate precipitated ; 2. In the iron containing solution originating from acid leaching and in the wash-water together there must be as much SO_4 more, as is dissolved under the action of free sulphuric acid from the basic iron salts at acid leaching.

From all this may be and must be concluded that ; a) in the system as much SO_4 more has to be kept in circulation, as has gone into solution at acid leaching from basic iron salts precipitated at neutral leaching ; b) At leaching as much SO_4 per 1t raw ore has to be brought in the form of fresh sulphuric acid, as is carried off from the SO_4 of the leaching solution by the ore residue of acid leaching washed out with water. For instance, from the above tests it can be ascertained that in leaching operation the material originating from 1 t of reduced ore, leached out twice and washed out, consumes in round figures 12—35 kg sulphuric acid, that is, to each ton of the reduced ore *on the average* 25 kg of sulphuric acid has to be added at neutral leaching.

b) *The participation of ammonium sulphate in leaching*

In the Bradley process [14] the manganous oxide present in the reduced ore is leached out with ammonium sulphate. The question arises whether if these tests are carried out in the presence of ammonium sulphate, this compound has a share in the dissolution of manganese. To answer this question a fresh experiment has been carried out (Table 2).

This was executed similarly to one of the previous experiments, the difference was only, that at the new test not final lye was applied to either the neutral or to the acid leaching process, but dilute sulphuric acid equal in volume to the final lye, in which there was neither ammonium sulphate nor manganous sulphate, but it carried as much free sulphuric acid as was contained in the final lye at the previous experiments (about 60 g/l). At the experiments of Table 2, both leachings were carried out with stirring. After leaching filtration was carried out in a filtering vessel whose bottom was covered with filter paper, at small vacuum. The catolyte coming forth from neutral leaching was, here too, free from iron

Table 2

		Mn, g	Fe, g	SO_4, g
Reduced material	5 g	1,2334		—
Dilute H_2SO_4	30 ccm	—	—	1,7650
Catolyte		0,6750	—	1,5600
Material leached out once		0,5584		0,2050
Dilute H_2SO_4	30 ccm	—	—	1,7650
Irony solution		0,4670	0,2260	1,7700
Brought out with wash water		0,0500	0,0468	0,2130
Material washed out		0,0414		0,0596

and contained from the manganese content of the ore about the same amount, 0,675 g, as the catolyte of one of the previous tests (0,735—0,090 = 0,665 g). On the other hand, more iron and manganese went into the irony solution than at the afore-mentioned previous test, the cause of which may have been, that now the acid leaching had been executed similarly with stirring.

Oxidation of ferrous sulphate containing solution with manganese dioxide

In the following information was to be gathered as to how much manganese dioxide was required for the oxidation of the iron content of the ferrous sulphate solution containing about the same amount of iron as the irony solution arising in operation on plant scale, and whether the total amount of iron contained in the solution could be separated.

Fig. 11 was drawn from data of the experiment. This shows the amounts of manganese and of iron contained in the solution obtained, as functions of the quantity of MnO_2 added to 20 ccm. of irony solution. Dashed lines in the figure show the different experiment results.

From Fig 11 is evident that with the increase of the amount of manganese dioxide treated with 20 ccm of irony solution the amount of manganese going into solution increases only up to a certain limit, and the amount of iron remaining in the solution decreases at the same rate. The increasing or decreasing value reaches the limit when all the ferrous iron has been oxidized to ferric iron. This occurred at one experiment when the 0,1936 g of ferrous iron met $\frac{0,24—0,152}{2} = 0,044$ g of oxigen, capable of oxidizing, combined with 0,152 g of manganese. (Theoretically for oxidizing 0,1936 g of ferrous iron only $0,1936 \frac{8}{56} = 0,0277$ g of oxigen is required). Then 85,9 % of the iron precipitated. In the precipitate remained $\frac{0,0452}{0,1520} 100 = 29,7$ % of the manganese brought in, the rest was dissolved.

Provided that the precipitate contains the manganese in the form of manganese dioxide, the composition of the iron contained in the precipitate can be computed. The investigations show that the iron precipitates in the form of basic sulphate, and that the composition of the basic sulphate precipitated is not constant, but it contains the more sulphate, the higher is the excess of manganese dioxide, the more iron is precipitated, the shorter the duration and the lower the temperature of leaching. The composition of iron precipitate approaches, depending upon the duration and temperature of leaching, in the case on hand that of the compound of $Fe_2(SO_4)_3 \cdot 3\,Fe(OH)_3$, and $Fe_2(SO_4)_3 \cdot 4\,Fe(OH)_3$.

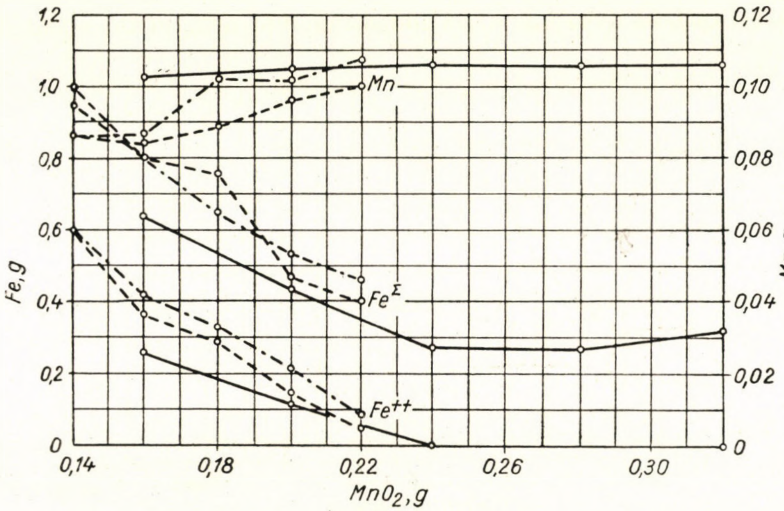


Fig. 11

Treatment of ferric sulphate solution with reduced ore

This investigation aimed at finding how much reduced ore is required to separate all ferric iron from a ferric sulphate solution of given composition.

The artificially prepared irony solution contained per litre 0,146 g of ferrous iron, 9,35 g of total iron and 28,34 g of SO_4 (1,84 g of free sulphuric acid). With 20 ccm of this solution various amounts of reduced ore were leached at room temperature, without stirring, at the 5 tests for 22—24 hours, at 5 further investigations for 73—74 hours. Fig. 12 shows the amounts of dissolved manganese and iron remaining in the solution, at the treatment of 20 ccm of irony solution with reduced ore, as functions of the quantity of reduced ore added to the solution.

Evidently about 2 g of reduced ore throw down all the ferric iron contained in the 20 ccm of irony solution. The amount of 0,00292 g of ferrous iron contained in the solution added to leaching has increased to 0,0116 g, probably under the effect of the metallic iron in the reduced ore and of the free sulphuric acid present in the leaching liquor.

For throwing down 0,1870—0,0116 = 0,1754 g of iron separated 2 g of reduced ore, that is about 0,5 g of manganese was necessary. From this manganese only 0,21 g was dissolved.

It may be supposed that the difference (0,29 g) is present in the precipitate in the form of MnO. If the separation of the iron took place according to the reaction equation $Fe_2(SO_4)_3 + 3MnO + 3H_2O = 2Fe(OH)_3 + 3MnSO_4$, then, since the atomic weights of iron and of manganese are nearly equal, the ferric sulphate could dissolve an amount of manganese corresponding to 1,5 times of the iron separated, that is $0{,}1754 \cdot 1{,}5 = 0{,}253$ g of manganese. The 0,0368 g of free sulphuric acid present in the solution added to the leaching can dissolve

$0{,}0368 \frac{55}{98} = 0{,}0206$ g of manganese so that a total of $0{,}253 + 0{,}0206 = 0{,}2736$ g of manganese should be in the solution. Only 0,21 g was dissolved, therefore the SO_4 of $0{,}0636 \frac{96}{56} = 0{,}111$ g necessary for the solution of 0,2736—0,21 = 0,0636 g of manganese must be present in the precipitate partly bound to calcium, partly to iron.

From these experiments and from the investigations previously described it can be ascertained that at neutral leaching to the reduced ore besides the irony solution so much final lye has to be added that 40—50% of the manganese con-

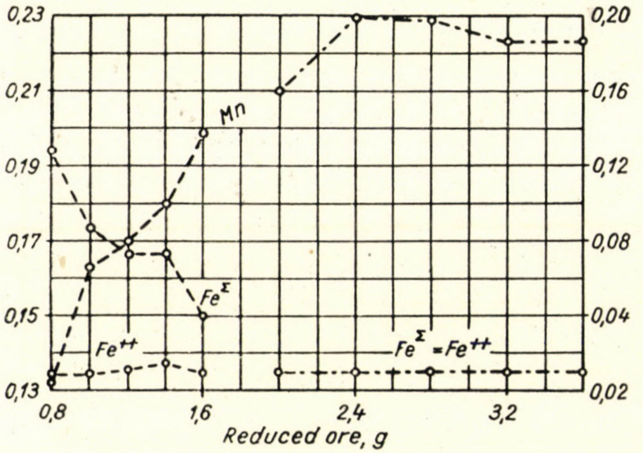


Fig. 12

tained in the ore be dissolved in this process. On the other hand it is easily conceivable that the acid leaching has to be executed in the presence of so much final lye that the manganese remaining in the material leached-out once be just dissolved.

REFERENCES

1. HELGE LÖFQUIST : Jernkontorets Ann. 125 (1941) 147—83.
2. R. SPRINGER : Die elektrolytische Abscheidung des Mangans. Akademische Verlagsgesellschaft, Leipzig (1951).
3. V. ENGELHARDT : Handbuch der technischen Elektrochemie. Akademische Verlagsgesellschaft, Leipzig (1931) Vol. II., Part 2, p. 133.
4. D. M. LIDDELL : Handbook of Non-Ferrous Metallurgy, McGraw-Hill Book Co., New York—London, 1st edition (1926) Vol. II. p. 1272, and 2nd edition (1945) Vol. II. p. 574.
5. DR. FRITZ ULLMANN : Enzyklopädie der techn. Chemie. Urban & Schwarzenberg, Berlin—Wien, 2nd edition (1931).
6. DR. R. SCHMIDT-ELIGIUS : Mineral Raw Materials of Hungary. (Hungarian) Faust Publishing House, Budapest (1947) pp. 26—27.
7. SZÉKI-HORVÁTH : General Metallurgy. (Hungarian) Tankönyvkiadó Váll. Budapest (1953).
8. WALTER BAUKLOH : Die physikalisch-chemischen Grundlagen der Metallurgie. Berlin (1949).
9. U. S. Bureau of Mines Bulletin 270 (1927) p. 59.
10. Brennstoff Chemie, 1 (1920) p. 87 and 2 (1921) p. 182.

11. H. Biltz and W. Biltz: Ausführung quantitativer Analysen, 2nd edition, S. Hirzel, Leipzig (1937) p. 214.
12. U. S. Bureau of Mines Bulletin 226 (1925) p. 36.
13. V. Tafel: Lehrbuch der Metallhüttenkunde. S. Hirzel, Leipzig (1929) Vol. II. pp. 410—418.
14. Engineering and Mining Journal, 127 (1929) pp. 1039—41, and (1929) pp. 14—19.

SUMMARY

Aim of this work was to find an economical method of processing Úrkút washery waste. It was tried to make of this clayey ore, containing manganese in the form of MnO_2, a sulphate electrolyte to be electrolyzed for manganese.

According to laboratory test results the most favourable conditions of preparing a sulphate electrolyte fit for the electrolysis of manganese are:

a) Reduction of the ore in gas stream, at 400—500 deg. C in a suitable furnace, for instance, in a rotary kiln,

b) Cooling in reducing atmosphere,

c) Leaching with stirring in counter-current, at ordinary temperature, with the final lye of manganese electrolysis recycled, which contains 200 g/l of ammonium sulphate, 60 g/l of free sulphuric acid and some manganous sulphate. At the tests from Úrkút ore ground to 0,4 mm max. grain size 93,33 or 94,04% of the manganese could be leached out.

93,33% of the manganese were dissolved when to 100 g of reduced ore:

1. in neutral leaching for 3 hours — besides the irony solution obtained from acid leaching — 200 ccm of final electrolyte lye,

2. and to acid leaching, for 3 hours too, 600 ccm of electrolyte final lye were added. The recovery of 94,04 % of manganese was obtained, when:

1. to neutral leaching only the irony solution originating from acid leaching, and

2. to acid leaching only 750 ccm of electrolyte final lye are run.

The examinations have established the following:

a) Twice leached out, washed material originating from 1 t of reduced ore carries off on the average 25 kg of sulphuric acid.

b) At leaching executed according to the above the ammonium sulphate does not take part in dissolving manganese.

c) In neutral leaching iron separates in the form of basic ferric sulphate.

d) The composition of the iron percipitate — depending on the duration and temperature of leaching — approaches the compounds of $Fe_2(SO_4)_3 \cdot 3Fe(OH)_3$ or of $Fe_2(SO_4)_3 \cdot 4Fe(OH)_3$.

e) In neutral leaching to the reduced ore — besides the irony solution — so much final electrolyte lye is to be added that 40—50 % of the manganese contained in the reduced ore be dissolved in this operation.

f) Acid leaching has to be carried out in presence of so much electrolyte final lye, that the manganese remaining in the material leached-out once be only just dissolved.

HERSTELLUNG VON ELEKTROLYSIERBARER MANGANOSULFATLAUGE AUS ÚRKÚTER ERZWÄSCHEABGÄNGEN

Prof. Z. HORVÁTH
Kand. der Ingenieurwissenschaften

ZUSAMMENFASSUNG

Die Zielsetzung dieser Arbeit war, ein wirtschaftliches Verarbeitungsverfahren für die Abgänge der Urkúter Erzwäsche zu finden. Im Laufe der Untersuchungen wurde versucht, aus dem tonigen Erz, welches Mangan in der Form von MnO_2 enthält, einen Sulfatelektrolyt herzustellen, der zur Manganelektrolyse geeignet ist.

Laut Laboratoriumsversuchen sind die optimalen Bedingungen der Herstellung eines für die Manganelektrolyse geeigneten Sulfatelektrolyts die folgenden:

a) Reduktion des Erzes in Gasstrom, bei 400—500°C, durch eine Stunde in einem geeigneten Apparat, z. B. in einem Drehrohrofen.

b) Kühlung in reduzierender Atmosphäre.

c) Laugung mit Umrührung in Gegenstrom, mit einer aus der Manganelektrolyse rückgewonnenen Endlauge, die 200 g/l Ammoniumsulfat, 60 g/l freie Schwefelsäure und wenig Manganosulfat enthält. Bei den Versuchen konnten aus dem auf die maximale Korngröße von 0,4 mm zerkleinerten Úrkúter Erz 93,33, bzw. 94,04% des Mangans ausgelaugt werden. 93,33 % wurden gelöst, bei den folgenden Zugaben auf 100 g reduziertes Erz:

1. Bei der 3-stündigen neutralen Laugung — außer der aus der sauren Laugung gewonnenen eisenhaltigen Lösung — 200 ccm,
2. bei der ebenfalls 3-stündigen sauren Laugung 600 ccm Elektrolytendlauge.

Ein Manganausbringen von 94,04 % wurde erreicht bei den folgenden Zugaben:

1. Bei der neutralen Laugung nur die eisenhaltige Lösung aus der sauren Laugung,
2. bei der sauren Laugung 750 ccm Elektrolytendlauge.

Die Versuche führten zu den folgenden Feststellungen:

a) Das aus 1 Tonne reduziertem Erz stammende, zweimal ausgelaugte, ausgewaschene Material führt im Durchschnitt 25 kg Schwefelsäure mit,

b) bei der nach obigen durchgeführten Laugung hat das Ammoniumsulfat keinen Anteil an der Lösung des Mangans,

c) bei der neutralen Laugung scheidet sich das Eisen als basisches Ferrisulfat ab,

d) die Zusammensetzung des ausgefällten Eisens steht — in Abhängigkeit von der Dauer und des Temperatur der Laugung — den Verbindungen von $Fe_2(SO_4)_3 \cdot 3Fe(OH)_3$ bzw. $Fe_2(SO_4)_3 \cdot 4Fe(OH)_3$ nahe,

e) bei der neutralen Laugung ist dem reduzierten Erz soviel Endlauge zuzugeben, daß bei dieser Laugung 40—50 % des im reduzierten Erz befindlichen Mangans gelöst werde,

f) die saure Laugung ist in Gegenwart von soviel Elektrolytendlauge durchzuführen, daß das im einmal ausgelaugten Material verbliebene Mangan eben noch gelöst werde.

PRÉPARATION A L'ELECTROLYSE D'UNE SOLUTION DE SULFATE MANGANEUX A PARTIR DES DÉCHETS DE LAVAGE DES MINERAIS D'ÚRKÚT

Prof. Z. HORVÁTH
Cand. des sc. techn.

RÉSUMÉ

Cette étude avait pour but de trouver une méthode d'utilisation économique des déchets de lavage d'Úrkút. On a cherché à préparer un électrolyte sulfurique à partir des minerais argileux contenant le manganese dans l'état de MnO_2.

Selon les essais de laboratoire les meilleures conditions de la préparation d'un électrolyte sulfurique se prêtant à l'électrolyse du manganèse sont les suivantes:

a) Réduction du minerai dans du courant gazeux à une température de 400—500° C, pendant une heure dans un appareil approprié, par exemple un four rotatif,

b) refroidissement dans une atmosphère réductrice,

c) lixiviation par contre-courant, à une température ordinaire par une lessive revenant de l'électrolyse du manganèse, contenant 200 g/l de sulfate d'ammonique, 60 g/l d'acide sulfurique libre et une petite quantité de sulfate manganeux.

Au cours des essais on a pu extraire des minerais d'Úrkút, broyée à 0,4 mm, 93,33 % resp. 94,04 % du manganèse.

93.33 % du manganèse ont été récupérés si pour 100 g de minerai réduit on a ajouté

1. à la lixiviation neutre durant 3 heures — en dehors de la solution retour de lixiviation acide — 200 ccm,
2. à la lixiviation acide, également de 3 heures, 600 ccm de lessive revenant de l'électrolyse.

La récupération de 94,04 % de manganèse a été atteinte en ajoutant:

1. à la lixiviation neutre seulement la solution ferrifère revenant de la lixiviation acide,
2. à la lixiviation acide seulement 750 ccm de lessive retour d'électrolyse.

Au cours des essais on a établi que

a) la matière provenant d'une tonne de minerais réduit, lixivié deux fois, lavé, porte en moyenne 25 kg d'acide sulfurique,

b) à la lixiviation exécutée comme il a été exposé ci-dessus, le sulfate d'ammoniaque ne joue aucun rôle dans la dissolution du manganèse,

c) à la lixiviation neutre le fer est précipité en état de sulfate ferrique basique,

d) la composition du précipité ferrique — en fonction de la durée et de la température de la lixiviation — correspond approximativement aux formules $Fe_2(SO_4)_3 \cdot 3Fe(OH)_3$ resp. $Fe_2(SO_4)_3 \cdot 4Fe(OH)_3$,

e) à la lixiviation neutre il faut ajouter en dehors de la solution ferrifere-autant de lessive retour d'électrolyse qu'au cours de cette lixiviation 40—50 % du manganèse contenus dans le minerai réduit soient dissous,

f) la lixiviation acide est à exécuter en présence d'autant de lessive retour d'électrolyse que le manganèse contenu dans la matière lixiviée une fois soit tout juste dissout.

ПОЛУЧЕНИЕ МАНГАНОСУЛЬФАТНОГО РАСТВОРА, ПРИГОДНОГО ДЛЯ ЭЛЕКТРОЛИЗА, ИЗ ПОРОДЫ МОЙКИ МАРГАНЦЕВОЙ РУДЫ М-Р УРКУТ

Канд. техн. наук З. ХОРВАТ

РЕЗЮМЕ

Этой работой ставилась цель найти экономически выгодные условия переработки породы мойки марганцевой руды м-р Уркут. Во время проведенных опытов ставилась задача получить из этой глинистой руды, содержащей марганец в виде MnO_2, сульфатный электролит, пригодный для целей электролиза марганца.

А) Согласно проведенным лабораторным опытам наиболее благоприятными условиями получения сульфатного электролита, пригодного для целей электролиза марганца, являются следующие:

а) Восстановление руды в потоке газа при температуре 400—500° С в течение 1 *час* в пригодном для этой цели аппарате, например в барабанной печи.

б) Охлаждение в восстанавливающей атмосфере.

в) Выщелачивание при перемешивании противотоком при нормальной температуре и с таким последним возвратным раствором от электролиза марганца, который содержит 200 *г/л* сульфата аммония, 60 *г/л* свободной серной кислоты и небольшое количество сульфата марганца.

При опытах удалось добиться выхода марганца из руды м-р Уркут, подверженной размолу до максимальной крупности 0,4 *мм*, порядка 93,33% и, соответственно, 94,04%. 93,33% марганца в том случае, когда на 100 *г* восстановленной руды подавалось:

1. При нейтральном выщелачивании в течение 3 *час* — кроме железистого раствора от кислого выщелачивания — 200 *см*³ последнего раствора электролита;

2. При кислом же выщелачивании также в течение 3 *час* 600 *см*³ последнего раствора электролита.

94,04% выход марганца получался в том случае, когда:

1. Для нейтрального выщелачивания подавался только железистый раствор от кислого выщелачивания;

2. Для кислого выщелачивания подавалось 750 см³ конечного раствора электролита.

Б) Во время проведенных опытов установлено:

а) Двукратно выщелоченный и промытый материал, получающийся из 1 *т* восстановленной руды, уносит с собой в среднем 25 *кг* серной кислоты.

б) При выщелачивании, проведенном по вышеописанной схеме, сульфат аммония не принимает участия в растворении марганца.

в) При нейтральном выщелачивании железо выделяется в виде основного феррисульфата.

г) Состав железного осадка — в зависимости от времени и температуры выщелачивания — приближается к составу соединений $Fe_2(SO_4)_3 \cdot 3Fe(OH)_3$ или же $Fe_2(SO_4)_3 \cdot 4Fe(OH)_3$.

д) К восстановленной руде при нейтральном выщелачивании — кроме железистого раствора — необходимо добавлять такое количество последнего раствора электролита, чтобы при этом выщелачивании растворялось 40—50% содержания марганца в восстановленной руде.

е) Кислое выщелачивание следует проводить в присутствии такого количества последнего раствора электролита, чтобы маргане, еще находящийся в однажды уже выщелоченном материале, как раз растворился.

ПОСТРОЕНИЕ И РАЗБИВКА ДУГ ОКРУЖНОСТИ В ПОЛЕВЫХ УСЛОВИЯХ

К. АПОР

[Поступило 6. XII. 1955 г.]

Введение

Часто встречается необходимость разбивки кривых в полевых условиях с затратой возможно меньшего времени, избегая длительных расчетов. Например, наводнение изменило всю ранее существовавшую ситуацию и поэтому заранее рассчитанные данные круга стали непригодными. Производство новых картографических работ требует больших расходов и вообще для производства такой лишней работы совершенно нет времени, другими словами, необходимо разбить совершенно другую кривую не только быстрым, но одновременно и точным методом.

Довольно известны точные методы инструментальной разбивки, но эти методы недостаточно быстры.

В нижеследующих разделах будут даны объяснения нескольких быстрых методов разбивки и по ним будет видно, что круги можно разбивать без использования каких-либо инструментов, лишь используя эккер, и метод будет совершенно точным. Наконец, но не в последнюю очередь, следует отметить, что совершенно лишне использовать специальные справочники, в которых можно найти данные кругов различных радиусов, но нет необходимого именно в данном случае радиуса.

Для разбивки кругов в полевых условиях используются, как известно, рулетка, колы, вешки и эккер.

1. Скоростная разбивка без эккера

Метод удлиненных хорд, ускоренный выбором рациональных размеров.

Быстрейшим методом, несомненно, является следующий метод.

Данный радиус разделяется на 10; пусть это будет равно хорде круга, тогда разделенный на 100 радиус будет равен расстоянию между точкой круга и конечной точкой двукратной длины хорды (см. рис. 1).

Пример. Пусть данный радиус $r = 1971$ *м*, тогда хорда будет $c = 197{,}1$ *м*, длина разности направления будет $2y = 19{,}71$ *м*. Расстояние до касательной: $y = 9{,}855$ *м*.

Этот метод с теоретической точки зрения является точным. Однако на практике редко достигается удовлетворительный результат, так как ошибка первой точки умножается числом разбиваемых точек, и поэтому редко встречается, что круг, начинающийся от точки O_a (т. е. от начала круга), достигает конечной точки дуги в желательном пункте E_a. Эту невязку направления совместно с промежуточными ошибками можно устранить линейным методом, т. е. ошибочную точку E'_a можно переместить в точку E_a и для прежних точек можно ввести поправку по формуле

$$e_m = e \frac{m}{n},$$

где e_m — поправка (или устраняемая ошибка) каждой прежней точки;
e — измеренная конечная ошибка, направление которой практически перпендикулярно к прямой O_aE_a (теоретически к биссектрисе);

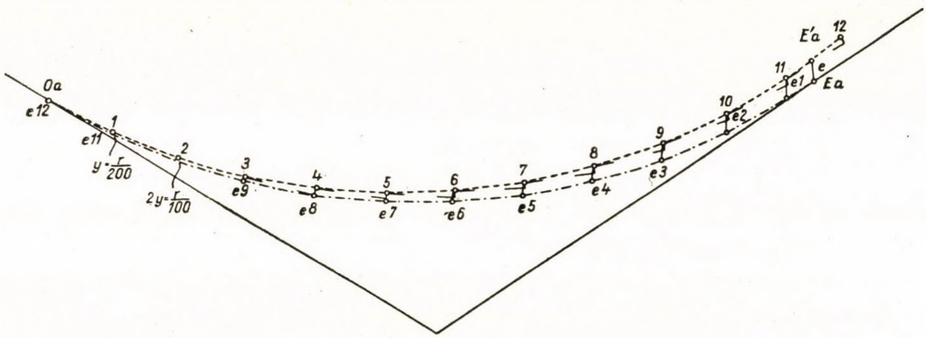


Рис. 1

η — длина между точками E_aO_a;
m — длина дуги между точкой O_a и корректируемой точкой.

Пусть в данном случае:

$$e = 6{,}0 \text{ м},$$

тогда вследствие линейного соотношения длины можно выразить числами мест:

$$e = 6{,}0 \frac{11{,}4}{11{,}4} = 6{,}00$$

$$e_1 = 6{,}0 \frac{11{,}0}{11{,}4}$$

$$c_2 = 6{,}0 \frac{10{,}0}{11{,}4}$$

$$e_{11} = 6{,}0 \frac{1{,}0}{11{,}4}$$

$$e_{12} = 6{,}0 \frac{0}{11{,}4} = 0$$

Расчеты можно легко упростить, если для делителя вместо 10 принять 100. В этом случае изменяется и пример. Если данная дуга $r = 1971$ *м*, хорда с $= 19{,}71$ *м* и $2y = 0{,}1971$ *м*.

Это означает лишь большую точность действительной длины хорды круга, но правильное место конца дуги E_a совершенно не обеспечено.

Следует напомнить, что если делитель выбирается равным 10, тогда действительная длина дуги может быть измерена с практически удовлетворительной точностью, так как длина дуги при условии, если a меньше $\left(\frac{r}{10}\right)$, тогда практически равна длине хорды.

Метод при любом делителе дает точку на круге, так как происходит из:

$$2y = \frac{c^2}{r},$$

что называется уравнением хорды круга и отличается от формулы:

$$2y = \frac{x^2}{r},$$

которая является уравнением параболы, и может быть использована лишь в случае более коротких абсцисс x.

Во всех случаях с обозначает хорду круга и лежит на самом круге.

Вывод происходит следующим образом:

подставляя

$$c = \frac{r}{10},$$

получается

$$2y = \frac{r^2}{100\,r} = \frac{r}{100}$$

или подставляя

$$c = \frac{r}{100},$$

получается

$$2y = \frac{r}{10\,000}.$$

Если делитель принять равным менее 10, тогда хорда будет относительно большей и также разница между хордой и дугой будет большей.

Но несмотря на это все точки лежат на окружности круга, что легко можно показать в предельном случае, когда делитель равен 1, т. е. когда

$$c = r$$

подставляя

$$2y = \frac{r^2}{r} = r$$

(см. рис. 2).

При построении кругов меньшего радиуса и при условии достаточно большой свободной площади, применение такого меньшего делителя в интересах того, чтобы получить основные точки круга, т. е. каркас круга, может быть очень полезным. Но в случае недостаточности свободной площади, инженер обычно вынужден оставаться близко возле берега реки или данной линии.

Кроме того, данный метод дает места кольев в неокругленных цифрах. Пикетаж в округленных цифрах дает очень большое преимущество. Прямые линии во всех случаях имеют округленную нумерацию и в этих случаях

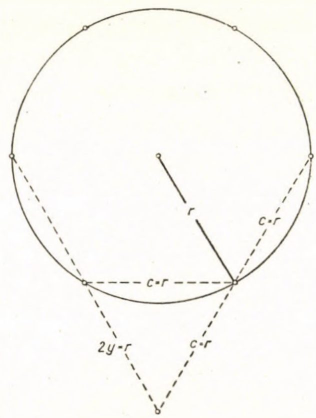


Рис. 2

применение пикетажа для кривых в округленных цифрах вызывает затяжку времени при измерениях и расчетах. Последующая интерполяция округленной нумерации пикетажа увеличивает число погрешностей и требует дополнительных работ и времени. Поэтому в следующем разделе рассматривается другой метод, при помощи которого можно устранить этот недостаток.

2. Построение кругов при помощи эккера

Метод окружных углов с использованием вспомогательных кругов. Пикетаж в округленных цифрах.

Здесь вновь необходимо упомянуть, что эккер служит для совершенно другой цели, чем известно было это до сего времени. Т. е. не используются таблицы, содержащие данные кругов, не имеется готовых координат, не имеется даже инструмента, доставка которого на место, или же сложность использования которого увеличивало бы запаздывание в выполнении работ.

Применение этого нового метода является целесообразным особенно в случае разбивки линий на вогнутой стороне реки или берега по двум причинам.

Во-первых всегда возможно скорее необходимо защитить именно вогнутый берег, кроме того небольшая площадь, необходимая для производства соответствующих операций, лежит всегда на вогнутом береге (см. рис. 3).

Пусть даны основные точки хорды круга : O_a — начало хорды и E_a — конец хорды, т. е. конечные точки той же дуги ; первая из которых лежит на касательной t_0, а другая на касательной t_e. Длины касательных и данные основных точек нельзя изменить ; верхнюю точку T геометрически также невозможно передвинуть, ввиду того, что лежит на равном расстоянии от упомянутых основных точек, а также благодаря своего положения, т. е. не представляется возможным сдвинуть ни в сторону реки, ни в сторону берега. Например, в обоих случаях сильно удорожало бы производство работ. В первом случае необходимо было бы использовать излишний строительный материал из-за большей глубины реки, а во втором случае стоимость земляных работ была бы слишком высокой.

Если бы имелось достаточно времени, необходимо было бы рассчитать радиус на основании трех данных точек круга. Исходя из предположения, что вычисления уже выполнены, сталкиваемся с новым затруднением, так как рассчитанный радиус не содержится в таблице кривых. Применение большего или меньшего радиуса приводит к вышеупомянутому экономически невыгодному производству строительных работ. Интерполяция необходимого круга или же вычисление его данных была бы связана с большей потерей времени и не следует забывать того, что разрушающее действие реки или воды не ожидает пока будут выполнены требующие много времени вычисления. Может иметь место случай, когда после завершения вычислений положение вновь изменяется и необходимо приступить к выполнению новых вычислений.

Все это можно устранить и единственно необходимый и правильный круг может быть разбит в течение короткого времени при использовании нижеописываемого метода :

1. Первая задача заключается в разбивке точки C, т. е. в разбивке двух касательных t_0 и t_e путем их удлинения до точки сечения. Контроль точного места пересечения состоит в равенстве расстояний $O_aC = CE_a$. Расстояние c и t до T равны между собой.

Может иметь место случай, когда разбивка точки C связана с большими затруднениями и почти-что невозможна из-за имеющихся строений или деревьев ; в этом случае точка C замещается двумя точками C_o и C_e (см. рис. 3).

Легко проверить нижеприведенными уравнениями :

$$O_aC_o = C_oT = TC_e = C_eE_a = t',$$

и проверить измерениями.

2. Расстояния

$$O_aT = TE_a = c'$$

необходимо также измерить; если невозможно произвести измерения, или же измерение является очень затруднительным, тогда необходимо измерить хотя бы расстояние $C_oC_h = h'$. Косвенное измерение может быть исполь-

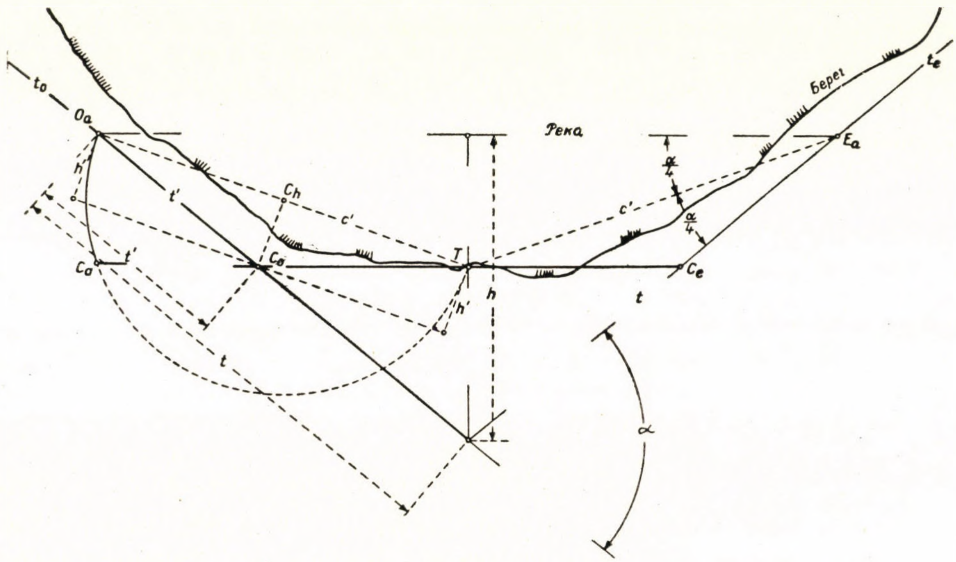


Рис. 3

зовано применением перпендикулярных прямых в точках O_a и T, если трудно разбить C_h.

3. При помощи эккера можно фиксировать небольшой круг от O_a до C_a. Необходимо лишь рассматривать в эккер изображение рейки T и прикрыть рейку O_a, которая видна непосредственно, или наоборот.

4. Эта небольшая часть окружности проводится колами, лежащими друг от друга на редуцированном расстоянии (d_r), рассчитаном по формуле

$$d_r = \frac{h'}{t'} d\,,$$

в которой обе данные (h' и t'), как это уже упомянулось выше, определены измерением, а третья данная d — расстояние между колами разбиваемого круга. Например, на практике 10 *м*, 20 *м* или же 50 *м*. Первый кол после O_a вряд-ли будет лежать на расстоянии в округленных цифрах, так как пикетаж прямой линии не будет оканчиваться шагом в округленных цифрах, совпадающим с O_a, поэтому разность необходимо редуцировать и фиксировать на малой окружности, которую в дальнейшем будем называть вспомогательным кругом по сравнению с основным кругом, который предполагается разбить.

5. Колы с редуцированным расстоянием вспомогательного круга видны на рис. 4.

Соединение любой из точек с T дает соответствующую прямую линию, на которой лежит соответствующая пикетажная точка основного круга. Таким образом в данном случае необходимо следить лишь за тем, чтобы точки 1′... 11′ вспомогательного круга покрывали бы точки 1...11 основного круга (или держащие в конце рулетки) в направлении точки T.

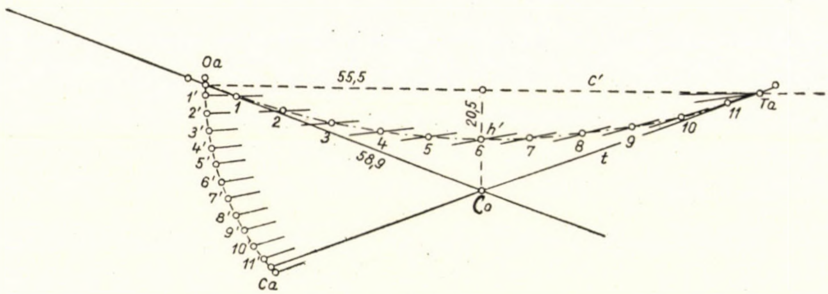


Рис. 4

Для освещения этого метода позволено будет привести следующий числовой пример.

t' — Измеренное расстояние = 58,9
h' — Измеренное расстояние = 20,5,

следовательно :

$$d_r = \frac{20{,}5}{58{,}9}\, d = 0{,}349\, d$$

$$\overline{O_a\,;\ 1} = 6{,}4\ м \quad \overline{O_a;\ 1'} = 0{,}349 \cdot 6{,}4 = 2{,}23\ м$$

$$\overline{1'\,;\ 2'} = 10{,}0\ м \quad \overline{1\,;\ 2} = 0{,}349 \cdot 10 = 3{,}49\ м$$

$$\overline{10'\,;\ 11'} = 10{,}0\ м \quad \overline{10\,;\ 11'} = 0{,}349 \cdot 10 = 3{,}49\ м$$

Проверка

$$11'C_a = 0{,}349 \cdot 6{,}9 = 2{,}41\ м$$

Если точки 1, ... 11 основного круга уже разбиты, что можно выполнить за короткое время, то разбивку можно продолжать таким же образом; создается другой вспомогатльный круг на диаметре $\overline{TE_a}$ (см. также рис. 3) и принятием T в качестве начальной точки.

Нет необходимости знать радиус r, ведь круг геометрически был определен тремя точками O_a, T и E_a и круг был разбит, не зная r.

Быть может, что для цели картографирования действительная длина r будет полезной ; расчет длины радиуса тоже происходит просто.

По уравнению

$$\frac{h'}{t'} = \frac{c'}{2\,r}$$

получаем

$$r = \frac{t'\,c'}{2\,h'},$$

если c' нельзя измерить :

$$c' = \sqrt{t^2 - h^2},$$

В применении к данному примеру получаем

$$r = \frac{58{,}9}{20{,}5} \cdot 55{,}2 = 1597\ \text{м}.$$

В уравнении $\frac{h'}{t'} = \sin\frac{\alpha}{4}$ угол α- центральный угол круга (данный основными точками O_a и E_a и их касательными), и собственно говоря это использовалось для редукции расстояний точек вспомогательного круга.

Этот вспомогательный круг, выведенный из $\sin\frac{\alpha}{4}$, является кругом синуса, или же вследствие того, что диаметр идентичен с хордой основного круга, вообще может быть назван хордовым кругом и в дальнейшем будет называться так.

Если обстоятельства позволяют этого, тогда бóльший вспомогательный круг строится на диаметре $O_aE_a = c$, коэффициент редукции которого будет

$$\frac{h}{t} = \sin\frac{\alpha}{2}$$

$\frac{h}{t}$ должен также рассматриваться и называться коэффициентом редукции. Теоретически величина различных коэффициентов редукции изменяется в пределах между 0 и 1 ; практически важным пределом является

$$\frac{1}{10} < \frac{h}{t} < \frac{1}{2}$$

Если $\frac{h}{t}$ больше $\frac{1}{2}$, то это означает, что использование вспомогательного круга имеет меньшее практическое значение. Невероятно, что имеется в распоряжении необходимая свободная площадь. Поэтому целесообразно увеличивать число основных точек биссектрисами, как это видно на рис. 3.

Если $\frac{h}{t} = 1$, тогда излишне использовать вспомогательный круг, так как основной и вспомогательный круги будет совпадать. То есть основной круг можно построить с концевых точек диаметра.

Если $\frac{h}{t}$ ниже $\frac{1}{10}$, то это означает, что совершенно лишне применять вспомогательный круг и можно его легко заменить короткой прямой (пер-

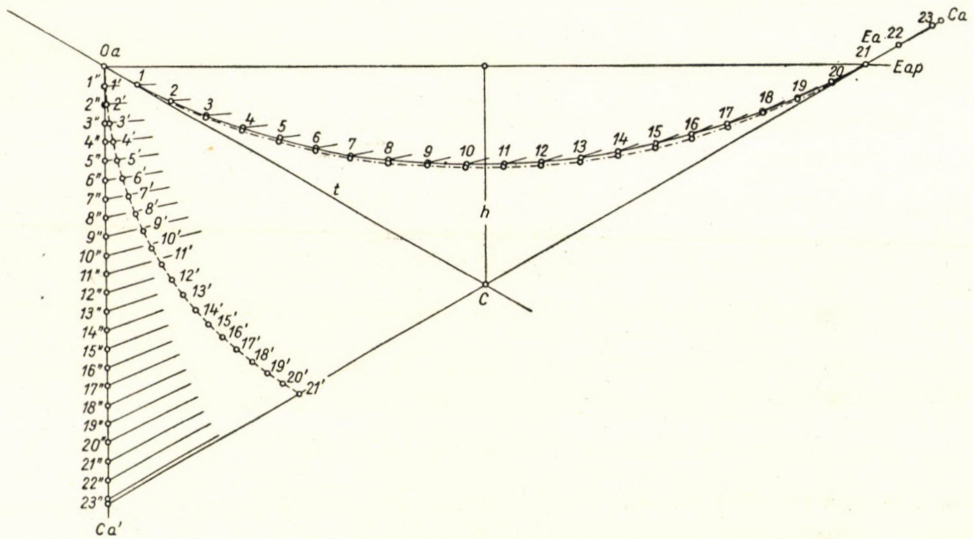


Рис. 5

пендикулярной к хорде), так как элементы круга практически нельзя отличить от элементов тангенциальной кривой.

3. Построение тангенциальной кривой, пикетажем в округленных цифрах

Замещая вспомогательный круг перпендикулярной прямой, можно построить тангенциальную кривую и в том случае, когда

$$\frac{1}{10} < \frac{h}{t} < \frac{1}{2}$$

Эту тангенциальную кривую можно разбить также пикетажем в округленных цифрах (см. рис. 5).

Как это видно на рис. 5, который отображает одновременное построение одной тангенциальной кривой и одного круга в предельном случае, когда $\frac{h}{t} = \frac{1}{2}$ имеет место очень небольшое отклонение в положении тангенциальной кривой и круга. Тангенциальная кривая является более короткой и изображена сплошной линией, а круг является более длинным и изображена пунктирной линией.

Выгодность применения тангенциальной кривой может быть определен лишь на месте соответственно данных условий.

Здесь следует отметить, что этот предлагаемый метод требует значительно меньше времени, чем разбивка круга, так как легче производить измерение на прямой, чем на окружности вспомогательного круга. Даже отсутствие эккера не вызывает затруднений ; простой перпендикуляр можно разбить без значительной потери времени при использовании лишь рулетки и вешки.

Дальнейшим преимуществом использования тангенциальной кривой в гидротехнике заключается в лучшем приближении к действительному очертанию направления течения.

В качестве отрицательной стороны можно считать то, что другой касательной точкой является не E_a ; тангенциальная кривая даже не касается, а сечет прямую CE_a, и практически сначала точки E_a (теоретически перед этой точкой) и во второй раз в точке C_a. Это отклонение уменьшается в той степени, насколько $\frac{h}{t} < \frac{1}{2}$.

Другая отрицательная сторона проявляется при картографировании, так как замедляет производство картографирования. Построение тангенциальной кривой на чертеже требует больше времени чем черчение круга.

Наконец, круг легко характеризовать его радиусом (например, $r = 265$) ; тангенциальная кривая же не имеет неизменного радиуса, кривизна же вершинной точки представляет собою отдельную проблему. Быть может для нас подходило бы использование радиуса того круга, коэффициент редукции которого идентичен $\left(\frac{h}{t}\right)$, который, собственно говоря, можно было бы называть не радиусом кривизны, а радиусом сопряженного круга.

Если коэффициент редукции будет

$$\frac{h}{t} > \frac{1}{2},$$

тогда построение тангенциальной кривой с пикетажем в округленных цифрах будет иметь меньшее практическое преимущество.

Тоже можно сказать о синусоидальной кривой (рис. 5a), с той лишь разницей, что построение этой кривой несколько сложнее, поскольку конец хорды следует искать в направлении данной касательной.

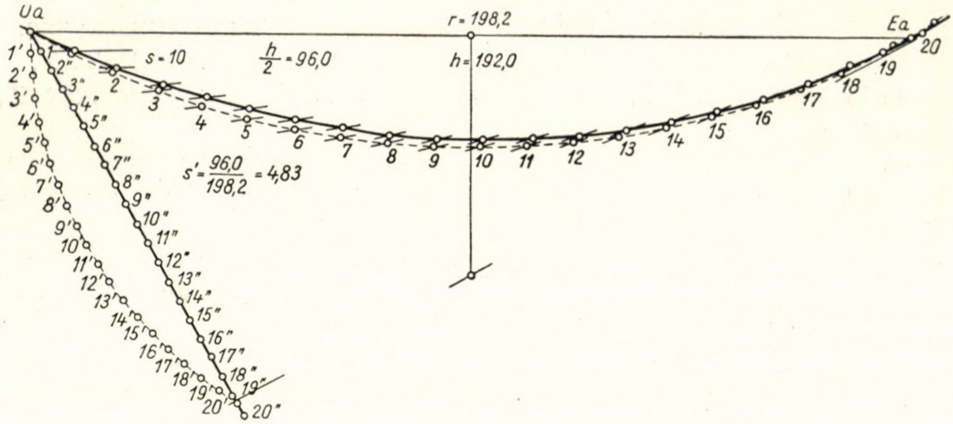


Рис. 5а

К преимуществу этой кривой можно отнесто то, что лучше приближается к действительному очертанию направления течения, которая строго определяется спиральной волютой.

4. Решение практических задач круга с помощью вспомогательного круга хорды

а) Даны две касательные и три абсциссы основного круга; необходимо построить соответствующие ординаты основного круга без прочих его точек (см. рис. 6).

Абсциссы на касательной обозначены цифрами 1, 2, 3. Решение происходит следующим образом.

1. В точке O_a опускается перпендикуляр на прямую $O_aE_a = c$:

$$v \perp c$$

Этот перпендикуляр является касательной круга хорды.

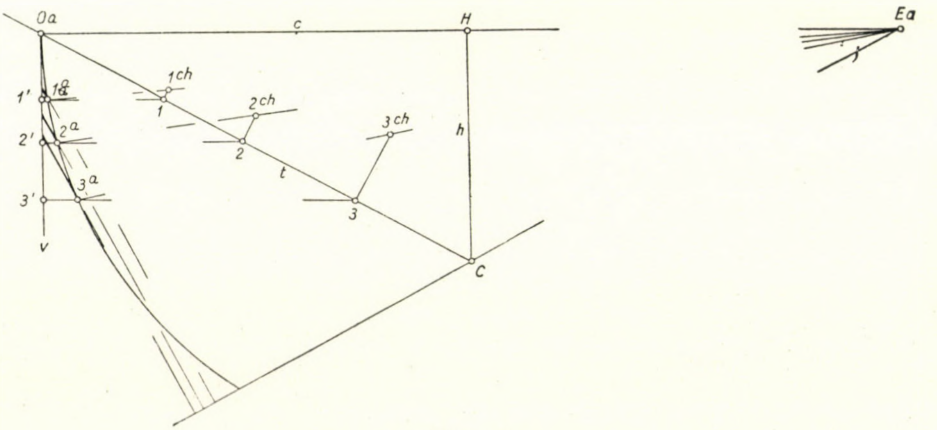


Рис. 6

2. При помощи эккера точки 1, 2, 3 проектируются перпендикулярно на v (то есть параллельно с c) и засекаются на прямой v точки 1′, 2′, 3′.

3. Прямые 1′ 1, 2′ 2, 3′ 3 секут вспомогательный круг в точках 1^a, 2^a, 3^a, которые точки и разбиваются.

4. В точках 1, 2, 3 строятся ординаты, т. е. перпендикулярные к O_a C прямые, длина которых пока что неизвестна, но может быть точно построена, так как:

5. прямые 1^a E_a, 2^a E_a, 3^a E_a секут прямые ординат в точках 1^{ch}, 2^{ch} и 3^{ch}, которые лежат также на основном круге, и таким образом задача решена. Искомые ординаты будут: 1, 1^{ch}; 2, 2^{ch}; 3, 3^{ch}.

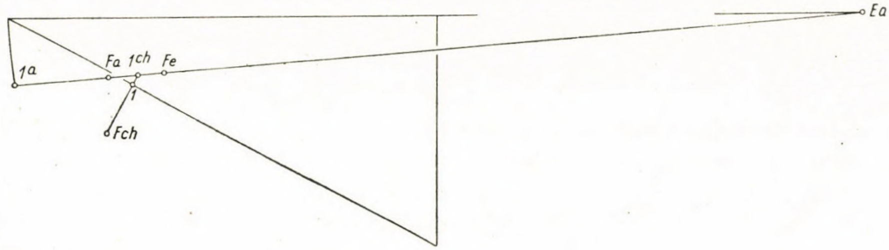


Рис. 7

Вообще следует отметить, что нахождение секущих точек требует значительно меньше времени и будет более точной, если операция будет производиться не при помощи подачи сигналов с конечных точек, что требует дополнительно двух вспомогательных работников, а путем продолжения прямой указанным на рис. 7 образом.

F_a, F_e и F_{ch} — вспомогательные вешки. Эти наводятся на прямой провешиванием перед разбивкой, чтобы с вешкой для разбивки можно было бы становиться в направление без провешивания. 1^aF_a можно легко удлинить одним лицом пока не достигнет продолжения F_{ch1}, и тогда может быть использован в противоположном направлении F_eE_a для контроля.

Другой метод подходит в случае соответствующих условий местности, который заключается в удлинении E_aC и опускании отсюда перпендикуляров, которые проходят через точки 1^a, 2^a и 3^a, секут прямую v и таким образом дают действительные длины ординат; это обозначено на рис. 6 жирной линией. Указанное можно проделать дополнительно и использовать для проверки, если на месте имеется достаточно свободной площади. Более независимой проверкой является это построение при продолжении с противоположной касательной, но незначительна вероятность, что имеется такая большая свободная площадь без застройки и деревьев, и кроме того более крупные измерения связаны с потерей времени, и поэтому применение этого метода можно решить только на месте.

Вышеупомянутый метод не требует производство каких-либо вычислений или расчетов. Радиус r был дан косвенно треугольником O_aE_aC.

Любой случай можно довести до такого треугольника и в каждом случае можно успешно использовать систему треугольника.

б) Вторая задача будет двойственной первой задачи.

В системе треугольника O_aE_aC даны ординаты o_1, o_2, o_3; необходимо построить соответствующие абсциссы (см. рис. 8).

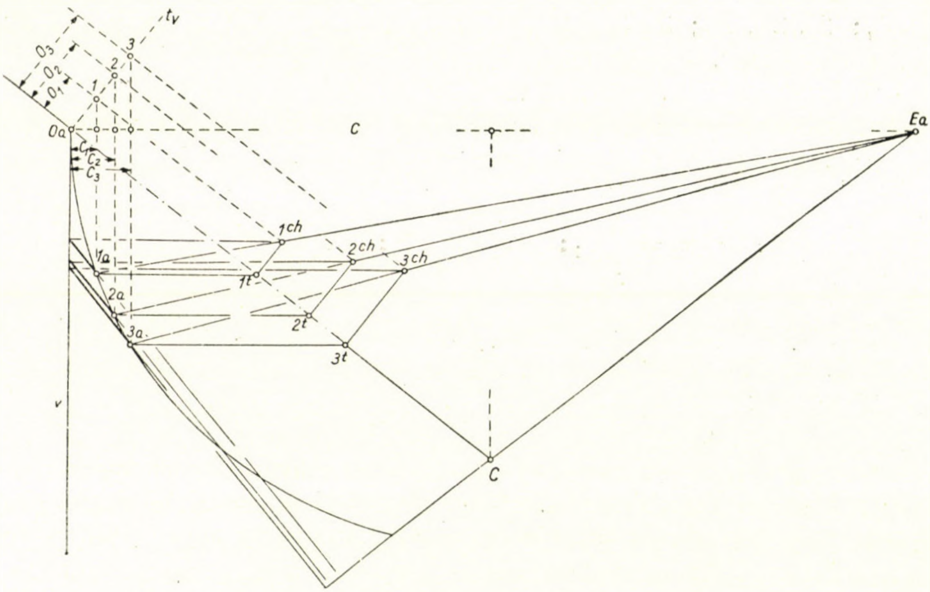


Рис. 8

Ординаты даны как числовые длины. Метод заключается в следующем

1. Длины o_1, o_2, o_3 разбиваются на прямой t_v, которая перпендикулярна к t.

$$t_v \perp t\,.$$

$$o_1 = O_a\ 1, \quad o_2 = O_a\ 2, \quad o_3 = O_a\ 3$$

2. Конечные точки o_1, o_2, o_3, т. е. точки 1, 2, 3 необходимо спроектировать перпендикулярно на O_aE_a и продолжить до сечения вспомогательного круга. Точки пересечения на вспомогательном круге 1^a, 2^a и 3^a также разбиваются.

3. Прямые 1^a, 1^t; 2^a, 2^t; 3^a, 3^t параллельны с c, следовательно могут быть построены возведением вертикали на прямой v, или же перенесением параллельного расстояния при измерении с помощью рулетки.

4. В разбитых точках 1^t, 2^t, 3^t возводятся перпендикуляры к прямой t и переносятся данные ординаты, следовательно

$$o_1 = 1^t,\ 1^{ch}; \qquad o_2 = 2^t,\ 2^{ch}; \qquad o_3 = 3^t, 3^{ch}.$$

5. Так как сечения на прямой t являются слишком «острыми», поэтому точки 1^{ch}, 2^{ch}, 3^{ch} необходимо проверять со вспомогательного круга в направлении точки E_a. Если построение выполнено правильно, тогда точки 1^a, 1^{ch}, E_a; 2^a, 2^{ch}, E_a; 3^a, 3^{ch}, E_a находятся на прямых, поэтому вешки полностью прикрыты.

Если не имеется свободной площади для возведения прямой t_v или же прямая расположилась бы непосредственно в воде, тогда на прямой c необходимы редуцированные расстояния, а именно

$$c_1 = \frac{h}{t} o_1; \qquad c_2 = \frac{h}{t} o_2; \qquad c_3 = \frac{h}{t} o_3$$

В дальнейшем построение производится по схеме, приведенной в пункте 2.

Так как построение является очень простым, то излишне приводить числовые примеры.

5. Прочие вспомогательные круги

Вышерассмотренные задачи решались при помощи вспомогательных кругов хорды. Имеется еще большое число прочих задач, и любая из этих задач может быть легко решена при использовании вспомогательного круга. Вообще задачи являются хордовыми или же тангенциальными задачами и поэтому необходимо иметь хордовые или тангенциальные круги.

Тангенциальные или кратко тангенсные круги отличаются от хордовых кругов, так как их диаметр идентичен с двукратным тангенсом основного круга и наоборот. Поэтому сечения во всех случаях перпендикулярны. Рис. 9 изображает тангенсный круг в сравнении с хордовым кругом.

Центр тангенсного круга идентичен C, в тоже время центр хордового круга находится в точке H, т. е. в точке биссетрисы хорды c.

Круг с центром T, или построенный на любой лежащей на окружности основного круга точке, применяемой в качестве центра, называется полухордным кругом.

Полухордный круг и его применение

Полухордный круг является очень полезным только для разбивки основного круга и предполагая, что элементы или интервалы пикетажа довольно коротки. Для решения прочих задач, когда недопустима взаимозаменяемость хорды и дуги, нельзя использовать полухордный круг.

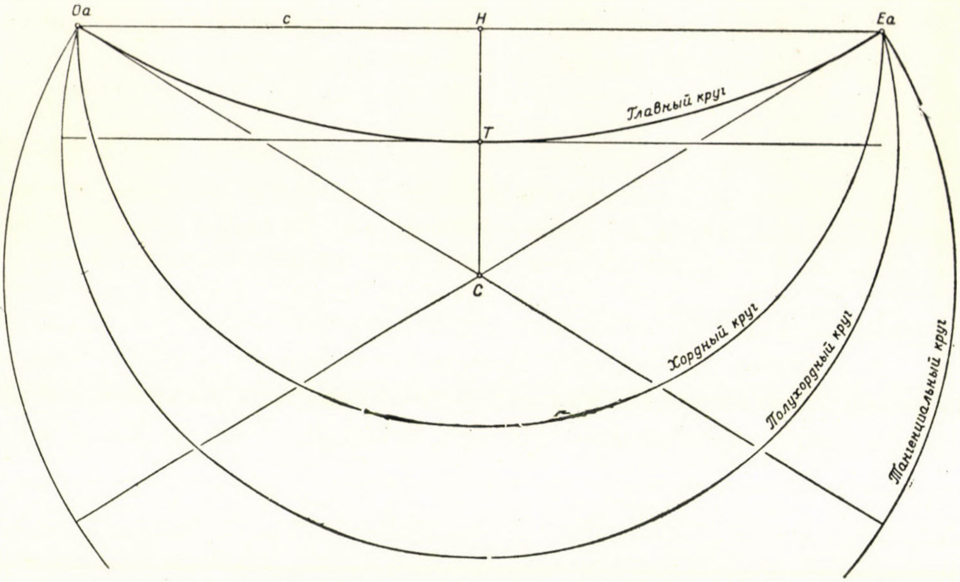


Рис. 9

В качестве примера на рис. 10 приводится такое применение полухордного круга.

Коэффициент редукции по сравнению с хордным кругом такого же диаметра составляет лишь половину последнего; следует указать, что может быть использован лишь для целей разбивки.

Коэффициент редукции вышерассмотренного хордного круга будет

$$\varrho_c = \frac{h}{t},$$

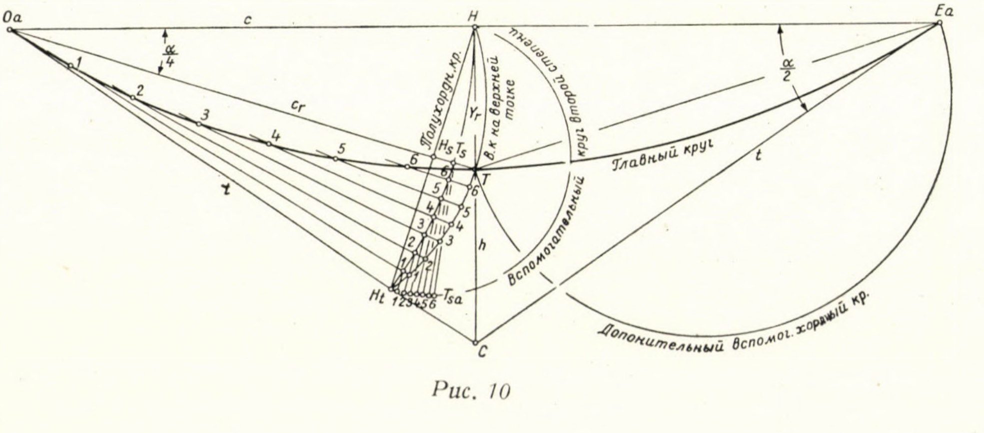


Рис. 10

коэффициент же редукции полухорды для разбивки основного круга будет иметь следующий вид

$$\varrho_s = \frac{h}{2t}.$$

Для объяснения приведем числовой пример.

$$\left.\begin{aligned} h &= 44{,}6 \text{ м} \\ t &= 79{,}4 \text{ м} \end{aligned}\right| \quad \text{итак} \quad \varrho_s = \frac{h}{2t} = \frac{44{,}6}{2 \cdot 79{,}4} = 0{,}281.$$

Так как пикетажный интервал основного круга равен 10 м :

$$s_{ch} = 10 \, м .$$

а разбивочный промежуток полухордного круга будет 2,81 *м:*

$$s_s = 2{,}81 \, м.$$

Несомненным преимуществом полухордного круга является то, что для построения требуется небольшая площадь, мало времени и, таким образом, небольшие расходы.

Другим вопросом является то, что полухордный круг нельзя разбить при помощи эккера, как это мы видели выше, так как с точки H продолжение прямой через O_a попадает в воду, вообще диаметр нельзя построить экономно. Диаметр необходимо построить особо. Однако это отдельное его построение связано с очень небольшими дополнительными работами, так как полухордный круг является очень плоским и построение главной точки его T_s в большинстве случаев является вполне достаточным. Измерение хорды H_tT_s вместо дуги H_tT_s дает незначительное отклонение.

Если в наличии не имеется эккера, тогда можно использовать вышеупомянутый метод.

Второстепенные вспомогательные круги.

Если в наличии имеется эккер и, кроме того, необходимо довиться большей точности, тогда используется второстепенный вспомогательный круг, как это видно на рис. 10. Это можно выполнить в течение короткого времени, так как расстояния являются небольшими.

Так как разбивочный промежуток полухордного круга вычислен в 2,81 *м*

$$s_s = 2{,}81 \, м ,$$

редуцируется вторично для целей второстепенного вспомогательного круга. Коэффициент редукции второстепенного круга будет

$$\varrho_{sc} = \frac{H_s T}{H_t T} = \frac{6{,}2 \ м}{20{,}4 \, м} = 0{,}304.$$

Следовательно, разбивочные интервалы второстепенного вспомогательного круга будут

$$s_{sc} = 0{,}304 \cdot 2{,}81\, м = 0{,}855\, м.$$

Вершинный хордный круг. (См. рис. 10.)

Если в наличии имеется эккер и предварительно произведена проверка вершины основного круга, тогда разбивка основного круга будет происходить быстрее в случае применения вершинного хордного круга; вершинным хордным кругом называется потому, что в него входит вершина основного круга (**T**).

Коэффициент редукции вершинного хордного круга имеет вид

$$\varrho_T = \frac{H_t T}{O_a T} = \frac{y_r}{c_r} = \sin\frac{\alpha}{4}.$$

В применении к рис. 10

$$\varrho_T = \frac{20{,}4\, м}{68{,}5\, м} = 0{,}288.$$

Так как пикетажные интервалы основного круга равны 10 *м*, то поэтому разбивочные промежутки вершинного хордного круга будут

$$10 \cdot 0{,}288\, м = 2{,}88\, м.$$

Диаметр вершинного круга идентичен меньшей хорде, т. е. равен $O_a T$.

Вершиный круг сечет тангенс *t*, а также полухордный круг в точке H_t, или же, другими словами, здесь располагается сечение перпендикуляра, опущенного из T на *t*. Таким образом, если построение выполнено правильно, тогда

$$O_a H = O_a H_t = \frac{c}{2},$$

и поэтому $\frac{c}{2}$ можно измерить измерением $O_a H_t$, если не представляется возможным измерить $O_a H$.

Здесь следует отметить, что

$$HT = TH_t.$$

Применение вершинного хордного круга является также теоретически точным и его коэффициент редукции можно использовать также для решения других задач круга и в тех случаях, когда данная хорда имеет относительно столь большую длину, что нельзя ее заменить дугой окружности.

Тангенсные круги

Как уже видно было выше, тангенсные круги принадлежат к совершенно другой группе вспомогательных кругов, значит их коэффициент редукции является не синусом а тангенсном центрального половинного угла основного круга

$$\varrho_t = \frac{t}{r} = \frac{h}{\frac{c}{2}} = \frac{2h}{c} = \operatorname{tg}\frac{\alpha}{2}.$$

Его применение является совершенно точным и теоретически и он может быть использован для разбивки основного круга, как это имело место в

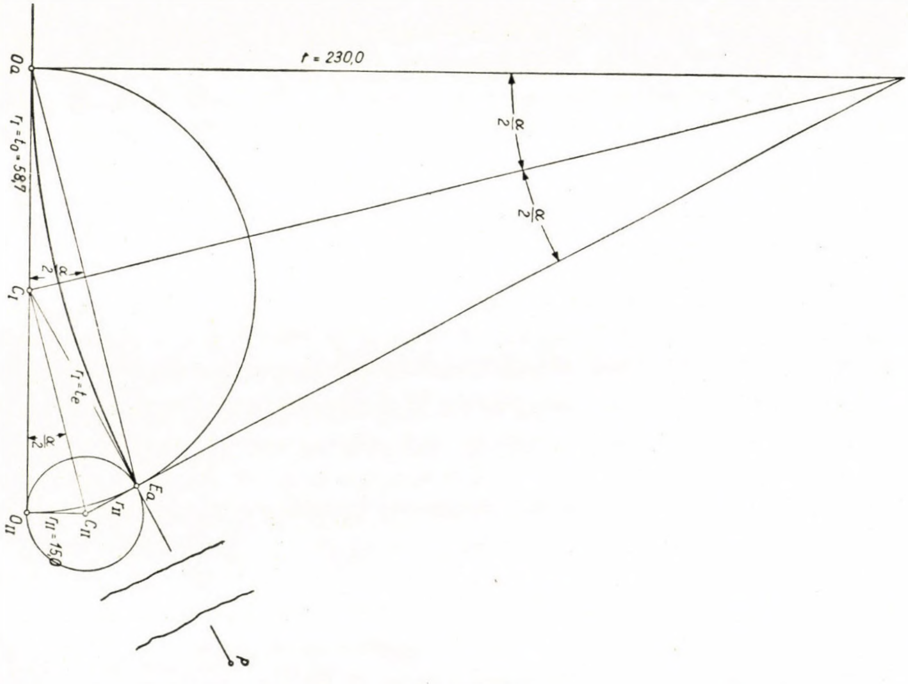


Рис. 11

случае использования хордных кругов. Недостаток, согласно сравнения, является чисто практическим, так как требуется больше площади, что вообще встречается редко. Предпологая, что имеется достаточно свободной площади, тогда все еще остается в качестве недостатка недочет времени и никто не будет выбирать более длинный путь вместо короткого, особенно в том случае, когда весь метод применяется именно для экономии времени и средств.

Поэтому разбивка с применением тангенсных кругов — как метод, имеющий меньшую практическую ценность — здесь не рассматривается.

Однако, с точки зрения решения трудных проблем или сложных вопросов, имеет место совершенно другое положение.

Практической важной задачей является разбивка конечной касательной точки круговой дуги, радиус которой совместно с началом дуги O_a и касательной дуги t_0 даны, при предположении, что для разбивки самого основного круга не имеется времени и в то же время, вторая касательная дана только через одну точку, которая лежит

а) на очень далеком, неизмеримом расстоянии;

б) в бесконечности, дано только направление.

Решение задачи.

а) На рис. 11 следует представить точку P на неизмеримом расстоянии. Однако, это обстоятельство совершенно не изменяет важность задачи. Предположим, что расстояние между P и C является неизмеримым, например, из-за реки или леса и точка P видна лишь в качестве заводской трубы или вершины вышки.

Если бы r не был дан, тогда имелось бы бесконечно большое число решений. Т. е. точка C_I, которая одновременно является также центром первостепенного вспомогательного круга, может быть разбита в любом месте прямой t_0, т. е. другими словами длина O_aC_I, следовательно t_0, зависит от нашего пожелания, необходимо лишь выдержать $t_0 = t_e$ и разбить точку E_a на прямой C_IP, и с этим задача была бы решена.

Но r задан и нельзя изменять ни O_a, ни t_0, и таким образом остается еще вопрос: каким образом зависит действительное положение C_I от данного r, или же другими словами: каким образом можно было бы определить это место точным методом с использованием заданого r?

Поэтому необходимо выполнить вычисления, но эти вычисления упрощаются при применении второстепенного тангенсного круга, одна из касательных которого не является общей с касательной первостепенного тангенсного круга и длина также равна, следовательно являются вполне совпадающей; другая касательня равна t_e и t_0, лежит в продолжении прямой t_0. Следовательно, как это видно на рис. 10, радиус второстепенного круга можно определить, так как

$$r : r_I = r_I : r_{II} \ ,$$

а из этого

$$r_I = \sqrt{r\, r_{II}}$$

r_{II} также неизвестен; его можно определить приближенным методом следующим образом:

1. Разбивается точка C_{Ip} на некотором вероятном расстоянии от точки O_a на прямой t_0, длину которой необходимо определить.

2. Измеренное вероятное расстояние переносится с C_{Ip} в направлении P и, таким образом, получим вероятное E_{ap}.

3. Возводится перпендикуляр в точке E_{ep} и принимается расстояние $E_a p C_{IIp}$, следя за тем, чтобы

$$E_{ap}\, C_{IIp} = C_{IIp}\, O_{IIp} = r_{IIp}\,.$$

Подставляя в формулу r_{IIp},

$$r_{Ip} \lesseqgtr \sqrt{r \cdot r_{IIp}}$$

первый r_{Ip} не будет равен рассчетному $\sqrt{r \cdot r_{IIp}}$, поэтому необходимо продлить или укоротить для достижения $r_I = \sqrt{r \cdot r_{IIp}}$.

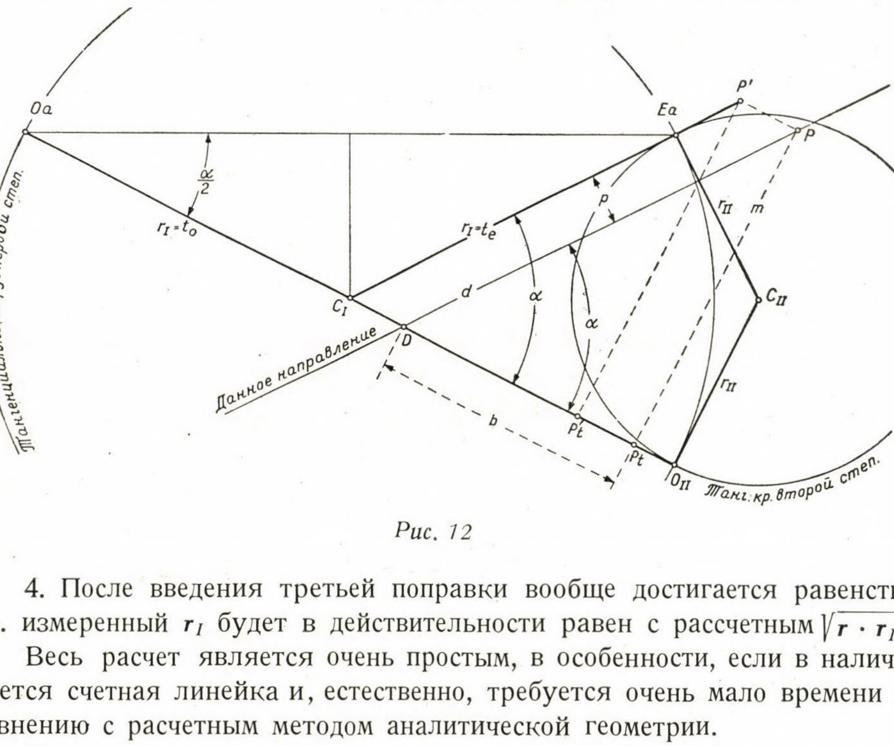


Рис. 12

4. После введения третьей поправки вообще достигается равенство, т. е. измеренный r_I будет в действительности равен с рассчетным $\sqrt{r \cdot r_{IIp}}$.

Весь расчет является очень простым, в особенности, если в наличии имеется счетная линейка и, естественно, требуется очень мало времени по сравнению с расчетным методом аналитической геометрии.

Если имеется достаточно времени для разбивки основного круга еще перед построением Ea, вероятное место легко найти и точное место можно определить первым или вторым приближением.

б) Если точка лежит в бесконечности, тогда она дана направлением, т. е. некоторой прямой, с которой должна быть параллельна построенная касательная (см. рис. 12).

Это является более простой задачей и нет необходимости применить приближение.

При данном направлении является данным также угол α и $\operatorname{tg}\alpha$ можно определить измерением m и G, среди которых один может выбираться свободно, а другой необходимо построить.

Тогда

$$\operatorname{tg}\alpha = \frac{m}{b},$$

и так как

$$t_0 = r \operatorname{tg}\frac{\alpha}{2},$$

$$\operatorname{tg}\frac{\alpha}{2} = \frac{\sin\alpha}{1+\cos\alpha} = \frac{\frac{m}{d}}{1+\frac{b}{d}},$$

поэтому

$$t_0 = r\,\frac{\frac{m}{d}}{1+\frac{b}{d}},$$

так как

$$r : r_I = r_I : r_{II}; \quad r_{II} = \frac{r_I^2}{r}.$$

Разбиваемые точки:

$$O_a C_I = C_I O_{II} = t_0 = r_I = r\,\frac{\frac{m}{d}}{1+\frac{b}{d}},$$

$$O_{II} C_{II} \perp t_0$$

и

$$O_{II} C_{II} = r_{II} = \frac{r_I^2}{r}$$

и, наконец,

$$C_I E_a = t_0,$$

следя за тем, чтобы

$$E_a C_{II} = r_{II},$$

и проверяя, чтобы

$$C_I E_a \perp C_{II} E_a.$$

Другую проверку можно произвести, если d лежит на легко измеримом близком расстоянии, чтобы при этом параллельное расстояние между $C_I E_a$ и $D\ P$ было бы естественно неизменным.

Путь получения E_a является более коротким хотя и без проверки, если данный угол α переместить путем перемещения треугольника DPP_t в $C_IP'P'_t$.

E_a лежит на прямой C_IP' на расстоянии r_I от C_I.

В этом случае второстепенный тангенсный круг может быть использован для проверки, что во всех случаях можно выполнить гораздо быстрее чем проверку при помощи ординат, которая требует продолжительное вычисление абсциссы и ординаты и не может быть выполнена без таблиц, содержащих данные круга.

Вспомогательные круги вообще

На рис. 11 и 12 измеренные длины обозначены жирными линиями. То есть сами круги на местности не разбиты. На чертеже круги начерчены только потому, чтобы выведенный из них метод был бы ясно понятным. В полевых условиях или же на свободной площади измерения производятся только по жирным линиям, так как строится или же находится лишь точка E_a.

Этот метод можно применить также для хордных кругов.

Как это видно на рис. 10 в случае вершинного вспомогательного круга, можно построить также другой хордной круг, диаметр которого будет TE_a.

Вообще, в системе треугольников для любой точки основного круга имеется по два хордных круга и построение, завершенное на первом, можно продолжать на втором, и таким образом можно удвоить проверку.

Принадлежащие друг к другу хордные круги, так как дополняют свое применение, — могут рассматриваться и называться дополнительными вспомогательными хордными кругами.

Жирные линии на рис. 6 и 8 основываются на соответствующем применении дополнительных вспомогательных хордных кругов.

Прочие задачи.

Рассматренные задачи были решены и проверены без использования инструментов, справочников, таблиц и т. д. Метод может быть использован для решения любой задачи круга; может быть использован для решения теоретически важных задач, среди которых позволено будет упомянуть точки, данные на хорде, на касательной, на перпендикуляре в O_a или E_a, и точку пересечения прямой E_aO_a с окружностью основного круга; далее для соотношений между дополнительными хордными кругами и тангенсными кругами, измерения длины дуги основного круга (перед разбивкой) на вспомогательном круге и т. д.

Рассматрение всех этих задач слишком сильно увеличило бы объем данного сообщения.

Инженер вообще доволен, если разбит круг, затем проведена проверка и круг найден безошибочным. Более трудные проблемы встречаются редко.

Поэтому упущены решения чисто теоретического характера задач.

РЕЗЮМЕ

Данным сообщением ставится цель, чтобы во время производства гидротехнических работ инженер-гидротехник мог бы производить необходимые работы во всех встречающихся в практике случаях и работы не запаздывали бы даже в том случае, когда необходимо производить неожиданные изменения разработанных проектов. Предлагаемый автором метод является на столько простым, что при помощи точного, но быстро выполнимового метода легко решить возникающие задачи. Дуга окружности с любым радиусом может быть немедленно разбита продолжением хорды, если принять длину хорды равной $\frac{r}{10}$ и отклонение от направления $\frac{r}{100}$.

Теорема основывается на уравнении хорды окружности. Преимуществом предлагаемого метода является то, что требуется обзор только для следующей точки. К недостатку метода можно отнести, что не получается пикетаж в округленных цифрах и что погрешности невязки направлений необходимо уравнивать. Пикетаж в округленных цифрах можно разбивать при помощи вспомогательных кругов. Вместо инструментальной разбивки углов существуют на вопомогательном круге направления, получаемые редуцированным пикетажем эккера, в которых должны быть точки разбиваемого главного круга. Вспомогательную окружность, которую можно разбить непрерывно при помощи эккера на хорде главной окружности как на диаметре называется хордным кругом. Таким же образом возможно разбить соответствующие вспомогательные круги с концов полухорды и тангенса, при помощи которых в полевых условиях возможно решить различные задачи окружности. Метод распространяется на площадь, ограничиваемую хордой, тангенсом и вспомогательным кругом разбиваемого круга. Точность предлагаемого метода превышает точность инструмента минутной точности.

DIE ABSTECKUNG VON KRÜMMUNGEN BEI WASSERARBEITEN

K. APOR

ZUSAMMENFASSUNG

Das Ziel der Arbeit ist, dem Wasseringenieur bei der Ausführung der Wasserarbeiten eine Methode in die Hand zu geben, die es ihm ermöglicht, auf alle Fälle vorbereitet zu sein, so daß die Arbeiten auch dann keine Verzögerung erleiden, wenn sich eine plötzliche Planänderung als notwendig erweist. Die Methode ist derart einfach, daß es auf eine exakte, doch schnell durchführbare Art und Weise möglich ist, die Aufgabe ohne Schwierigkeiten zu lösen.

Ein Kreisbogen mit einem beliebigen Radius läßt sich von einer verlängerten Sehne sofort abstecken, wenn man die Länge der Sehne zu $\frac{r}{10}$ und die Richtungsabweichung zu $\frac{r}{100}$ nimmt. Der Satz beruht auf der Sehnengleichung des Kreises. Der Vorteil dieser Methode besteht darin, daß sie nur bis zum nächsten Punkt Aussicht erfordert, während ihr Nachteil darin liegt, daß man keine rundzahlige Stationierung erhält und daß der Schlußfehler der Richtungen ausgeglichen werden muß. Stationierungen mit runden Zahlen kann man durch Anwendung von Hilfskreisen abstecken. Hierbei kommen statt der Winkelabsteckungen des Instruments die durch die reduzierten Stationierungen des Hilfskreises gegebenen Richtungen vor, in denen sich die Punkte des abzusteckenden Hauptkreises befinden müssen. Der auf dem ander Sehne des Hauptkreises gemessenen Durchmesser mit dem Winkelspiegel kontinuierlich absteckbare Hilfskreis wird Sehnenkreis genannt. Genau so kann die Halbsehne und von den Endpunkten der Tangente der betreffende Hilfskreis abgesteckt werden, mit dessen Hilfe sich verschiedene Kreisaufgaben auf der Arbeitsstelle lösen lassen. Der Aussichtsanspruch dieser Methode erstreckt sich auf das durch die Sehne des abzusteckenden Kreises, durch dessen Tangente und den Hilfskreis umschlossene Gebiet. Ihre Genauigkeit übertrifft die eines Instrumentes, das auf die Minute genau ist.

THE LAYING OUT OF BENDS OF HYDRAULICS

K. APOR

SUMMARY

The paper aims at preparing the hydraulic engineer for all eventualities when constructing hydraulic structures and to prevent delays even in case of unexpected modification of the plans. The method is so simple that the task may be solved quickly and correctly. An arc of circle of any radius can be set out immediately, if we take the length of chord as $\frac{r}{10}$ and the deviation as $\frac{r}{100}$. The theorem is based on the chord equation of the circle; its advantage is that it requires intervision only between two adjacent points. Its disadvantage is that we cannot use whole chainages and that the final error of the direction must be adjusted.

Whole chainages can be laid out with the help of auxiliary circles. Instead of the directions set out by the instrument, appear the directions determined by the reduced distances of the points laid out on the auxiliary circle, in which direction the points of the principal circle must be. The auxiliary circle which can be laid out continuously with the aid of an optical square on the chord of the principle circle as its diameter, is called chord circle. In the same way can be laid out auxiliary circles on the end points of the semi-chord or of the tangent, and by them various problems related to the circle can be solved in situ. The method needs intervision in the area limited by the chord of the principle circle which is to be laid out, its tangent and auxiliary circle. Its accuracy is better than that of an instrument with one minute accuracy.

JALONNEMENT DE COURBES AUX TRAVAUX HYDRAULIQUES

K. APOR

RÉSUMÉ

Le but que l'auteur s'est proposé dans cette étude est de fournir à l'ingénieur hydraulique une méthode lui permettant d'être préparé à toutes les éventualités, de façon à ce que les travaux ne subissent aucun retard, même au cas d'une modification inattendue des plans. À l'aide de cette méthode tout à fait simple, le problème peut être résolu sans difficulté aucune, de façon exacte et cependant rapide.

Tout arc de cercle de rayon quelconque peut immédiatement être jalonné à partir d'une corde prolongée, en considérant la longueur de la corde comme $\frac{r}{10}$ et la divergence de direction comme $\frac{r}{100}$. Le théorème est basé sur l'équation de corde du cercle. Son avantage est de n'exiger de libre vue que jusqu'au point suivant, son inconvénient de ne pas fournir un nombre rond de stationnements et de comporter une erreur finale de direction qui doit être égalisée. Des stationnements d'un nombre rond peuvent être jalonnés par l'application de cercles auxiliaires. Au lieu des jalonnements d'angle de l'instrument on y obtient des directions déterminées par les stationnements réduits du cercle auxiliaire, directions dans lesquelles doivent se trouver les points du cercle principal. Le cercle auxiliaire pouvant être jalonné de façon continue à l'aide du miroir sur le diamètre mesurée sur la tangente du cercle principal est appelé cercle de corde. On peut de même jalonner la demi corde et à partir des points d'extrémité de la tangente le cercle auxiliaire correspondant, à l'aide duquel différents problèmes de cercle peuvent être résolus sur le lieu de travail. L'exigence de vue de cette méthode s'étend sur le domaine limité par la corde du cercle à jalonner, sa tangente et le cercle auxiliaire. Sa précision dépasse celle d'un instrument d'une précision à la minute.

INVESTIGATION OF THE VOLUMETRIC LOSS OF A CENTRIFUGAL FAN

M. BLAHÓ and L. PRESZLER
DEPARTMENT OF THE THEORY OF FLOW, TECHNICAL UNIVERSITY, BUDAPEST

[Manuscript received January 26th 1956]

Introduction

In the case of centrifugal fans, air leaks over from the spiral casing to the suction pipe, through the clearance between the suction opening of the impeller and the end of the suction pipe. As a consequence to this, the fan discharges less than the quantity of air which flows through the impeller and the excess flowing through the impeller also makes the pressure losses larger. To investigate this effect, arrangements were made in the laboratories of the Department for the Theory of Flow, Technical University, Budapest, for a series of measurements to be carried out, with a variation of the clearance between the impeller and the suction pipe. As a result, by reducing the comparatively large clearance to a quite low value, the maximum of the efficiency has gone up to 79,5 p. c. from 64 p. c.

Measuring arrangements

Air was drawn in by the fan from the laboratory through a short suction cone (Fig. 1). In the interior of the suction hood inlet, there was a conic intermediate piece leading up to the opening of the impeller. It was the axial

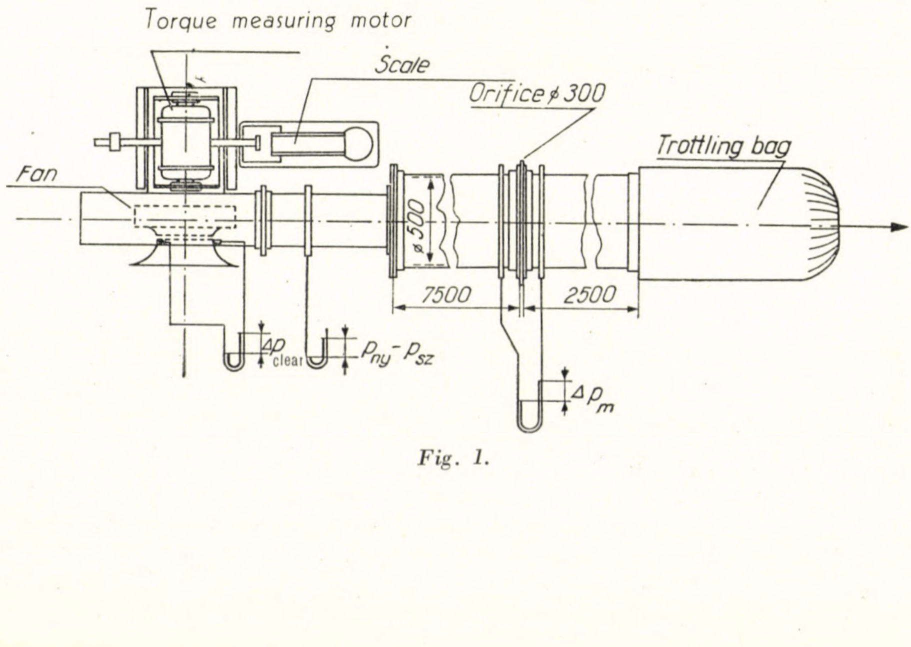


Fig. 1.

shift of this conic "confusor" that admitted of an alteration of the clearance. The diameter of the impeller's inlet was 62 p. c. of the outer diameter. $\frac{D_0}{D_2} = 0{,}62$. The outer diameter of the impeller was $D_2 = 500$ mm.

The quantity of the air carried was measured by an orifice disposed in the discharge pipe. The static pressure head of the fan was found as the difference of the pressure taken off by a circular conduit disposed at the beginning of the discharge pipe from atmospheric pressure. Throttling was applied at the end of the section of the discharge pipe posterior to the measuring orifice. We had a torque balance arrangement fitted to the motor for measuring the amount of power taken.

In addition to the data referred to before, permitting the plotting to the characteristics and of the efficiency of the fan, the difference in static pressure on both sides of the suction cone was also measured, the same as the dynamic head of the air circulating in the spiral casing, in the immediate vicinity of the clearance. From these pressures inference may be drawn on the quantity of the air flowing through the clearance.

Results of the measurements

The series of characteristic curves obtained by a variation of the clearance is shown in Fig. 2 and the pertaining efficiences may be seen in Fig. 3. The breadth of the clearance in front of the impeller was recorded on the curves in ratio to its outer diameter. The characteristics and the efficiency are shown in the usual dimensionless factors.

$$\varphi = \frac{V}{\frac{D_2^2 \pi}{4} u_2}; \qquad \psi = \frac{\Delta p_t}{\frac{\varrho}{2} u_2^2}; \qquad \eta = \frac{V \Delta p_t}{N}$$

where u_2 is the peripheral velocity of the impeller's outer point whereas ϱ is the density of the air and N the power required.

The maximum efficiency is plotted against the clearance breadth as it appears in Fig. 4. Although the clerance breadth $\frac{s}{D_2} = 0{,}03$ is considerably larger than customarily, it may be said that the efficiency can substantially be increased by a reduction of the clearance to the lowest possible value even if it was of the usual breadth of about 0,01 D_2. A limit is set to the reduction of the clearance breadth by securely avoiding friction and the fact that in conventional fabrication the suction pipe and the suction orifice of the impeller, are not true circular. At our experiments, the smallest clearance was of the size of about 1,5 mm. Its exact size we could, however, not ascertain by reason of excentricities.

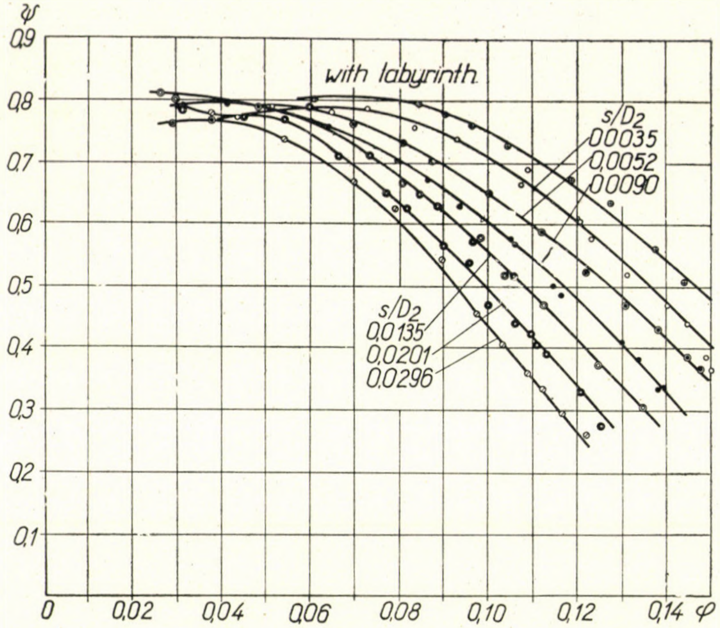

ψ
0,9
0,8
0,7
0,6
0,5
0,4
0,3
0,2
0,1
0
0,02
0,04
0,06
0,08
0,10
0,12
0,14 φ
with labyrinth
s/D2
0,0035
0,0052
0,0090
s/D2
0,0135
0,0201
0,0296

Fig. 2

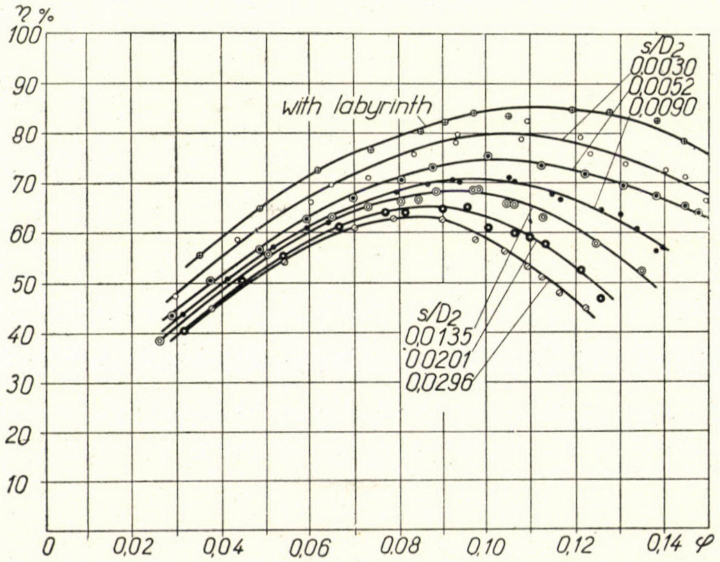

η %
100
90
80
70
60
50
40
30
20
10
0
0,02
0,04
0,06
0,08
0,10
0,12
0,14 φ
with labyrinth
s/D2
0,0030
0,0052
0,0090
s/D2
0,0135
0,0201
0,0296

Fig. 3

In order to see a further reduction of the clearance and a probable rise in efficiency, we provided for a labyrinth seal to be placed between the front of the impeller and the suction pipe (Fig. 5). Having disposed the two labyrinth

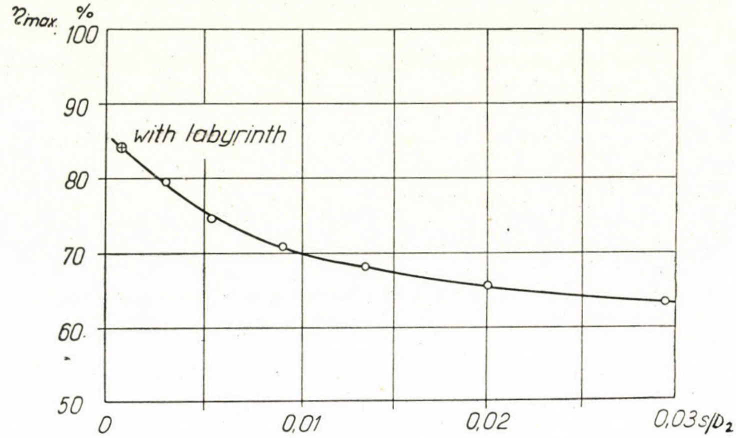


Fig. 4

discs at a distance of 1 mm from each other, the curves obtained were shown in Fig. 3 and the maximum efficiency went up to 84 p. c. We had this value recorded in Fig. 4 at the breadth of the clearance divided by square root of the number of labyrinth clearances $\left(\frac{1}{\sqrt{5}} = 0{,}45 \text{ mm}; \text{ at } s/D_2 = 0{,}0009\right)$.

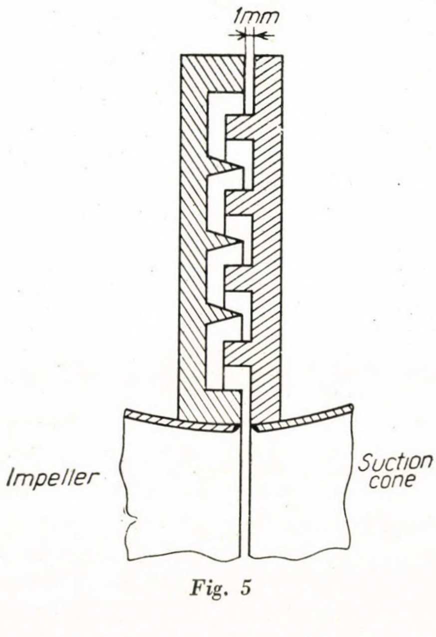


Fig. 5

Approximate computation of the quantity of air passing through the clearance

Inference on the quantity of air passing through the clearance may be drawn from the pressure difference registered on both sides of the suction-cone. These pressure-differences were determined from the average of two take-offs opposite to each other and are subject as functions of the discharge, to a slight alteration only, in the neighbourhood of the maximal efficiency. Fig. 1 contains these values, likewise with respect to $\frac{\varrho}{2} u^2$.

Table 1

$\frac{s}{D_2}$	$\frac{\Delta p_{clear.}}{\frac{\varrho}{2} u_2^2}$	$\frac{V''_{clear.}}{\frac{D_2^2 \pi}{4} u_2}$	$\frac{V'''_{clear.}}{\frac{D_2^2 \pi}{4} u_2}$	$\frac{\Delta V''_{clear.}}{\frac{D_2^2 \pi}{4} u_2}$	$\Delta \varphi$
0,0030	0,58	0,0037	0,0043		
0,0052	0,48	0,0058	0,0070	0,0027	0,010
0,0090	0,34	0,0084	0,0107	0,0037	0,010
0,0135	0,28	0,0116	0,0153	0,0046	0,008
0,0201	0,21	0,0150			
0,0296	0,16	0,0191			

The third column contains quantities of air (indicated by dimensionless values) computed with a contraction factor $\mu = 0{,}65$, in the usual way from pressure difference as a quantity flowing out from a space where the velocity is zero:

$$\frac{V_{clear.}}{\frac{D_2^2 \pi}{4} u_2} = \frac{F_{clear.}}{\frac{D_2^2 \pi}{4}} \mu \sqrt{\frac{\Delta p_{clear.}}{\frac{\varrho}{2} u_2^2}} = 4 \mu \frac{D_0}{D_2} \frac{s}{D_2} \sqrt{\frac{\Delta p_{clear.}}{\frac{\varrho}{2} u_2^2}} .$$

Previous experiences showed that the air now dealt with made a circular flow also on the outer side of the clearance. We could observe the velocity of the flow when setting the second clearance $\left(\frac{s}{D_0} = 0{,}0052\right)$, as the function of the quantity delivered. As indicated by a thread disposed on the side of the clearance through the outlet, the velocity on the side of the intake of the impeller takes a tangential direction, deviating by 10 to 15 degrees toward the clearance. Later on, we measured the dynamic pressure corresponding to the circulation, by a Prandtl tube insensitive to direction up to ± 15 degrees and held tangential to the clearance. Its variation may be seen in Fig. 6.

On the basis of the diagram we can expect a value of $\frac{p_{dyn}}{\frac{\varrho}{2} u_2^2} = 0{,}21$, in the neighbourhood of $\varphi = 0{,}11$, in accord with the opimal efficiency. In considering this value independent of the breath of the clerance, we had this value added to the $\frac{\Delta p_{clear.}}{\frac{\varrho}{2} u_2^2}$ and, in accordance with the Bernoulli equation, computed new quantitites of clearance-air, larger than the previous ones, viz.,

$$\frac{V''_{clear.}}{\frac{D_2^2 \pi}{4} u_2} = 4 \mu \frac{D_0}{D_2} \frac{s}{D_2} \sqrt{\frac{\Delta p_{clear.} + p_{dyn.}}{\frac{\varrho}{2} u_2^2}} .$$

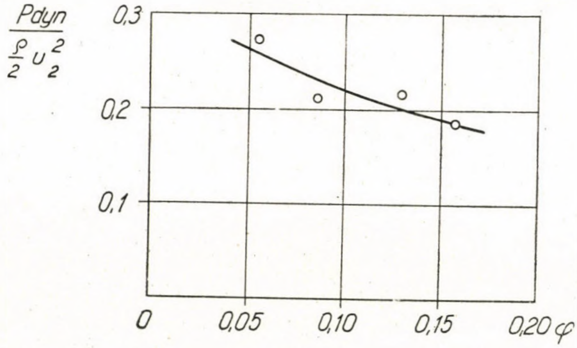


Fig. 6

This computation tacitly implies that the velocity computed on the basis of the Bernoulli equation is perpendicular to the surface of the clearance. The observations made with thread prove that the velocity of the air entering the sucking pipe through the clearance was genuinely radial, although this observation was rendered uncertain through the air flowing in the suction pipe. In view of this all we vould say in respect of the quantity of air computed by the formula as given above is that its quantity is not below that actually passing through the clearance.

Columns 5 and 6 in table 1 show the deviations between the quantities of leakage air thus computed and the shifting to the left of the characteristic curves owing to a growth of the clearance (the latter taken from Fig. 2 with approximation). The deviation is larger than what is indicated by the figure showing an increase in the quantity of clearance air. This seems to permit the inference that the loss in the airsurplus flowing over the impeller is responsible for a further shift in the characteristic curves. This loss makes a particularly subtantial figure in the case of small clearances.

The computation as given above grows uncertain where the breadth of clearances is large. This may be accounted for partly by that the pressure is taken off at a distance of 8 mm from the edge of the clearance and so at a point comparatively near to 15 mm maximal clearance ; another reason responsible for it is that the constancy of the value $\frac{p_{\mathrm{dyn}}}{\frac{\varrho}{u} u_2^2} = 0{,}21$ can no longer be maintained if we are faced with large breadth of the clearances.

SUMMARY

1. Clearance between the impeller of a centrifugal fan and the suction cone can greatly influence the efficiency. For this reason it should be made as small as possible.

2. Consideration must be given to the circulation of the air in the spiral casing beside the clearance, in computing the quantity of air flowing through the clearance.

3. Clearance is responsible not only for lowering the quantity of air delivered but also for further loss of head.

UNTERSUCHUNG DES VOLUMETRISCHEN VERLUSTES EINES ZENTRIFUGAL-VENTILATORS

M. BLAHÓ und L. PRESZLER

ZUSAMMENFASSUNG

1. Der Spalt zwischen Laufrad und Einlaufkegel beeinträchtigt sehr den Wirkungsgrad, somit ist derselbe so klein wie möglich zu nehmen.

2. Die Drehbewegung der Luft im Spiralgehäuse neben dem Spalt darf bei der Berechnung der Spaltluft nicht außer acht gelassen werden.

3. Die Spaltluft vermindert nicht nur die Liefermenge, sondern verursacht auch weitere Druckverluste.

EXAMEN DE LA PERTE VOLUMÉTRIQUE D'UN VENTILATEUR CENTRIFUGE

M. BLAHÓ et L. PRESZLER

RÉSUMÉ

1. Le jeu entre la roue mobile et le cône d'aspiration influant beaucoup sur le rendement il est recommandé de le faire autant que possible minime.

2. Au calcul de la quantité d'air passant à travers cette fente, on doit aussi tenir compte de la circulation d'air dans la boîte spirale, auprès de la fente.

3. La quantité d'air passant à travers la fente ne réduit pas seulement le débit, mais donne aussi lieu à des pertes de pression additionnelles.

ИССЛЕДОВАНИЕ ВОЛЮМЕТРИЧЕСКОЙ ПОТЕРИ НЕКОТОРОГО ЦЕНТРОБЕЖНОГО ВЕНТИЛЯТОРА

М. БЛАХО и Л. ПРЕСЛЕР

РЕЗЮМЕ

1. Зазор между рабочим колесом и входным конусом сильно влияет на кпд, следовательно зазор следует брать возможно меньшим.

2. Вращательное движение воздуха в спиральной камере возле зазора нельзя упускать при расчете количества воздуха зазора.

3. Количество воздуха зазора уменьшает не только количество подаваемого воздуха, но и вызывает также дополнительные потери давления.

BERECHNUNG VON IN GESTEIN GEBETTETEN DRUCKROHREN UND BEHÄLTERN

F. KOVÁCSHÁZY
KANDIDAT DER TECHNISCHEN WISSENSCHAFTEN,
TIEFBAUPLANUNGSAMT DER STADT BUDAPEST

[Eingegangen am 25. Februar 1956]

1. Einleitung

Die Innenverkleidung von in Gestein gebetteten und grossem inneren Druck ausgesetzten Druckrohren und Behältern presst sich infolge des Betriebsdruckes an das umschliessende Gestein und dieses und die Verkleidung beteiligen sich nach Massgabe ihrer Elastizität an der Aufnahme der dem inneren Betriebsdruck entspringenden Kräfte. Daraus folgt, dass in Gestein gebettete Druckrohre und Behälter mit erheblich geringeren Wandstärken gebaut werden können, als frei stehende.

In unserem Vaterland erstehen technische Fragen, bei denen in Gestein gebettete Druckrohrleitungen von Wasserkraftwerken und ebenso in Gestein angelegte Lagertanks für Flüssigkeiten oder Gase eine Rolle spielen, unsere Planer des Bauwesens verfügen jedoch über keinerlei technische Daten, weil eben derartige Objekte bei uns noch nicht errichtet wurden. Man muss also für diesen Themenkreis ein heimisches Schrifttum schaffen und in Verbindung damit müssen einerseits die in der ausländischen Fachliteratur auf Druckstollen bezüglichen Ergebnisse gesammelt und ergänzt werden, andererseits müssen für die Berechnung von in Gestein gebetteten und innerem Druck ausgesetzten Behältern neue Verfahren entwickelt werden.

Die im ausländischen Fachschrifttum erörterten Lösungen von in Gestein gebetteten Druckrohren befassen sich nur mit den wesentlicheren Belastungstypen bzw. berichten von den aus Versuchen an der Arbeitsstätte gewonnenen praktischen Ergebnissen. Ein Nachteil der ausländischen Lösungen ist, dass sie das wichtigste Detail der Berechnung, die Grenze der um das Objekt herum geborstenen Gesteinzone, nur schätzungsweise bestimmt und das gestaltet die Resultate problematisch.

Verfasser hat sich die Aufgabe gestellt, die derzeit auf Druckrohre bezüglichen bekannten ausländischen Verfahren vom Gesichtspunkt der praktischen Anwendung zu ergänzen und unter Berücksichtigung ihrer wirtschaftlichen Fragen analog der Berechnung von Druckrohren ein Berechnungsverfahren für grossräumige zylindrische Behälter zu schaffen.

2. Berechnungsverfahren für in Gestein gebettete Druckrohre

Die Berechnung des in Gestein gebetteten Druckrohres kann aus dem Kräftespiel des Zylinders kreisförmigen Querschnittes abgeleitet werden.

Auf Grund der bisherigen Arbeiten von TIMOSHENKO, MÜHLHOFER, OBERTI und LELLI fasst der Autor die bisher bekannte Lösung der Berechnung unter Benutzung der nachstehenden Bezeichnungen wie folgt zusammen :

p_1 innerer Druck (der Druck hat negatives Vorzeichen),
p_2 äusserer Druck,
r_1 innerer Radius der Zylinders,
r_2 äusserer Radius des Zylinders,
r Radius eines beliebigen Punktes innerhalb der Zylinderwand,
σ_r radiale Spannung (der Druck hat negatives Vorzeichen),

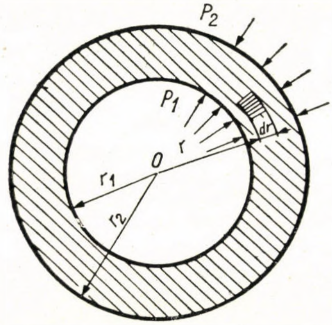


Bild 1. Durchschnitt des Kreisringzylinders

σ_t tangentiale Spannung (der Zug hat positives Vorzeichen),
σ_z axiale Spannung,
E Elastizitätsmodul,
m Poissonsche Zahl,
$\mu = \frac{l}{m}$ Poissonscher Faktor,
ε spezifische Verformung,
u radiale Verschiebung (positiv, wenn von innen nach aussen bewegt).

Die Gleichungen der Elastizitätslehre werden in dem Fall aufgestellt, wenn der Zylinder zu seiner Umgebung fixiert ist, d. h. also, sich in Längsrichtung nicht wegbewegen kann. Dann gelangt man zu folgender Differentialgleichung :

$$\frac{d^2 u}{dr^2} + \frac{1}{r}\frac{du}{dr} - \frac{u}{r^2} = 0 \tag{1}$$

durch deren von LAMÉ—CLAPEYRON stammender Lösung für die im Zylinder vorhandenen Spannungszustände folgende Werte gewonnen werden :

$$\sigma_r = \frac{1}{r_2^2 - r_1^2}\left[p_2 \cdot r_2^2 - p_1 \cdot r_1^2 - (p_2 - p_1)\frac{r_1^2 \cdot r_2^2}{r^2}\right]$$

$$\sigma_t = \frac{1}{r_2^2 - r_1^2}\left[p_2 \cdot r_2^2 - p_1 \cdot r_1^2 + (p_2 - p_1)\frac{r_1^2 \cdot r_2^2}{r^2}\right]$$

$$\sigma_z = \frac{1}{m}(\sigma_r + \sigma_t) = \frac{2}{m\,(r_2^2 - r_1^2)}(p_2 \cdot r_2^2 - p_1 \cdot r_1^2) = \text{konstant} \tag{2}$$

$$u = \frac{(m+1)\cdot(m-2)}{m^2 \cdot E} \cdot \frac{1}{r_2^2 - r_1^2}\left[(p_2 r_2^2 - p_1 \cdot r_1^2)\cdot r + \right.$$

$$\left. + \frac{m}{m-2}(p_2 - p_1)\frac{r_1^2 \cdot r_2^2}{p}\right].$$

*

Aus den bisherigen Resultaten kann schon ein besonderer Grundfall des in Gestein gebetteten Zylinders gewonnen werden. Bei einem unter innerer Spannung stehenden unverkleideten Behälter mit Kreisquerschnitt geht der Radius der äusseren Oberfläche gegen die Grenzlage $r_2 \to \infty$ und der äussere Druck $p_2 = 0$, wenn der Gesteindruck vorläufig nicht beachtet wird. Im Falle einer Anordnung nach Bild 2 nehmen die Gleichungen (2) folgende Grenzwerte an:

$$u = -\frac{m+1}{m \cdot E} \cdot \frac{r_1^2}{r} p_1$$

$$\sigma_r = +\frac{r_1^2}{r^2} \cdot p_1 \tag{3}$$

$$\sigma_t = -\frac{r_1^2}{r^2} \cdot p_1$$

$$\sigma_z = 0$$

was so zu verstehen ist, dass bei vorhandenem innerem Druck σ_r immer Druck bedeutet, dessen Wert an der Innenfläche des Behälters am grössten ist, während σ_t immer Zugspannung ist, deren absoluter Wert mit σ_r gleichwertig ist und schliesslich ist die Spannung in axialer Richtung immer 0. Das Bild 2 veranschaulicht, wie rapide die Spannungen in Richtung zum Gesteininneren sich verringern.

*

Es muss aber bemerkt werden, dass die Formeln nur innerhalb der Elastizitätsgrenze Geltung haben und daraus folgt, dass der unverkleidete Behälter im Prinzip nur bei sehr geringem innerem Druck verwendbar ist. Zu seinem Schutz wird der Behälter sowieso verkleidet. Vom Standpunkt der Statik aus prüfend erkennt man, dass auf der inneren Wandoberfläche des Behälters mit dem Betriebsdruck gleichwertige Zugspannung auftritt. Beim Gestein ist im allgemeinen die gestattete Zugspannung der 1/8 bis 1/10 Teil des Wertes der Reissfestigkeit, was einem Wert von höchstens 3 ∼ 5 kg/cm² entspricht. Hieraus folgt gleichfalls, dass bei einem inneren Überdruck von mehr als 2—3 Atm. das Druckrohr oder der Behälter mit einer solchen Verkleidung ausgestattet werden muss, die in der Lage ist, Zugkräfte aufzunehmen. Bei grösserem innerem Druck

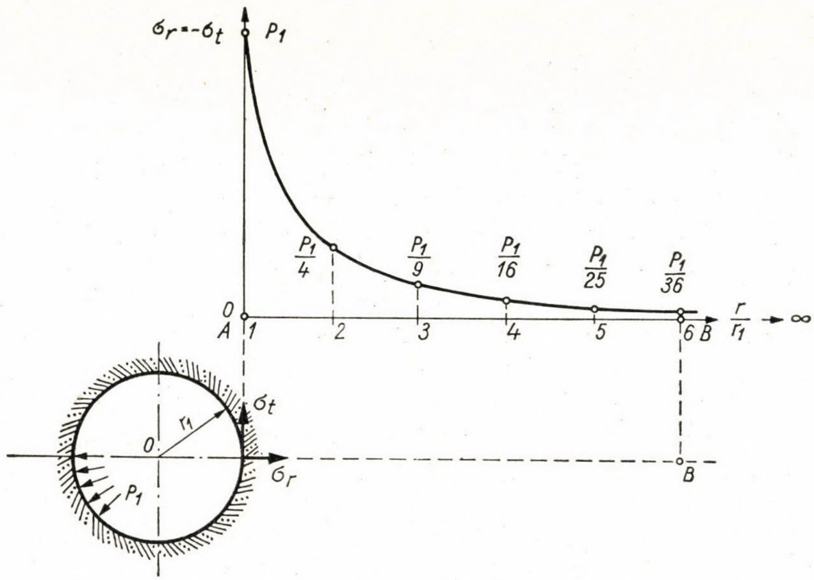


Bild 2. Verteilung der Spannungen in Richtung der waagrechten Symmetrieebene A—B

wird die Grenzspannung des Gesteins überschritten und handelt es sich um homogenes und isotropes Gestein, so erleidet bei zunehmendem Betriebsdruck das den Hohlraum umgebende Gestein zuerst plastische Verformung, während nach weiterer Zunahme des Druckes durch Überschreiten der Zugspannung des Gesteins in dem den Behälter umgebenden Gestein theoretisch radiale Sprünge auftreten.

Es muss also auch die Verteilung der Spannungen in solchen Gesteinen untersucht werden, die Zugspannungen nur bis zu gewissen Grenzen aufzunehmen vermögen.

In der sog. geborstenen Gesteinzone ist die tangentiale Zugspannung $\sigma_t = 0$, d. h. in dieser Zone ist das Gestein unfähig, Zugspannung aufzunehmen.

In der geborstenen Gesteinzone sinkt die radiale Spannung im umgekehrten Verhältnis zur Entfernung.

$$\sigma_r = p_1 \frac{r_1}{r} \,. \tag{4}$$

Nun wenden wir uns solcher Konstruktion zu, bei der ein Teil der Zugkräfte von der Verkleidung, ihr anderer Teil aber von der tragfähigen, nicht geborstenen Schicht des Gesteins aufgenommen wird. Zu diesem Zweck muss man als Grundfall das Kräftespiel des doppelwandigen Zylinders kennen lernen. Es wird angenommen, dass die beiden ineinandergeschobenen Zylinder kreisförmigen Querschnittes koaxial zu einander sind, die Ringe jedoch verschiedene Elastizitätseigenschaften besitzen (siehe Bild 3).

Werden in die Gleichung (2) zuerst die Werte

$$E = E_1, \quad m = m_1 \quad r_2 = r_3, \quad p_2 = p_3$$

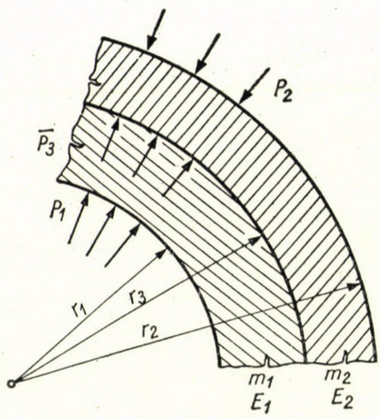


Bild 3. Doppelwandiger Zylinder

für den inneren Zylinder eingesetzt, danach für den äusseren Zylinder die Werte

$$E = E_2, \quad m = m_2 \quad r_1 = r_3, \quad p_1 = p_3$$

so bekommt man für die Werte u, σ_r, σ_t und σ_z für jeden Zylinder ein Gleichungssystem.

*

Auf der Grenzfläche zwischen den beiden Zylindern, d. i. am Platz $r = r_3$, ist aus Gründen der Kontinuität die Verschiebung des inneren und äusseren Zylinders gleichförmig.

Durch Aufstellen der Gleichung $u_1 = u_2$ bekommt man für den unbekannten Wert p_3 eine lineare Gleichung, aus der nach Berechnung des Wertes p_3 das Kräftespiel des doppelwandigen Zylinders bekannt wird.

Der Spezialfall des doppelwandigen Zylinders kann geschaffen werden, wenn man den Druck $p_2 = 0$ ausübt und $r_2 \to \infty$. Dann gewinnt man einen solchen in Gestein gebetteten verkleideten Behälter, bei dem die Verkleidung ebenso wie das Gestein in vollem Ausmass für die Aufnahme von Zugkräften geeignet sind (siehe Bild 4). In diesem Augenblick gibt es keine geborstene Zone. Wird dies in die früher erwähnte Gleichung $u_1 = u_2$ eingesetzt, so bekommt man mit den Grenzwerten $p_2 = 0$, $r_2 \to \infty$ für den an der Grenzfläche des Gesteins und der Verkleidung auftretenden unbekannten Druck $\overline{p_3}$ folgenden Wert :

$$\overline{p_3} = \frac{2\,\frac{m_1 - 1}{m\,1} \cdot p_1 \cdot r_1^2}{\left(1 - \frac{m_2 + 1}{m_1 + 1} \cdot \frac{m_1 \cdot E_1}{m_2 \cdot E_2}\right) r_1^2 + \left(\frac{m_1 - 2}{m_1} + \frac{m_2 + 1}{m_1 + 1} \cdot \frac{m_1 \cdot E_1}{m_2 \cdot E_2}\right) r_3^2} . \quad (5)$$

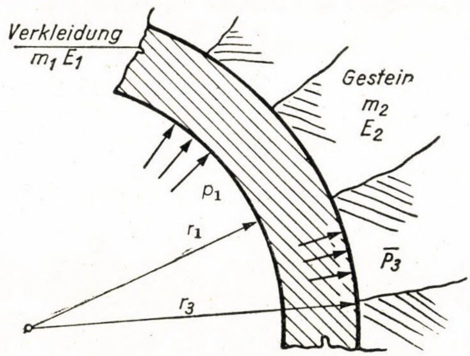


Bild 4. Verkleideter Behälter

Wird weiterhin der Wert von $\overline{p_3}$ in die sich auf den inneren Teil des doppelwandigen Zylinders beziehende Gleichung eingesetzt und ebenso in die Gleichung (3), so sind die statischen Probleme der Verkleidung und des Gesteins gelöst.

Auf die Verkleidung bezogen ist das :

$$u_1 = \frac{(m_1 + 1) \cdot (m_1 - 2)}{m_1^2 \cdot E_1} \cdot \frac{1}{r_3^2 - r_1^2} \left[(p_3 \cdot r_3^2 - p_1 r_1^2) \cdot r + \right.$$
$$\left. + \frac{m_1}{m_1 - 2} (p_3 - p_1) \frac{r_1^2 \cdot r_3^2}{r} \right]$$
$$\sigma_r = \frac{1}{r_3^2 - r_1^2} \left[p_3 \cdot r_3^2 - p_1 \cdot r_1^2 - (p_3 - p_1) \frac{r_1^2 \cdot r_3^2}{r^2} \right] \quad (6)$$
$$\sigma_t = \frac{1}{r_3^2 - r_1^2} \left[p_3 \cdot r_3^2 - p_1 r_1^2 + (p_3 - p_1) \frac{r_1^2 \cdot r_3^2}{r^2} \right]$$

$$\sigma_z = \frac{2}{m_1 (r_3^2 - r_1^2)} [p_3 \cdot r_3^2 - p_1 \cdot r_1^2] = \text{konstant}$$

und auf das Gestein bezogen :

$$u_2 = -\frac{m_2 + 1}{m_2 E_2} \cdot \frac{r_3^2}{r} \cdot p_3$$

$$\sigma_r = + \frac{r_3^2}{r^2} \cdot p_3 \qquad (7)$$

$$\sigma_t = - \frac{r_3^2}{r^2} \cdot p_3$$

$$\sigma_z = 0 .$$

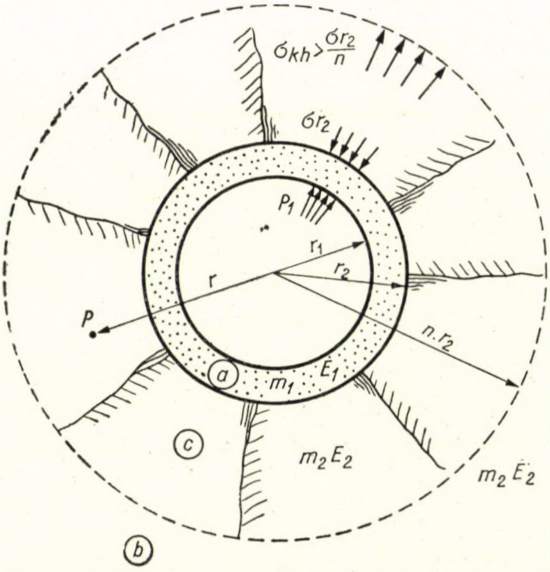


Bild 5. Die Verkleidung umgebende Zone des geborstenen Gesteins

Treten zufolge inneren Druckes in der die Verkleidung umgebenden Gesteinzone radiale Sprünge auf, so kann vom statischen Standpunkt aus betrachtet diese Anordnung in drei verschiedene Zonen eingeteilt werden (siehe Bild 5).

a) Verkleidung,

b) unversehrtes Gestein,

c) mittlere, geborstene aus viereckigen keilförmigen Elementen bestehende Gesteinzone.

Die Bestimmung der Spannungen geschieht in den einzelnen Zonen wie folgt :

a) *Verkleidung bzw. Zone der Verkleidung*

Innerhalb der Elastizitätsgrenze des Verkleidungsmaterials gelten die Gleichungen (2).

b) *Zone des unversehrten Gesteins*

Innerhalb der Grenzen r_2 und $r = n \cdot r_2 \rightarrow \infty$ sind die Gleichungen (3) der Elastizitätslehre gültig, jedoch müssen folgende Werte eingesetzt werden :

$$m = m_2 \qquad r_1 = n \cdot r_2$$

$$E = E_2 \qquad p_1 = \frac{\sigma_{r_2}}{n}$$

Die Spannung σ_{r_2} tritt an der Grenze der unbeschädigten und der geborstenen Gesteinzone auf und der Wert σ_{r_2} ist vorläufig unbekannt, der für die Grenze der geborstenen Gesteinzone charakteristische Wert »n« ist gleichfalls unbekannt. Aus der Fachliteratur wird der Wert »n« nach den bisher bekannten Verfahren durch Schätzung bestimmt. Das kann nicht gutgeheissen werden, weil für die Gestaltung der Grenze der geborstenen Gesteinzone kein Erfahrungswert festzustellen ist.

c) *Die Zone des geborstenen Gesteins,* in der nach dem gesagten axiale und tagentiale Spannungen grundsätzlich nicht auftreten können, ist nämlich ihrer Sprünge wegen nicht in der Lage, Zugspannungen aufzunehmen. Berechnet man die radiale Verschiebung der Zone »c« aus der Verschiebung der Zonen »c« und »b«, so bekommt man für die an der Grenze Verkleidung — Gestein auftretende radiale Spannung folgenden Wert :

$$\sigma_{r_2} = \frac{2\,(m_1 - 1)\,p_1 \cdot r_1^2}{\frac{m_1^2 E_1}{(m_1 + 1)\,E_2}\left(\frac{m_2 + 1}{m_2} + \log n\right) \cdot (r_2^2 - r_1^2) + (m_1 - 2)\,r_2^2 + m_1\,r_1^2}\,. \tag{8}$$

*

Kennt man aus der oben angegebenen Formel den Wert σ_{r_2}, so kann das Kräftespiel der drei verschiedenen Zonen festgestellt werden. Bemerkt sei, dass der Wert log n dem Wert des natürlichen Logarithmus entspricht.

3. Weitere Entwicklung des Berechnungsverfahrens für in Gestein gebettete Druckrohre

Die Grenze des geborstenen Gesteins lässt sich an Stelle der Schätzung auch auf Grund folgender Überlegung genauer bestimmen. Es kann nämlich vorausgesetzt werden, dass das Gestein infolge der durch Überdruck auftretenden tangentialen Zugspannungen so weit springen wird, bis die Zuggrenzspannung des Gesteins (σ_{kh}) erreicht wird.

Dieser Grenzspannungswert ist nach gründlichem Erschliessen und Prüfen des Gesteins feststellbar.

An der Grenze des geborstenen und unversehrten Gesteins bestehender Zusammenhang :

$$\sigma_{r=n \cdot r_2} = \frac{\sigma_{r_2}}{n} . \tag{9}$$

Es ist bekannt, dass die absoluten Werte der in demselben Punkt des unversehrten Gesteins auftretenden radialen und tangentialen Spannungen gleich sind, so dass man schreiben kann :

$$\sigma_{kh} = \frac{\sigma_{r_2}}{n} \qquad \text{oder} \qquad n = \frac{\sigma_{r_2}}{\sigma_{kh}} \tag{10}$$

weil an der Grenze des geborstenen und unversehrten Gesteins gerade die Grenzzugspannung des Gesteins auftritt.

Nach Vergleichen der Gleichungen (7) und (10)

$$\sigma_r = \sigma_{kh} \frac{n^2 \cdot r_2^2}{r^2} \tag{11}$$

sieht man, dass im unversehrten Gestein immer an der Grenzspannung des Gesteins geringere Spannung entsteht, weil die äussere Grenze der geborstenen Gesteinzone

$$n \cdot r_2 < r .$$

Dieser Sachverhalt deckt sich mit der Ausgangsvoraussetzung des Verfassers.

In das auf der Elastizitätslehre beruhende Berechnungsverfahren wurde jedoch eine Bruchvoraussetzung eingefügt, weshalb betont werden muss, dass diese Berechnung nur annährend richtige Werte ergibt, diese sind jedoch viel genauer als die auf einfacher Schätzung beruhenden.

Nach Erklärung des Wertes »*n*« durch die Gleichung (10) ist die Aufgabe gestellt, die unbekannte Spannung σ_{r_2} genau festzustellen. Deshalb werden in die Formel (8) folgende Bezeichnungen eingeführt :

$$\begin{aligned}
&A = 2\,(m_1 - 1) \cdot p_1 \cdot r_1^2 \\
&B = \frac{m_1^2 \cdot E_1}{(m_1 + 1)\, E_2} \qquad C = \frac{m_2 + 1}{m_2} \\
&D = r_2^2 - r_1^2 \qquad \log n = X \\
&E = (m_1 - 2)\, r_2^2 \qquad F = m_1 \cdot r_1^2 \\
&H = B \cdot C \cdot D + E + F.
\end{aligned} \tag{12}$$

Die hier mit grossen Buchstaben bezeichneten Werte sind von der geometrischen Form des Objektes, dem inneren Betriebsdruck und den Elastizitätskennwerten abhängig, können also bei der gegebenen Aufgabe als bekannt angesehen werden. Nach Einführung dieser Bezeichnungen ist die Gleichung (8)

$$\sigma_{r_2} = \frac{A}{B(C+X)\cdot D+E+F} = \frac{A}{B\cdot D\cdot X+H}. \tag{13}$$

Man weiss aus Erfahrung, dass der Wert »n« am häufigsten zwischen 2 und 5 wechselt.

Der Wert

$$X = \log n = 2.3026 \log n \tag{14}$$

wird für ganzzahlige Werte von »n« festgestellt. Dieser liegt in den meisten Fällen zwischen 2 und 5. Mit diesen X-Werten werden mit Hilfe der Gleichung (13) die Werte für σ_{r_2} einzeln berechnet. Wird jetzt der veränderliche Wert σ_{r_2} als Funktion von »n« abgebildet u. z. so, dass die Werte von σ_{r_2} auf der Ordinate, die Werte von »n« und gleichzeitig die Werte von $n \cdot \sigma_{kh}$ auf der Abszisse aufgetragen werden, welch letztere lt. Gleichung (10) ebenfalls Werte für σ_{r_2} bedeuten, so bekommt man zwischen $n = 2 \rightarrow 5$ für ersteres eine Kurve und für letzteres eine Gerade, die sich in dem Punkt schneiden, in dem der Wert σ_{r_2} die Gleichungen (8) und (10) befriedigt.

An dieser Stelle kann man den definitiven Wert σ_{r_2} ablesen. Setzt man diesen Wert in den Zusammenhang (2) ein, so wird das Kräftespiel der Konstruktion bekannt.

Die sich auf die drei verschiedenen Zonen beziehenden Formeln werden folgendermassen zusammengefasst:

a) *In der Verkleidungszone*

$$u_a = \frac{(m_1+1)\cdot(m_1-2)}{m_1^2\cdot E_1}\cdot\frac{1}{r_2^2-r_1^2}\left[(\sigma_{r_2}\cdot r_2^2 - p_1 r_1^2)\, r + \right.$$

$$\left. + \frac{m_1}{m_1-2}(\sigma_{r_2}-p_1)\frac{r_1^2\cdot r_2^2}{r}\right]$$

$$\sigma_r = \frac{1}{(r_2^2-r_1^2)}\left[\sigma_{r_2}\cdot r_2^2 - p_1 r_1^2 - (\sigma_{r_2}-p_1)\frac{r_1^2\cdot r_2^2}{r^2}\right] \tag{15}$$

$$\sigma_t = \frac{1}{(r_2^2-r_1^2)}\left[\sigma_{r_2}\cdot r_2^2 - p_1 r_1^2 + (\sigma_{r_2}-p_1)\frac{r_1^2\cdot r_2^2}{r^2}\right]$$

$$\sigma_z = \frac{2}{m_1(r_2^2-r_1^2)}(\sigma_{r_2}\cdot r_2^2 - p_1 r_1^2).$$

An der Innenfläche der Verkleidung aber:

$$u_a = \frac{(m_1+1)\cdot(m_1-2)}{m_1^2 \cdot E_1} \cdot \frac{1}{(r_2^2 - r_1^2)} \left[(\sigma_{r_2} \cdot r_2^2 - p_1 r_1^2) \cdot r_1 + \right.$$

$$\left. + \frac{m_1}{m_1 - 2} (\sigma_{r_2} - p_1) r_1 \cdot r_2^2) \right]$$

$$\sigma_r = \frac{1}{r_2^2 - r_1^2} \left[\sigma_{r_2} \cdot r_2^2 - p_1 r_1^2 - (\sigma_{r_2} - p_1) r_2^2 \right] = p_1 \tag{16}$$

$$\sigma_t = \frac{1}{r_2^2 - r_1^2} \left[2\,\sigma_{r_2} \cdot r_2^2 - p_1 (r_1^2 + r_2^2) \right]$$

$$\sigma_z = \frac{2}{m_1 (r_2^2 - r_1^2)} (\sigma_{r_2} \cdot r_2^2 - p_1 \cdot r_1^2).$$

c) *In der Zone des geborstenen Gesteins*

$$u_c = -\frac{r_2 \sigma_{r_2}}{E_2} \left(\frac{m_2 + 1}{m_2} + \log \frac{n r_2}{r} \right)$$

$$\sigma_r = \frac{r_2}{r} \cdot \sigma_{r_2} \qquad \sigma_t = 0 \; \sigma_z = 0. \tag{17}$$

b) *Im unversehrten Gestein*

$$u_b = -\frac{m_2 + 1}{m_2 E_2} \cdot \frac{n}{r} \cdot r_2^2 \cdot \sigma_{r_2}$$

$$\sigma_r = n \frac{r_2^2}{r^2} \cdot \sigma_{r_2} = n^2 \frac{r_2^2}{r^2} \cdot \sigma_{kh} \tag{18}$$

$$\sigma_t = n \frac{r_2^2}{r^2} \cdot \sigma_{r_2} = -n^2 \frac{r_2^2}{r^2} \cdot \sigma_{kh}.$$

Es muss noch der Verwendungszweck der Beton- und Stahlbetonverkleidung geprüft werden. Betonverkleidung betreffend bemerkt der Verfasser, dass diese nach Erreichen der Zuggrenzspannung Sprünge erhält und so kann sie nicht mehr als unversehrt und als nach der Elastizitätslehre berechnete Verkleidungszone bezeichnet werden. Die Betonverkleidung ist deshalb nur bei geringerem inneren Überdruck zu gebrauchen und für den Fall des Auftretens namhafterer Zugspannung muss Stahlbetonverkleidung verwendet werden. Ihr Elastizitätsmodul muss unter Berücksichtigung der perzentuellen Stahlarmierung festgestellt werden.

Elastizitätsmodul der Stahlbetonverkleidung:

$$E_{vb} = E_1(f) = E_b \left(1 + \frac{f}{100} \cdot \frac{E_v - E_b}{E_b} \right) \tag{19}$$

wo

E_b = der Elastizitätsmodul des Betons,
E_v = der Elastizitätsmodul der Stahleinlage,
f = das perzentuelle Verhältnis von Stahl- und Betonquerschnitt
d. i. $\frac{F_v}{F_b} \cdot 100 = f$.

Werden die Wiederholungen der Belastungen berücksichtigt, so muss auch bei Stahlbetonanordnungen eine gewisse Risslosigkeit vorausgesetzt werden, weil sonst die zuverlässige Aufnahme von Zugspannungen nicht gesichert ist.

Die Art der Verwendung von Rohrleitungen oder Behältern bringt es in den meisten Fällen mit sich, dass eine gewisse Risslosigkeit erwünscht ist. Wird eine besondere Stahlverkleidung nicht verwendet, so muss bei Beton- und Stahlbetonanordnungen auf die entsprechenden Grenzspannungen Rücksicht genommen werden.

Tafel I zeigt die Grenzspannungen von Beton- bzw. Stahlbetonkonstruktionen im Falle der Forderung der Risslosigkeit.

Bei der Berechnung muss natürlich der übergelagerte Maximalwert der Zugspannung (Gesteindruck, Eigengewicht, innerer Überdruck, Schwindung, Temperatureinwirkung usw.) niedriger bleiben, als die Grenzbeanspruchung.

Tafel I

Grenzspannungen des Betons vom Standpunkt der Risslosigkeit

Betonqualität			B 200 kg/cm²	B 280 kg/cm²	B 400 kg/cm²
Mittige Zugbeanspruchung, ausmittige Zugbeanspruchung (Zugzonendurchschnitt)	gesteigert	Risslosigkeit	9	11	13
	gemässigt		18	22	26
Bei Biegung oder ausmittigem Zug bzw. Druck in der äussersten Faser	gesteigert		18	22	26
	gemässigt		36	44	52

Zur Erläuterung des Berechnungsverfahrens und der Spannungsverteilung werden im Abschnitt 5 Zahlenbeispiele vorgeführt.

Obgleich die Formeln (15)—(19) die Berechnung der Verkleidung bzw. die Prüfung bei angenommen Werten ermöglichen, wird für weitere Untersuchungen der von M. LELLI benutzte Hilfselastizitätsmodul (E_2') eingeführt, mit dem die Gesteinzone c gleichfalls als unversehrt vorausgesetzt wird. Es kann nämlich in jedem Fall für den Elastizitätsmodul des Gesteins so ein Wert E_2' vorausgesetzt werden, bei dem durch die innere Belastung p_1 dieselben Verschiebungen u erfolgen, wie sie die Formel (3) angibt. Den Wert von u_c bekommt man aus der Formel (17), also:

$$u_c = -\frac{r_2}{E_2} \cdot \sigma_{r_2} \left[\frac{m_2+1}{m_2} + \log n\right] = -\frac{m_2+1}{m_2} \cdot \frac{1}{E_2'} \cdot \sigma_{r_2} \cdot r_2$$

d. i. beim Wert $r = r_2$

$$E_2' = \frac{E_2}{1 + \frac{m_2}{m_2 + 1} \log n} \tag{20}$$

und dieser Hilfswert ist natürlich viel kleiner als der Wert des ursprünglichen Elastizitätsmoduls E_2. Ist der Wert des inneren Betriebsdruckes grösser als 10 kg/cm², so wird die Druckrohr- bzw. Behälterwand aus stahlverkleidetem Beton bzw. Stahlbeton hergestellt. Verwendet man die Stahlverkleidung zusammen mit dem Stahlbetonring, so wird die Berechnung in der oben angegebenen Weise durchgeführt. In diesem Fall ist der Querschnitt der Stahlplatten in den perzentuellen Stahlgehalt f miteinzubeziehen, der für die Berechnung des Elastizitätsmoduls des Stahlbetonringes bzw. zur Bestimmung des Stahlquerschnittes nötig ist.

Bei Anwendung von Stahlplatten und Betonring dient die Betonverkleidung zur Aufnahme des Gesteindruckes, während die Stahlplatten die durch die innere Belastung p_1 entstehende Zugkraft mit dem Gestein zusammen aufnehmen. Infolge der wiederholten Belastung wird der Betonring ebenso wie das Gestein bis zu einer gewissen Tiefe Sprünge bekommen, weil sie nicht fähig sind, Zugspannungen aufzunehmen. Natürlich kann es sich da nur um Haarrisse handeln, weil in dem ringsherum gelagerten Gestein für die Entwicklung grösserer Sprünge kein Platz ist und infolge des radialen Druckes die Zunahme der Breite in Querrichtung die Masse der Sprünge ebenfalls verringert. Zwischen der Gestein-

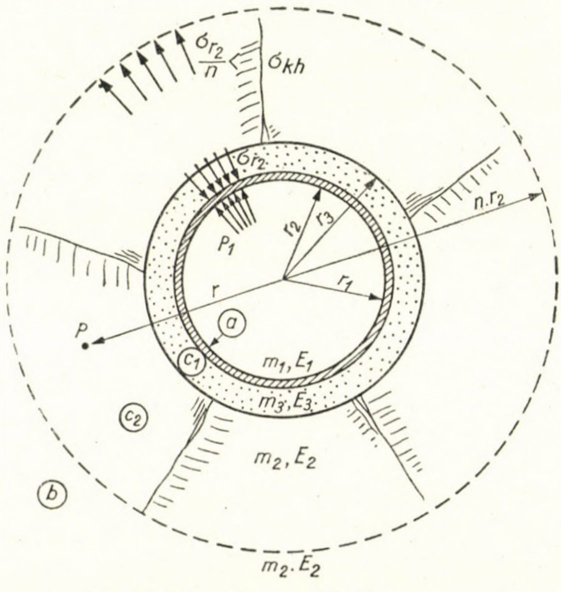


Bild 6. Darstellung der Stahlplatte, Betonverkleidung, geborstenen und unversehrten Gesteinzone

zone und den Stahlplatten müssen also geborstene Beton- und Gesteinzonen mit verschiedenen Elastizitätsmoduln angenommen werden. Man stelle sich ein Material vor, dessen Formveränderung in radialer Richtung derjenigen dieser beiden Zonen sowie der unversehrten Gesteinzone gleich ist und dessen Elastizitätsmodul E_r ist. Die weiteren Berechnungen werden dann so durchgeführt, als ob die Stahlplatte von einer unversehrten, nicht geborstenen Gesteinzone mit den Eigenschaften E_r und m_r umgeben wäre.

*

Im Bild 6 hat der Verfasser folgende Zonen dargestellt:

a) Stahlplattenverkleidung,

b) Zone des unversehrten Gesteins,

c_1) Betonzone,

c_2) Zone des geborstenen Gesteins.

In den Zonen c_1 und c_2 gibt es keine tangentiale und axiale Spannung, lediglich radiale Spannung kann auftreten. In den Felden c_1 und c_2 entsteht infolge der inneren Belastung p_1 folgende radiale Verschiebung:

$$u_c = \int_{r_2}^{r_3} \varepsilon_1 \, dr + \int_{r_3}^{n \cdot r_2} \varepsilon_2 \, dr = - \int_{r_2}^{r_3} \frac{\sigma_r}{E_3} \cdot dr - \int_{r_3}^{n \cdot r_2} \frac{\sigma_r}{E_2} \cdot dr = - \int_{r}^{n \cdot r_2} \frac{\sigma_r}{E_r} \cdot dr \,. \tag{21}$$

Berechnet man das Integral und setzt $\sigma_r = \sigma_{r_2} \dfrac{r_2}{r}$, so bekommt man

$$u_c = - \sigma_{r_2} \frac{r_2}{E_r} \log \frac{n \cdot r_2}{r} = - \sigma_{r_2} \frac{r_2}{E_3} \log \frac{r_3}{r_2} - \sigma_{r_2} \frac{r_2}{E_2} \log \frac{n \, r_2}{r_3} \tag{22}$$

Formveränderung der Zone b:

$$u_b = - \frac{m_2 + 1}{m_2 E_2} \cdot \sigma_{r_2} \cdot r_2 \,. \tag{23}$$

Infolge der Kontinuität ist die Verschiebung des äusseren Randes der Stahlplatte gleich der Gesamtverschiebung der Betonzone und der beiden Gesteinzonen, also

$$- \frac{r_2 \cdot \sigma_{r2}}{E_2} \left[\frac{m_2 + 1}{m_2} + \frac{E_2}{E_3} \log \frac{r_3}{r_2} + \log \frac{n \, r_2}{r_3} \right] =$$
$$= \frac{(m_1 + 1) \cdot (m_1 - 2)}{m_1^2 \cdot E_1} \cdot \frac{1}{r_2^2 - r_1^2} \left\{ \left[\sigma_{r2} \cdot r_2^2 - p_1 r_1^2 \right] r_2 + \right.$$
$$\left. + \frac{m_1}{m_1 - 2} \left[(\sigma_{r2} - p_1) \, r_1^2 \cdot r_2^2 \right] \right\} .$$

Diese Gleichung wird auf den unbekannten Wert σ_{r_2} aufgelöst.

$$\sigma_{r_2} = \frac{2 (m_1 - 1) \, p_1 r_1^2}{\dfrac{m_1^2 E_1}{(m_1 + 1) E_2} \left[\dfrac{m_2 + 1}{m_2} + \dfrac{E_2}{E_3} \log \dfrac{r_3}{r_2} + \log \dfrac{n \cdot r_2}{r_3} \right] \left[r_2^2 - r_1^2 \right] + (m_1 - 2) \, r_2^2 + m_1 r_1^2} \,. \tag{24}$$

Werden nun die unter (12) benutzten Bezeichnungen A—F wieder verwendet, ausserdem

$$G = \frac{E_2}{E_3} \log \frac{r_3}{r_2} \qquad J = B \cdot D\,(C + G) + E + F$$

$$X = \log n \frac{r_2}{r_3} \tag{25}$$

so bekommt man für σ_{r_2} folgenden Zusammenhang:

$$\sigma r_2 = \frac{A}{B \cdot D \cdot X + J}\,. \tag{26}$$

Nach Aufnahme der Grenzspannung des Gesteins wird der für die unversehrte Gesteinzone kennzeichnende Wert »n« in oben angegebener Weise bestimmt. Hierauf wird auf Grund der Verschiebungsgleichungen auch hier die Zusammendrückung desjenigen Hilfsgesteinmaterials festgestellt, das den Elastizitätsmodul E_r besitzt, in dem aber keine Risse aufgetreten sind und dessen Gesamtzusammendrückung gleich ist dem Gesamtwert der unversehrten und geborstenen Gesteinzone.

$$-\frac{r_2}{E_2}\,\sigma r_2 \left[\frac{m_2 + 1}{m_2} + \frac{E_2}{E_3} \log \frac{r_3}{r_2} + \log \frac{n r_2}{r_3}\right] = \frac{m_2 + 1}{m_2} \cdot \frac{1}{E_r}\,\sigma_{r2} \cdot r_2\,.$$

Auf der rechten Seite müsste eigentlich der Wert m_r stehen, jedoch ist im allgemeinen einesteils die Betonschicht im Verhältnis zur Gesteinzone sehr dünn, andererseits ist der Unterschied der Werte m in den Poissonschen Zahlen

$$\frac{m_2 + 1}{m_2}$$

für Beton und Gestein sehr gering, weshalb also der Wert m_2 benutzt werden kann.

Der Elastizitätsmodul des Hilfsgesteinmaterials ist demnach

$$E_r = \frac{(m_2 + 1)\,E_2}{m_2 \left[\frac{m_2 + 1}{m_2} + \frac{E_2}{E_3} \log \frac{r_3}{r_2} + \log \frac{n r_2}{r_3}\right]}\,. \tag{27}$$

Da jetzt schon alle Kennwerte bekannt sind, können die auftretenden Spannungen weiterhin mit den einfachen Formeln für doppelwandige Zylinder berechnet werden.

Verfasser bemerkt, dass infolge der geringen Wandstärke der Stahlplatte der Wert $r_2^2 - r_1^2$ recht klein ist und deshalb muss die Berechnung mit erhöhter Genauigkeit erfolgen.

Zahlenbeispiel siehe im Abschnitt 5.

4. Berücksichtigung von Temperatureinwirkungen, Schwindung, Kriechen und baulichen Ungenauigkeiten

Die Wirkung der Temperaturänderung und Schwindung im Verkleidungsring wird in gleicher Weise berücksichtigt, weil im allgemeinen die Schwindung des Betonringes einer Abkühlung von 10—15° C entspricht.

Wünscht man die Schwindung des Betonringes präziser auszudrücken, so bediene man sich der Formel

$$\delta zs = \frac{1}{10^4 w}\left[\sqrt[3]{i_{\max}} - \sqrt[3]{i_1}\right] \cdot [r_2 - r_1] \tag{28}$$

wo w = der Wasserzementfaktor des Betons.
i_{max} = die Zeitspanne der vollkommenen Schwindung in Monaten, im allgemeinen 24 Monate,
i_1 = die Zeitspanne zwischen der Verfertigung des Betonringes und seiner Verpressung, in Monaten,
δ_{zs} = die Veränderung der Ringstärke.

Jetzt vergewissere man sich, einer wievielgrädigen Abkühlung die Veränderung der Ringstärke δ_{zs} entspricht und deshalb wird die Formel für die durch Abkühlung verursachte Änderung der Wandstärke des Ringes aufgeschrieben:

$$\delta_t = \alpha_t (T_2 - T_1) \cdot (r_2 - r_1) \tag{29}$$

wo α_t = der Wärmeausdehnungskoeffizient des Ringmaterials,
$T_2—T_1$ = der Temperaturunterschied.

Da der Temperaturunterschied für gleiche Änderung der Wandstärke gesucht wird

$$\delta zs = \delta t$$

d. i.

$$T_2 - T_1 = \frac{10^{-4}}{\alpha_t \cdot w}\left(\sqrt[3]{i_{\max}} - \sqrt[3]{i_1}\right). \tag{30}$$

Danach wird die Wirkung der gemeinsamen Temperaturänderung des Gesteins und Zylinders mit Betonverkleidung gesucht.

Man geht vom doppelwandigen Zylinder auf Bild 3 aus und nimmt nach M. Lelli an, dass die Temperatur T von der Achse des Zylinders aus gerechnet in der Entfernung r folgenden Wert hat:

$$T(r) = t_i \cdot \frac{\log \frac{R}{r}}{\log \frac{R}{r_2}} \tag{31}$$

wo t_i = die bei der Entfernung $r = r_2$ entstehende Temperatur,
R = die Grenze der Temperaturänderung.
(Siehe Bild 7).

*

Die Verschiebung der Punkte der Zylinderfläche des doppelwandigen Zylinders mit dem Radius r_3 setzt sich aus zwei Teilen zusammen:

$$u_{r=r_3} = u_1 + u_2 \,,$$

hier ist u_1 die durch die Temperaturänderung des inneren Ringes bewirkte Verschiebung, u_2 jedoch die durch gehemmte Dehnung verursachte Verformung, die infolge der Spannung σ_{r_2} zwischen den beiden Zylindern an der Stelle $r = r_3$ entsteht.

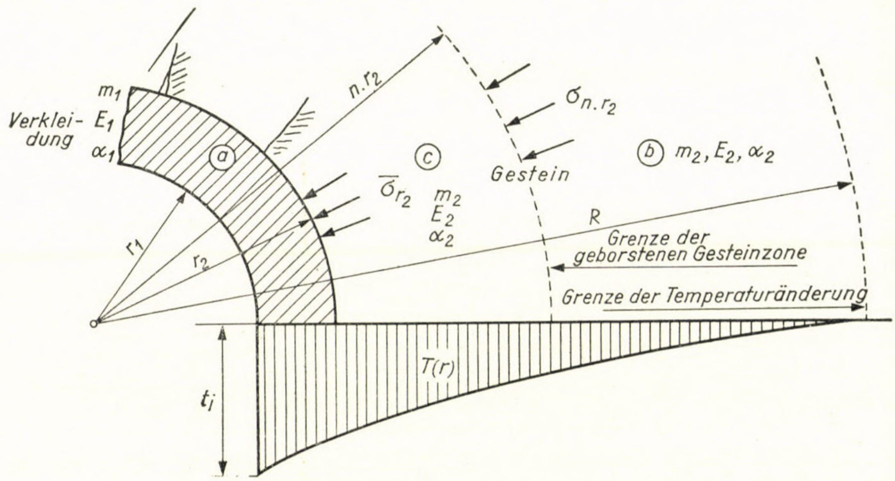


Bild 7. Temperaturänderung

Die auf der Mantelfläche des Zylinders vom Radius r_3 mögliche Verformung $u_{=r_3}$ ist jedoch gleich der Verformung, die durch die Spannung σ_{r_3} am äusseren Ring verursacht wird.

Beim Wert $r_2 = \infty$ ist der Wert des unverkleideten Behälters

$$u = -\frac{m_2 + 1}{m_2 E_2} \cdot r_3 \cdot \sigma_{r_3} \,. \tag{32}$$

Nach Aufschreiben der Werte der Verschiebungen

$$\sigma_{r_3} = \frac{2 \cdot E_1 \cdot \alpha_1 \cdot \int\limits_{r_1}^{r_3} T \cdot r \cdot dr}{r_1^2 \cdot \left(1 - \frac{m_2+1}{m_1+1} \cdot \frac{m_1 E_1}{m_2 E_2}\right) + r_3^2 \cdot \left(1 - \frac{2}{m_1} + \frac{m_2+1}{m_1+1} \cdot \frac{m_1 E_1}{m_2 E_2}\right)} \,. \tag{33}$$

Nach Bestimmung der Werte von σ_{r_n} sind die durch Temperatureinwirkung entstehenden Spannungen gelöst, u. z. für die Verkleidung bei den Werten $p_1 = 0$ und $p_2 = \sigma_{r3}$, während im Gestein $p_1 = \sigma_{r_3}$ angenommen wird.

Berücksichtigt man ferner, dass die geborstene Gesteinzone unfähig ist Zugspannungen aufzunehmen, so treten in dem Behälter nach Abb. 7 die folgenden Verformungen auf:

b) *Unversehrte Gesteinzone*

Ihre Verschiebungen infolge Temperatureinwirkungen zwischen $r = n \cdot r_2$ und $r \to \infty$ bei Belastungen σ_{nr2}:

$$u = \frac{m_2 + 1}{m_2 - 1} \cdot \frac{\alpha_2}{r} \int_{n \cdot r_2}^{r} T \cdot r \cdot dr - \frac{m_2 + 1}{m_2 E_2} \cdot \frac{n^2 \cdot r_2^2}{r} \sigma_{nr_2} . \tag{34}$$

Nachdem der Zusammenhang (9) sowohl für die Belastung durch inneren Betriebsdruck als auch für Temperatureinwirkungen in der geborstenen Gesteinzone Geltung hat:

$$\sigma_{nr_2} = \frac{\sigma_{r_2}}{n} .$$

Deshalb wird die Formel (34) folgendermassen geschrieben:

$$u = \frac{m_2 + 1}{m_2 - 1} \cdot \frac{\alpha_2}{r} \int_{nr_2}^{r} T \cdot r \cdot dr - \frac{m_2 + 1}{m_2 E_2} \cdot \frac{n \cdot r_2^2}{r} \cdot \sigma r_2 . \tag{35}$$

Bewegungen der ***geborstenen Gesteinzone*** *c* innerhalb der Grenzen $r = r_2$ und $r = n \cdot r_2$:

$$u' = u_{n r_2} - \alpha_2 \int_{r}^{nr_2} T \cdot dr - \frac{r_2}{E_2} \sigma_{r_2} \cdot \log \frac{n \cdot r_2}{n} \tag{36}$$

wo $u_{n\,2}$ die Verschiebung der Grenzflächen der Zonen *b* und *c* bedeutet, wenn das Glied *r* der rechten Seite der Formel (35) den Wert $r = n \cdot r_2$ annimmt, also

$$u_{nr_2} = - \frac{m_2 + 1}{m_2 E_2} \cdot \sigma r_2 \cdot r_2 . \tag{37}$$

Die Verschiebungen des Verkleidungsringes *a* bekommt man, wenn man zum Wert der Formel für die freie Wärmedehnung diejenigen Formveränderungen hinzuzählt, die auf der Mantelfläche des Zylinders durch die Spannung $p_2 = \sigma_{r2}$ entstehen. ($p_1 = 0$, weil innere Belastung nicht vorhanden ist.)

$$u = \frac{m_1 + 1}{m_1 - 1} \cdot \alpha_1 \cdot \left[\frac{1}{r} \int_{r_1}^{r} T \cdot r \cdot dr + \frac{1}{r_2^2 - r_1^2} \int_{r_1}^{r_2} T \cdot r \cdot dr \left(\frac{m_1 - 2}{m_1} \cdot r + \frac{r_1^2}{r} \right) \right] +$$

$$+ \frac{(m_1 + 1) \cdot (m_1 - 2)}{m_1^2 \cdot E_1} \cdot \frac{r_2^2 \cdot \sigma r_2}{r_2^2 - r_1^2} \left(r + \frac{m_1}{m_1 - 2} \cdot \frac{r_1^2}{2} \right). \tag{38}$$

Setzt man $r = r_2$ ein, so bekommt man aus den Formeln (36) und (38)

$$\sigma r_2 = - \frac{2 \cdot E_1 \cdot m_1 \cdot \alpha_1 \int_{r_1}^{r_2} T \cdot r \cdot dr + \frac{r_2^2 - r_1^2}{r_2^2} \cdot \alpha_2 \int_{r_2}^{nr_2} T \cdot dr \cdot \frac{m_1^2 E_1}{m_1 + 1}}{\frac{m_1^2}{m_1 + 1} \cdot \frac{E_1}{E_2} \left(\frac{m_2 + 1}{m_2} + \log n \right) \cdot (r_2^2 - r_1^2) + (m_1 - 2)\, r_2^2 + m_1 r_1^2}. \tag{39}$$

Wird auch hier der die Grenze der geborstenen und unversehrten Gesteinzone gleichzeitig berücksichtigende Hilfselastizitätsmodul E_2' eingeführt

$$\left(\frac{m_2 + 1}{m_2} + \log n \right) \frac{1}{E_2} = \frac{1}{E_2'} \, \frac{m_2 + 1}{m_2}$$

nach der Einsetzung

$$\sigma_{r_2} = - \frac{2 \cdot E_1 \cdot \alpha_1 \int_{r_1}^{r_2} T \cdot r \cdot dr + \frac{m_1 E_1}{m_1 + 1} \cdot \frac{r_2^2 - r_1^2}{r_2} \cdot \alpha_2 \cdot \int_{r_2}^{n \cdot r_2} T \cdot dr}{\left(1 - \frac{m_2 + 1}{m_1 + 1} \cdot \frac{m_1 E_1}{m_2 E_2'} \right) r_1^2 + \left(1 - \frac{2}{m_1} + \frac{m_2 + 1}{m_1 + 1} \cdot \frac{m_1 E_1}{m_2 E_2'} \right) r_2^2}. \tag{40}$$

Nun sei die Wirkung der Temperaturänderung untersucht. Wenn im Verhältnis zur ursprünglichen Temperatur nach der Inbetriebsetzung ein Absinken der Temperatur eintritt, dann ist der Wert $T(r) < 0$, d. h. also negativ. Bei in grössere Tiefe verlegten Druckrohren kommt es besonders während der kalten Jahreszeit recht häufig vor, dass das Gestein erheblich wärmer ist, als das zu leitende Wasser. Genau so liegen die Dinge bei Wasserbehältern, wenn ihre Auffüllung im Winter erfolgt. Bei Gasbehältern aber ist im allgemeinen die Wirkung der Temperaturschwankungen unerheblich.

Betrachtet man die Formel (40), so kann man sehen, dass bei negativen T-Werten $\sigma_{r_2} > 0$, d. h. es entsteht Zugspannung, was auch begreiflich ist, weil ja bei Abkühlung der Verkleidungsring zusammenschrumpft, während sich das Gestein in Richtung zur Gesteinzone zusammenzieht; es ergibt sich so die Neigung zur Fugenbildung zwischen der Innenverkleidung und dem Gestein. Da im allgemeinen vom Zylindermantel mit dem Radius r_2 Zugspannungen nicht übernommen werden können, sind nur die Formeln für den einfachen Zylinder anwendbar.

Setzt man voraus, dass Abkühlung und Betriebsdruck gleichzeitig auftreten, so wird der Gesamtwert σ_2 der durch den Betriebsdruck verursachten negativen und der durch die Abkühlung verursachten positiven Spannung wirken. Ist der Gesamtwert σ_{r_2} negativ, so ist das in den Abschnitten 2 und 3 beschriebene Bemessungsverfahren anzuwenden, während bei positivem Gesamtwert σ_{r_2} nur die Formeln für den freistehenden Zylinder gültig sind, am Zylindermantel vom Radius r_2 entsteht keine Kraftübertragung.

Es muss noch die dauernde Verformung und das Kriechen des Gesteins berücksichtigt werden. Ein Teil der dauernden Verformung wird von dem Umstand verursacht, dass der Elastizitätsmodul des Gesteins bei der ersten Belastung kleiner ist als im Verlauf wiederholter Belastungen, woraus folgt, dass bei der ersten Belastung grössere Eindrückung entsteht. Ebenso wirkt die Menge der im Gefolge von Abbausprengungen entstehenden und bei der ersten Belastung gleichfalls schliessenden Haarrisse. Das sog. Kriechen entsteht im Gefolge der längere Zeit hindurch währenden Belastung des Gesteins auch bei geringerer Belastung, als die plastische Grenze des Gesteins ausübt.

$$\delta_{t \cdot a} = \delta_t + \delta_1 \tag{41}$$

wo

$$\delta_t = \nu_t \frac{1}{E_2} \frac{m_2 + 1}{m_2} \cdot r_2 \cdot \sigma_{r2}$$

$$\delta_1 = \nu_1 \frac{1}{E_2} \frac{m_2 + 1}{m_2} \cdot r_2 \cdot \sigma_{r2}$$

der Wert δ_t die durch die erste Belastung verursachte dauernde Verformung bedeutet. Der Wert von ν_t muss durch Versuche bestimmt werden. δ_1 ist aber der Wert des Kriechens.

Die Werte δ bedeuten die an der Grenze der Verkleidung und des Gesteins auftretende, zum Gestein gerichtete radiale Verformung.

Der Wert $\frac{\delta_{ta}}{\sigma_{r2}}$ kann im allgemeinen zwischen $0{,}001 \sim 0{,}004$ cm/kg/cm² angenommen werden, je nach der Grösse der Fuge und von der Art des Gesteins abhängend. Es muss aber bemerkt werden, dass für diese Werte bisher nur sehr geringe Erfahrungen zur Verfügung stehen.

Bei längere Zeit wirkender Belastung entsteht auch im Betonring Kriechen und dessen Wert hängt ab von der Zeitdauer der Belastung, der Menge von Zement und Wasser, der Qualität der Zuschlagstoffe, der Art des Einstampfens sowie von dem ausgeübten Druck.

Die infolge des Kriechens auftretende Zusammendrückung kann annähernd mit nachstehender Formel ausgedrückt werden :

$$\delta_{b1} = 6 \times 10^{-6} \cdot p_1 \left(\sqrt[3]{i_{k\,\max}} - \sqrt[3]{i_{k_1}} \right) \cdot (r_2 - r_1) \tag{42}$$

wo

δ_{b1} = in cm zu verstehen ist,
p_1 = der Wert des Betriebsdruckes in kg/cm²,
$i_{k\max}$ = die Zeitdauer in Monaten, während der das Kriechen andauert (allgemein 30—36 Monate),
i_{k1} = die zwischen der Verlegung des Betonringes und der Inbetriebsetzung vergehende Zeit, in Monaten.

Ebenso wirkt sich auf die im Betonring auftretende Spannung die Ungenauigkeit der Bauarbeit aus, die sich in der zwischen dem Betonring und dem Gestein auftretenden Fuge äussert. Mit dem Vorhandensein einer solchen Fuge muss man auch dann rechnen, wenn man die Fuge zwischen Gestein und Betonring auspresst, weil nach der Schwindung des ausgepressten Mörtels noch eine Fuge von ungefähr einigen Hundertstel mm verbleibt. Deren Wert bezeichnet man mit $\delta_{\dot{e}}$.

Dies zusammengefasst ist festzustellen, dass bei einer eventuellen Temperaturänderung des Gesteins und des Ringes ein Druck $\sigma_{t2}\,(T)$ an der Grenzfläche des Ringes und Gesteins auftritt. Die dauernde Verformung bzw. das Kriechen des Gesteins und Betonringes, die gemeinsame Wirkung der Schwindung des Betonringes und der baulichen Ungenauigkeiten äussern sich aber in einer in radialer Richtung auftretenden Fuge von der Grösse $\Sigma\,\delta$, die an der Grenzwand des Ringes und Gesteins auftreten könnte.

$$\Sigma\,\delta = \delta_{t,a} + \delta_{b1} + \delta_{zs} + \delta_{\dot{e}} = u\,. \tag{43}$$

Der infolge des inneren Betriebsdruckes auftretende Überdruck presst jedoch den elastischen Ring an das Gestein, dadurch dehnt sich der Ring und nimmt Mehrbelastung auf. Diese Mehrbelastung wird als Wert eines solchen substituierenden Innendruckes bezeichnet, der in einem freistehenden Ring Mehrbeanspruchung verursacht (weil er eben von einer Fuge umgeben ist).

Den Wert für diesen Druck bekommt man aus den Formeln für den freistehenden Ring, wenn man bei $p_1 < 0$ und $p_2 = 0$ also für inneren Druck die entstehende Fuge $\Sigma\,\delta$ und die Formveränderung u des Ringes gleichsetzt.

$$p' = \frac{\Sigma\,\delta \cdot E_1 \cdot m_1^2 \cdot (r_2^2 - r_1^2)}{(m_1 + 1) \cdot (m_1 - 2) \cdot r_1^3 + \dfrac{m_1}{m_1 - 2} \cdot r_1^2 \cdot r_2}\,. \tag{44}$$

Mit diesem Ersatzdruck ist der Wert der Ergänzungsspannung bestimmt, der zu den gemäss Abschnitt 2 und 3 im Ring festgestellten Spannungen hinzuzuzählen ist.

Man weiss demnach, dass der Ersatzbetriebsdruck p' eigentlich einen Teil des Betriebsdruckes aufnimmt. Mit der Mehrbelastung des Ringes müsste also gleichzeitig die Belastung p des Gesteins dem Wert p' entsprechend verringert werden. Es sei jedoch hier einerseits daran erinnert, dass das δ_t, das Kriechen, vom Wert p abhängt und so nur nach der Entwicklung des nötigen Druckes, erheblich nach der Inbetriebsetzung des Objektes sich entwickelt und deshalb der Verkleidungsring nur später Mehrbelastung aufnimmt. Andererseits muss auch die Frage der Sicherheit erwogen werden, weil der Wert $\Sigma\delta$ solche Glieder enthalten kann, die eventuell nicht wirksam werden, weshalb es unbegründet ist, die auf das Gestein entfallende Belastung zu vermindern.

Der Vollständigkeit wegen sei erwähnt, dass in dem eingebauten Stahlbetonring auch vom Gebirgsdruck verursachte Spannungen entstehen. Für deren Bestimmung vermittelt das Schrifttum des Tunnelbaues entsprechende Verfahren, weshalb sie hier nicht besonders behandelt werden müssen.

5. Zahlenbeispiele

Zur Erklärung des bisher besprochenen Bemessungsverfahrens werden einige Zahlenbeispiele genannt.

a) *Stahlbetonverkleidung*

Innerer Radius der Verkleidung :	$r_1 = 2{,}5$ m $r_1^2 = 6{,}25$ m²
Äusserer ,, ,, ,,	$r_2 = 2{,}8$ m $r_2^2 = 7{,}84$ m²
Unterschiede der Radiusquadrate :	$r_2^2 - r_1^2 = 1{,}59$ m²
Summe ,, ,,	$r_2^2 + r_1^2 = 14{,}09$ m²
Elastizitätsmodul des Betons :	$E_b = 2{,}1 \times 10^5$ kg/cm²
Elastizitätsmodul der Stahleinlage :	$E_v = 2{,}1 \times 10^6$ kg/cm²
Bewehrungsprozent :	$f = 1{,}05$

Elastizitätsmodul des Stahlbetons :

$$E_1 = E_{vb} = 2{,}1 \left[1 + \frac{1{,}05}{100} \frac{21-2{,}1}{2{,}1}\right] = 2{,}3 \times 10^5 \text{ kg/cm}^2$$

Elastizitätsmodul des Gesteins :	$E_2 = E_k = 1{,}47 \times 10^5$ kg/cm²
Poissonsche Zahl des Betons :	$m_1 = 6$
,, ,, ,, Gesteins	$m_2 = 10$
Zuggrenzspannung des Gesteins :	$\sigma_{kh} = 3$ kg/cm²

Innerer Betriebsdruck (mit Sicherheitskoeffizient multipliziert) : $p_1 = -10$ kg/cm²

$$A = 2\,(m_1-1)\cdot p_1\cdot r_1^2 = -\,2\cdot 5\cdot 6{,}25\cdot(-10) = -\,625$$

$$B = \frac{m_1^2}{m_1+1}\,\frac{E_1}{E_2} = \frac{36}{7}\cdot\frac{2{,}30}{1{,}47} = 8{,}05$$

$$C = \frac{m_2+1}{m_2} = \frac{10+1}{10} = \frac{11}{10} = 1{,}1$$

$$D = r_2^2 - r_1^2 = 1{,}59$$
$$E = (m_1-2)\, r_2^2 = 4 \times 7{,}84 = 31{,}3$$
$$F = m_1\, r_1^2 = 6 \times 6{,}25 = 37{,}5$$

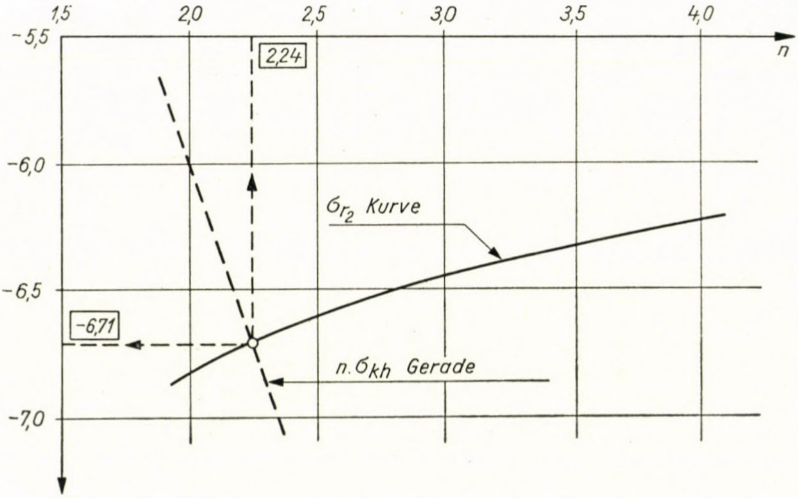
$$H = B \cdot D \cdot C + E + F = 8{,}05 \cdot 1{,}59 \cdot 1{,}1 + 31{,}3 + 37{,}5 = 82{,}9$$
$$B \cdot D = 8{,}05 \cdot 1{,}59 = 12{,}8$$

$$\sigma_{r2} = -\frac{A}{B \cdot D \cdot X + H} = -\frac{625}{12{,}8 \cdot X + 82{,}9}$$

Tabellarisch gerechnet mit im voraus angenommenen ganzzahligen Werten für »*n*«:

n	Log n	X = log n	σ_{r2} kg/cm²	$n \cdot \sigma_{kh}$ kg/cm²
2	0,3010	0,693	6,82 ↓	↑ 6,00
2,5	0,3979	0,915	6,60	7,50
3,0	0,4771	1,098	6,46	9,00
3,5	0,5441	1,252	6,33	10,50
4,0	0,6021	1,386	6,22	12,0

Die beiden Linien schneiden sich zwischen den Werten $n = 2{,}0 \sim 2{,}5$. Aus Abb. 8 ersieht man, dass der Wert »*n*« 2,24 beträgt, wozu ein Wert von $\sigma_{r2} = 6{,}71$ kg/cm² gehört.



— σ_{r_2} kg/cm$_2$ *Bild 8.* **Bestimmung der Grenze der geborstenen Zone**

Mit der tabellarischen Berechnung kann die Genauigkeit des Wertes »*n*« selbstverständlich gesteigert werden.

*

Man suche ferner die tangentiale Spannung an der inneren und äusseren Oberfläche der Verkleidung:

$$\sigma_t^b = \frac{1}{r_2^2 - r_1^2}\left[2\sigma_{r_2} \cdot r_2^2 - p_1 (r_1^2 + r_2^2)\right] = \frac{1}{1{,}59}\left[-2 \cdot 6{,}71 \cdot 7{,}84 + 10 \cdot (6\,25 + 7{,}84)\right] =$$

$$= \frac{1}{1{,}59}(-105{,}0 + 140{,}9) = \underline{+\ 22{,}6 \text{ kg/cm}^2}$$

$$\sigma_t^k = \frac{1}{1{,}59}(-6{,}71 \cdot 14{,}09 + 2 \cdot 10 \cdot 6{,}25) = \underline{+\ 19{,}2 \text{ kg/cm}^2}.$$

Querschnitt der erforderlichen Betonstahleinlage

$$F_v = \frac{22{,}6\ \text{kg/cm}^2 + 19{,}2\ \text{kg/cm}^2}{2} \cdot 30\ \text{cm}^2 \ \frac{1}{2000\ \text{kg/cm}^2} = 0{,}313\ \text{cm}^2/\text{cm}\,.$$

Kontrolle des Bewehrungsperzentsatzes:

$$f = \frac{0{,}313}{30} \cdot 100 = 1{,}045 \sim 1{,}05\,.$$

Auf die Längeneinheit entfallende Zugkraft:

$$h = \frac{22{,}6\ \text{kg/cm}^2 + 19{,}2\ \text{kg/cm}^2}{2} \cdot 30\ \text{cm} = 627\ \text{kg/cm}\,.$$

Dieser Wert würde bei freistehendem Behälter nach der sogenannten Kesselformel h′ = 250 cm · 10 kg/cm² = 2500 kg/cm betragen.

Auch hieraus ist die grosse Bedeutung des Vorhandenseins des Gesteins zu erkennen, besonders dann, wenn man bedenkt, dass der angenommene Wert $E_2 = 150{,}000\ \text{kg/cm}^2$ des Elastizitätsmoduls des Gesteins nicht einmal so gross ist.

Man sieht weiterhin, dass diese Konstruktion bei einer Betonqualität B 400 den Ansprüchen der Risslosigkeit genügt, vorausgesetzt, dass nach Überlagerung sämtlicher Spannungen und Multiplizieren mit allen Sicherheitsfaktoren

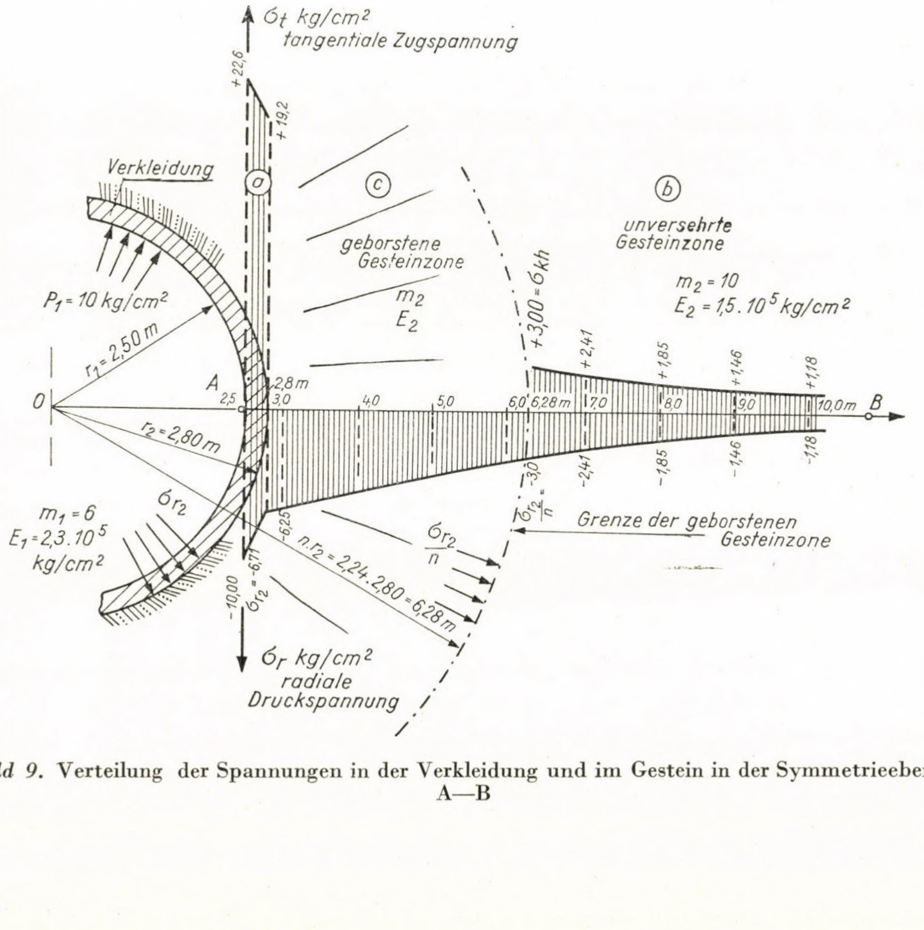


Bild 9. Verteilung der Spannungen in der Verkleidung und im Gestein in der Symmetrieebene A—B

(Gesteindruck, Eigengewicht usw.) die gesamte Zugspannung den Wert von 26 kg/cm² nicht überschreitet.

Nach Durchführen der gesamten Berechnung muss noch in jedem Fall die Richtigkeit des im voraus geschätzten Bewehrungsperzentsatzes (f) überprüft werden.

Die Spannungsverteilung um den Behälter obigen Zahlenbeispiels ist im Bilde 9 durch Skizzierung der Spannungen σ_t und σ dargestellt.

Das vorgeführte Zahlenbeispiel erhärtet die auch im Ausland gewonnene Erkenntnis dass bei einem Betriebsdruck von höherem Wert als p_1 — 10 kg/cm² die Stahlbetonverkleidung nicht mehr genügt und man also zur Stahlplattenverkleidung übergehen muss.

*

b) *Stahlplatten- und Betonverkleidung*

In dem mitgeteilten Zahlenbeispiel wurden bei einem Behälter von gleichem inneren Durchmesser und Druck für die Spannungsverteilung folgende Ergebnisse gewonnen :

$r_1 = 2{,}500$ m $r_2 = 2{,}505$ m $v = 0{,}005$ m (d. h. die Wandstärke der Stahlplatte ist 5 mm).
$r_3 = 2{,}80$ m
$E_1 = 21 \cdot 10^5$ kg/cm² $m_1 = 3{,}33$
$E_2 = 1{,}47 \; 10^5$ kg/cm² $m_2 = 10$
$E_3 = 2{,}1 \times 10^5$ kg/cm²
$p_1 = -10$ kg/cm²
$\sigma_{r2} = 9{,}347$ kg/cm² $n = 3{,}13$
$E_r = -0{,}732 \times 10^5$ kg/cm²
$\sigma_{t,=r_1} = 317{,}8$ kg/cm² tangentiale Spannung
$\sigma_z = 93{,}0$ kg/cm² axiale Spannung

Wie man sieht, ist die Stahlplatte im Falle eines inneren Druckes von $p_1 = -10$ kg/cm² bei weitem nicht ausgenutzt, die weiteren Haupt- und Nebenkraftwirkungen sind jedoch in der oben angegebenen Weise zu berücksichtigen. Ausserdem muss die vom Standpunkt der Schweissbarkeit erwünschte minimale Wandstärke der Stahlplatten, die mit 5 mm angenommen werden kann, vorgesehen werden. Berücksichtigt man, dass bei einem freistehenden zylindrischen Stahlplattenbehälter bei einem inneren Druck von $p_1 = -10$ kg/cm² eine Wandstärke von wenigstens $v = 25$ mm nötig wäre, so wird man erkennen, in welch hohem Ausmass das Gestein die Belastung aufnimmt.

c) *Wirkung zusätzlicher Belastungen*

Zur Erläuterung des Wertes von $\Sigma\delta$ und des sich daraus ergebenden Wertes von p′ für den Verkleidungsring werden folgende informative Zahlenwerte bei einer Wandstärke des Betonringes von $r_2 - r_1 = 30$ cm und bei $p_1 = 10$ kg/cm² $= \sigma_{r2}$ angegeben :

$$\delta_{t,a} = 0{,}0015 \cdot \sigma_{r2} = 0{,}0015 \text{ cm/kg/cm}^2 \cdot 10 \text{ kg/cm}^2 = 0{,}0150 \text{ cm}$$

$$\delta_b = 6 \times 10^{-6} \cdot 10 \left[\sqrt[3]{24} - \sqrt[3]{12}\right] \cdot 30 \text{ cm} \qquad = 0{,}0018 \;,,$$

$$\delta_{zs'} = \frac{1}{10^4 \cdot 0{,}55}\left(\sqrt[3]{24} - \sqrt[3]{12}\right) \cdot 30 \text{ cm} \qquad = 0{,}0018 \;,,$$

$$\delta_{\acute{e}} = \text{(aufgenommen)} \qquad = 0{,}0114 \;,,$$

$$0{,}0300 \text{ cm}$$

also nach der Formel (44)

$$p' = -\frac{0{,}03\ \text{cm} \cdot 1{,}5 \cdot 10^5\ \text{kg/cm}^2 \cdot 6^2 \cdot 1{,}59 \cdot 10^4}{7 \cdot 4 \cdot 2{,}53 \cdot 10^6 + \frac{6}{4}\ 2 \cdot 5^2 \cdot 2{,}8 \cdot 10^6} = 5{,}53\ \text{kg/cm}^2,$$

was beweist, dass der Wert von p′ auch bei anscheinend kleinen Werten von $\Sigma\delta$ beachtlich sein kann.

6. Gegenseitige Wirkung mehrerer nebeneinander errichteter Objekte

Es wurde im Zuge des Bemessungsverfahrens festgestellt, dass das Gestein den Grossteil der inneren Belastung trägt und daraus folgt, dass bei der Errichtung mehrerer Rohrleitungen oder Behälter in erster Linie die im Gestein auftretenden Spannungsverhältnisse zu bestimmen wären, wie nah diese zueinander placiert werden können. Da die Spannungsverteilung bei Rohren oder Behältern mit horizontaler bzw. vertikaler Achse verschieden ist, muss man sich im folgenden mit diesen besonders befassen.

Zuerst prüfe man den Spannungszustand, wenn von in horizontaler Ebene liegenden Behältern die Rede ist. Im Fall eines Behälters tritt infolge der Wirkung des inneren Druckes in der horizontalen Symmetrieebene in der unversehrten Gesteinzone der Formel (18) gemäss folgende tangentiale Zugspannung auf:

$$\sigma_t^t = -\frac{(n \cdot r_2^2)}{r^2} \cdot \sigma_{kh}\,. \tag{18}$$

Diese Spannung strebt mit Anwachsen des Wertes »r« gegen 0, allerdings recht langsam. Nimmt man jetzt zwei Behälter an, so ist die Kurve σ_t des zweiten Behälters das Spiegelbild der Kurve des ersten Behälters. Addiert man die Zugspannungen, so bekommt man auch bei grossen Abständen der Behälter voneinander grössere Werte als den Grenzwert σ_{kh} der Spannung des Gesteins.

Man weiss jedoch, dass ausser dem durch den inneren Druck σ_t entstehenden Zug nach den Formeln von KIRSCH und FÖPPL infolge des gesteigerten Druckes des Gesteins folgende Druckspannung auftritt,

$$\sigma_t^k = \frac{\sigma_z}{2} \cdot \frac{m}{m-1}\left(1 + \frac{r_2^2}{2}\right) + \frac{\sigma_z}{2} \cdot \frac{(m-2)}{(m-1)} \cdot \left(1 + \frac{3\,r_2^4}{r^4}\right) \tag{45}$$

die mit der vorhergehenden Zugspannung σ_t übergelagert werden kann.

Wenn man nicht mit der Entwicklung des ganzen geostatischen Druckes rechnet, weil dieser durch verschiedene tektonische Kräfte in mehreren geologischen Perioden eventuell abgeschwächt wurde, muss man dennoch genügende Vorsicht walten lassen, und deshalb wird die Zugspannung des Gesteins nicht ganz ausgenutzt. In der Praxis ist dies auch nicht nötig, weil der Wert von σ_{kh} höchstens 5 kg/cm^2 beträgt, während bei Rohren und Behältern von grösserem Durchmesser der geostatische Druck, 50 m Gesteinbelag vorausgesetzt, grösser ist als 10 kg/cm^2. Wenn man also die beiderseitigen Werte von σ_t überlagert, bekommt man als Resultat noch immer eine Druckspannung, trotzdem σ_{kh} Zugspannung zugelassen werden kann.

Man erlangt also auch bei verhältnismässig zur Oberfläche nah errichteten Behältern genügend Sicherheit, wenn man eine Verringerung des geostatischen Druckes um 50% annimmt.

In grösseren Tiefen nimmt natürlich der geostatische Druck erheblich zu, weshalb durch entsprechendes Feststellen des Minimalwertes des geostatischen Druckes und durch Überlagerung der beiden sich aus den inneren Betriebsdrucken der beiden Behälter ergebenden Zugspannungen die entsprechende Entfernung bestimmt werden kann. Da mit wiederholten Belastungen gerechnet

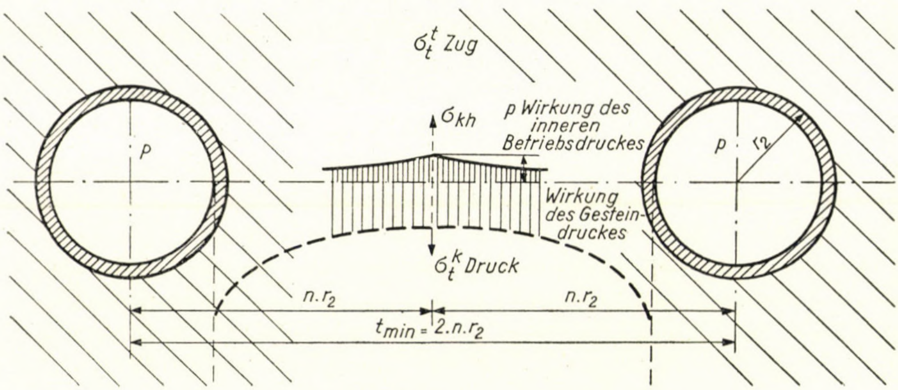


Bild 10. Geringste Entfernung liegender Zylinder

werden muss, darf man aus Gründen der Betriebssicherheit die beiden Behälter nicht zu nah aneinander aufstellen, auch dann nicht, wenn sich dadurch die Investitionskosten sehr verringern würden.

Die Abb. 10 zeigt eine solche günstige Anordnung, bei der die Entfernung der Achse der beiden Zylinder $t = 2 \cdot n \cdot r_2$ ist, was bedeutet, dass die Grenzen der doppelseitigen geborstenen Gesteinzone einander gerade berühren. Die Werte σ_{kh} überlagern sich dann noch nicht, jedoch verhindert der Druck σ_t^k die Ausbildung der geborstenen Zone.

Dies kann man als minimalen Achsenabstand ansehen, wenn man sich der erforderlichen Sicherheit bestrebt. Weil der Wert von n $2 \sim 5$ ist, ist die minimale Entfernung $4\ r_2 \sim 10\ r_2$.

*

Im Fall von mehr als zwei Behältern bestimmt man unter Berücksichtigung des Minimalwertes von »t« die geplante Lage der Behälter und überlagert die entstehenden Spannungen nach Ausrechnung derselben. Selbstverständlich muss das Ergebnis innerhalb der Zugspannung des Gesteins bleiben.

7. Fragen der Konstruktion und der Wirtschaftlichkeit

Verfasser behandelt in seiner Studie solche Objekte, die ringsherum von Felsgestein umgeben sind und wo infolge des bedeutenden Betriebsdruckes im Gestein beachtliche Spannungen auftreten. Bei der Dimensionierung des inneren Ringes hat man gesehen, dass infolge der zwischen Objekt und Gestein eventuell unausgefüllt bleibenden Fuge im Ring recht erhebliche Zugspannungen entstehen. Ebenso schädlich können in der Ringnähe im Gestein befindliche Fugen, Zwischenräume und Hohlräume sein. Deshalb muss das Gestein auch von diesem Gesichtspunkt aus genau untersucht und bei der Planung muss die sorgsame Auffüllung der zwischen dem Gestein und in der Umgebung des Objektes befindlichen Zwischenräume, Sprünge und Hohlräume vorgeschrieben werden.

Aus den im Laufe der Berechnung von in Gestein gelagerten Rohren und Behältern abgeleiteten Formeln sieht man, dass der Wert der entstehenden Spannungen sich durch die Änderung der Poissonschen Zahl des Gesteins nicht sehr ändert, dass jedoch der Elastizitäts- bzw. Druckmodul von entscheidender Bedeutung ist. Dieser muss also, möglichst am Originalgestein, mit besonderer Sorgfalt bestimmt werden.

Bei in Gestein verlegten Druckrohren oder Behältern muss die Richtung der im Gestein befindlichen Kluftspalten berücksichtigt werden. Waagrecht liegende Objekte sollen die Ebenen der Spalten möglichst senkrecht kreuzen, weil z. B. bei axialen Spalten das Gestein die Zugspannungen nicht aufnehmen kann. Bei senkrecht gerichteten Objekten soll dieses möglichst zwischen den Kluftspalten, eben wegen der Aufnahme der Zugspannungen, in der Mitte angeordnet werden.

Bei der Planung sind die richtige Anordnung des Objektes, die Vermeidung von Diskontinuität und die besonders sorgsamen statischen Berechnungen sehr wichtig. Bei Objekten grösserer Durchmesser werden auch Modellversuche und die Errichtung von Versuchsabschnitten notwendig, damit noch vor Beginn des Bauens alle schwebenden Fragen geklärt werden.

Bei der Konstruktionsplanung von Druckrohren und Behältern ist auf folgendes zu achten :

a) Profile ohne Entlastungsverkleidung können nur bei Druckrohren von niedrigem Druck und kleinem Durchmesser bei gutem Gesteinmaterial angewendet werden. Auch in diesem Fall benutzt man zur Verhinderung der Abnutzung, der Gesteinbröckelung und des Wasserverlustes eine Verkleidung aus Torkretbeton mit Stahlnetzeinlage. Vor der Betonierung wird das Stahlnetz an mehreren Stellen an das Gestein befestigt. Diese Konstruktion kann in Abhängigkeit vom Durchmesser und von der Gesteinqualität bis zu einem Überdruck von 0—5 Atm. gebraucht werden.

b) Betonverkleidung wird dort angewendet, wo nach der Entwicklung des Hohlraumes mit der Bildung eines ansehnlichen Bergdruckes gerechnet werden muss, hauptsächlich bei in grösseren Tiefen verlegten Druckrohren kleinen Durchmessers. Auch dieses Profil ist unfähig, Zugspannung aufzunehmen und darf deshalb nur bei solch niedrigem Druck (0—5 Atm.) angewendet werden, wo die Risslosigkeit des Betons noch gesichert werden kann. Nach dem Fertigen und der Schwindung des Betonringes muss der Spalt zwischen Ring und Gestein verpresst werden.

c) Stahlbetonverkleidung ist beim Bau von grösserem Druck ausgesetzten (5—10 Atm.) Druckrohren und Behältern zu gebrauchen. Auch hier muss bei der Bemessung für Risslosigkeit gesorgt werden. Bei Wasserbehältern muss für die Wasserdichtigkeit, bei Gas- und Luftbehältern jedoch für die Verhinderung der Diffusion des gasförmigen Stoffes besonders gesorgt werden.

d) Verkleidung von Stahlplatten und Beton bzw. Stahlbeton wird im allgemeinen bei Druckrohren und Behältern von höherem inneren Druck als 10 Atm. angewendet. Bei Druckrohren stellt man in erster Linie wegen der verschleissenden Wirkung des Wassers und des Gerölls die nötige Wandstärke fest und addiert zu dieser die vom Gesichtspunkt der Statik erforderliche Stärke der Stahlplatten. Bei der Bemessung berücksichtigt man natürlich nur das letztere Mass. Bei Gas- und Luftbehältern sind zwecks Vermeidung von Diffusion gassichere Schweissnäte zu fertigen. Um die Ungleichheiten des Gesteins auszugleichen, ist zwischen Stahlplatten und Gestein ein Beton- oder Stahlbetonring anzuordnen, der auch den Gebirgsdruck während des Bauens und den inneren drucklosen Zustand während des Betriebes aufnimmt. Die Fuge zwischen Stahlplatten und Betonring wird durch Verpressung ausgefüllt. Die Stahlplatten müssen auf den Verpressungsdruck bemessen und dünne Platten müssen während der Verpressung gestützt werden.

Man prüfe die obere Grenze des inneren Druckes von mit Stahlplatten hoher Druckfestigkeit ausgekleideten Behältern. Angenommen, dass der eine Komponent (q_1) des im Inneren des Behälters wirkenden Druckes p_1 in der Stahlplatte und der andere Komponent (q_2) im Gestein Verformung verursacht. In einem Behälter, dessen innerer Radius mit dem des angegebenen Zahlenbeispiels $r_1 = 250$ cm übereinstimmt, können bei Anwachsen des inneren Druckes folgende Veränderungen beobachtet werden :

Tafel II

p_1 kg/cm²	Wert von σ_{kh}: 3 kg/cm²		4 kg/cm²		5 kg/cm²		q_1 Durchschnitt kg/cm²	Plattenstärke v cm	In der Stahlplatte auftretende Zugspannung σ_t kg/cm²
	q_2 kg/cm²	n	q_2 kg/cm²	n	q_2 kg/cm²	n			
10	9,4	3,13	9,4	2,36	9,5	1,90	0,6	0,5	280
15	13,5	4,50	13,6	3,40	13,8	2,76	1,4	0,75	467
20	17,1	5,69	17,4	4,36	17,5	3,50	2,6	1,0	640
25	20,6	6,85	20,9	5,22	21,0	4,21	4,1	1,25	824

Man sieht hieraus den Vorteil der Zunahme des inneren Druckes p_1, denn obgleich die Stärke der Stahlplatte (v) auch mit dem Wert p_1 proportional wächst, so bleiben die Kosten des Gesteinabbaus und der Betonierung doch unverändert. Mit der Zunahme des Druckes verbessert sich der Ausnutzungsgrad der Stahlplatten, dagegen wächst der Wert »n«, der die Grenze der geborstenen Gesteinzone ausdrückt. Über eine gewisse Grenze ist das Anwachsen des Wertes »n« nicht vorteilhaft, weil die geborstene Gesteinzone in der Umgebung des Objektes dick ist und falls man mehrere Behälter aufstellen muss, würden infolge der Werte »n« die Behälter weit voneinander gelangen. Der Steigerung des Druckes ist also einesteils durch die geborstene Gesteinzone eine Grenze gesetzt, anderenteils durch den das Gestein belastenden Wert des radialen Druckes q_2. Nach den Fundamentierungsnormen (MNOSZ 15,003 Mt.) beträgt nämlich auch die Grenzspannung von unversehrten Felsböden mit größerer Bruchfestigkeit nur 20 kg/cm^2 und nur bei Granit, Diorit, Andesit und Gneis darf eine Belastung q_2 von 40 kg/cm^2 zugelassen werden.

Die Frage der Wirtschaftlichkeit muss von mehreren Gesichtspunkten aus geprüft werden, u. z. von denen der Investitionskosten, Ersparung von Stahlmaterial, Inbetriebhaltung und Aufrechterhaltung. Natürlich kann nur bei individueller Planung jedes Objektes eine genauere wirtschaftliche Prüfung erfolgen, weshalb Verfassers Feststellungen nur im allgemeinen gewertet werden können.

Bei den Investitionskosten sind die Aufwendungen für Gesteinabbau und Verstrebung entscheidend. Im allgemeinen kann man sagen, dass in Gestein verlegte Druckrohrleitungen und hohem Druck ausgesetzte Behälter billiger sind, als freistehende. Die Aufnahmefähigkeit des Gesteins für Belastungen ist nämlich immer wirtschaftlich vorteilhafter als die für Gesteinabbau und Verstrebung aufzuwendenden Kosten.

Was die Ersparnis an Stahlmaterial anlangt, ist der Vorteil von in Gestein verlegten Objekten ausser Zweifel. Hinsichtlich der Inbetriebhaltung und Aufrechterhaltung muss festgestellt werden, dass Reparaturarbeiten an in Gestein errichteten Objekten etwas höher kommen, dagegen kann der bei freistehenden Rohrleitungen und Behältern nötige Schutzanstrich gespart werden.

SCHRIFTTUM

1. S. TIMOSHENKO: Resistance des matériaux. Paris, 1947.
2. N. L. BEZUHOV: Bevezetés a rugalmasságtanba és képlékenységtanba. (Einführung in die Elastizitätslehre und Plastizitätslehre). Budapest, 1952.
3. K. TERZAGHI, F. E. RICHART: Stresses in rock about cavities. Geotechnique 1952, 2.
4. M. LELLI: Il comportamento statico, provocato della pressione idrostatica e delle variazioni termiche delle gallerie e dei possi praticati attraverzo rocce fratturate. L'Energia Elettrica 1952, 1.
5. K. BAYER: Statik im Eisenbetonbau. Berlin, 1934.
6. K. SZÉCHY: Alapozás (Fundamentierung). Budapest, 1952.
7. H. KASTNER: Über die Bemessung von gepanzerten Druckschächten. Österreichische Bauzeitschrift. 1951, 2.

8. A. Kieser: Wasserdichte Druckstollen und Druckschächte mit Kernring-Auskleidung. Schweizerische Bauzeitung 1950, 23.
9. И. Я. Бялер: Расчет обделки подземного сооружения кругового очертания. Гидротехническое строительсво. 1952, 11.
10. Rattier: Conduites forcées en galeries et puits blindés. Annales des Ponts et Chaussées. 1953, 1.
11. F. Goguel: Répartition des contraintes autour d'un tunnel cilindrique. Annales des Ponts et Chaussées. 1942, 1.

ZUSAMMENFASSUNG

Die Studie gibt ein umfassendes Bild der Probleme der Dimensionierung, Konstruktion und Wirtschaftlichkeit von in Gestein gebetteten Objekten und sie führt die Vorzüge dieser Konstruktionen vor. Die Ableitung der Berechnungen der Statik erfolgte nach den Gesetzen der Elastizitätslehre, jedoch im Hinblick auf die recht niedrige Zugfestigkeit des Felsgesteins musste auch bedacht werden, dass in der Umgebung des Objektes die Elastizitätsgrenze überschritten wird. Hinsichtlich der Tragfähigkeit wurde nur eine solche Gesteinzone berücksichtigt, in der elastische Formveränderungen auftreten. Von der elastischen oder gar plastischen Verformung von Felsgestein wissen wir heute noch verhältnismässig wenig. Mit der Entwicklung der Materialprüfung kann gehofft werden, dass in Gestein gebettete Objekte noch genauer bemessen werden können.

DIMENSIONING OF PRESSURE PIPES AND RESERVOIRS SITUATED IN ROCKS

F. KOVÁCSHÁZY
Cand. of Eng. Sc.

SUMMARY

The paper gives a general view on engineering structures located in rock, of their designing and economical problems. It shows the advantages of such structures. The statical computations are made in accordance with the laws of Elasticity, but with regard to the very tensile strength of rocks, it has been necessary to consider that in the proximity of the structure the limit of elasticity is exceeded and that only that zone of the rocks is considered from the point of view of load carrying capacity, where elastic deformations take place. Our knowledge of elastic and even plastic deformation of rocks is rather limited. We hope that the development of materials testing will permit still more precise dimensioning of engineering objects placed in rock.

DIMENSIONNEMENT DES CONDUITES DE PRESSION ET DES RÉSERVOIRS PLACÉS DANS LES ROCHES

F. KOVÁCSHÁZY
Candidat des sciences techniques

RÉSUMÉ

L'étude fait le tour des problèmes de dimensionnement, de construction et des problèmes économiques concernant les objets logés dans les roches, et montre leurs avantages. Les calculs statiques sont basés sur la théorie de l'élasticité, mais étant donné la résistance à la traction très basse des pierres de roche, il fallait considérer aussi que dans l'entourage des objets la limite d'élasticité est surpassée et que seulement cette zone des roches est considérée dans laquelle il y a des déformations élastiques. Nous savons encore assez peu de la déformation élastique et même plastique des pierres de roche. Nous espérons du développement des méthodes d'essai des matériaux qu'il sera possible de dimensionner avec encore plus de précision les objets logés dans les roches.

РАСЧЕТ НАПОРНЫХ ТРУБ И ЕМКОСТЕЙ, УЛОЖЕННЫХ В ГРУНТ

Канд. техн. наук Ф. КОВАЧХАЗИ

РЕЗЮМЕ

В работе обобщаются вопросы расчета, проектирования и экономичности уложенных в грунт технических сооружений. Показано преимущество таких конструкций. Вывод динамических расчетов производился на основе законов эластичности, однако, учитывая очень низкое сопротивление растяжению скалистых пород, необходимо было не упускать извиду и то, что в смежной с техническим сооружением среде мы заходим за пределы эластичности и с точки зрения нагрузки учитывается только та зона грунта, в которой возникают эластичные деформации. О эластичной, даже пластичной деформации скалистых пород имеется еще мало сведений. Можно предполагать, что с развитием методик испытания материалов будет возможным осуществить более точный расчет уложенных в грунт технических сооружений.

A NEW METHOD OF RECORDING VIBRATIONS IN THE FOUNDATION OF TURBOGENERATORS AND THE STRUCTURE OF POWER HOUSES*

A. MAJOR

D. ENG. SC.

PLANNING INSTITUTE FOR CIVIL ENGINEERING, BUDAPEST

[Manuscript received 14th March 1956]

Importance of industrial seismology

With the rapid development of industry and communication during recent years, the efficiency of machines, the speed of vehicles and, consequently, the size of machine-units have considerably increased, a fact that makes it imperative to pay special attention to the action of dynamic forces. While progress is marked in respect of forging and stamping machines, crushing mills and crankshaft engines, it is particularly pronounced as regards high-speed turbogenerators, performances of 100 to 150 MW being rarities no longer.

In the analysis of vibrations, problems where the mass of the elastic system may be regarded as concentrated, springs as weightless, and damping as negligible, are easiest of solution. Unfortunately, industrial seismology never offers conditions in such a convenient arrangement. Neither the mass of the buildings nor that of the soil can be taken as concentrated at a single point. Nor can we regard the spring, in our case the building material and the soil, which are supposed to have a natural elasticity, as being weightless. Damping may be neglected, but usually at the expense of economy. The adequate determination of the damping factor requires both theoretical and practical consideration. Though mathematical formulae will help us in solving our problems, they yield but approximate values, and the uncertainty concerning the constants, which characterize materials employed, is a further reason why results derived from theoretical calculations should be treated with due caution. It is therefore imperative that calculated values should be checked by measurements, and that the elaboration of new methods of calculation should rely upon practical observations so as to bring their results as near reality as possible.

Although the analysis of vibrations is not unknown either in Hungary or abroad, it was usually made only after damages, whether due to design or execution, had actually occurred in buildings already erected and put into service.

Consideration of future research-work demands that vibrations set up in finished machine foundations and the adjacent buildings should be subjected

* Lecture delivered in Hungarian language at the IInd Building Congress of the Hungarian Academy of Sciences in Budapest on October 14th, 1955.

to systematic analysis prior to the occurrence of actual damages, at a time when no irregularities attributable to conditions of vibration have become manifest yet. Data thus obtained are a conditio sine qua non for the elaboration of reliable methods of calculation, and also enable us to check the correctness of preliminary calculations.

A number of additional problems can be solved by means of vibration measurements ; for instance, whether some beam is built-in and, if so, to what extent.

To measure vibrations may be very important in the case of pre-fabricated non-monolithic structure. Beams must be, for instance, prevented from rising : while resonance, once it is set up, involves the entire monolithic structure, in split-up structures the supported element may become a new source of disturbance which will transmit secondary vibrations to the structures reposing on it. Damping, being proportional to absolute deformation, is reduced by the transfer-coefficient in split-up structures, whereas, in monolithic structures, deformation will cause the undivided whole of the structure to act as a damper. All these problems are easy to settle if vibrations are measured.

Such measurements enable us to ascertain deformation at more than one point of any supporting structure.

Importance of measurements made during the test-run of turbogenerators

This paper describes a suitable method to measure and analyze vibrations which, for the purposes of the present experiments, were set up in the foundation of a turbogenerator and in the partly prefabricated adjacent structural elements of the building of a power plant.

Desirous of observing the effect exerted by vibrations of constantly changing frequences upon machine foundations and the surrounding buildings, the measurements in question were made at the test-run of a turbogenerator.

Though of outstanding importance, measurements concerning vibrations set up by the acceleration and deceleration of unloaded turbogenerators have, generally not been extended to both machine-foundation and the structural elements of the surrounding buildings.

It is commonly known that, as regards vertical natural vibrations, the foundations of high-speed turbogenerators — apart from structures of exceptionally low natural frequency, such as steel structures or structures with prestressed concrete frames — are as a rule overtuned, i. e. their natural frequency exceeds the operating speed, while the horizontal natural frequency of machine foundations (including the said exceptional structures) is usually lower than the operating speed so that, as far as horizontal vibrations are concerned, even overtuned foundations can be said to be usually undertuned.

Ever since it has become customary to employ prefabricated or partly prefabricated slender reinforced-concrete structures for the building of power houses, the natural frequencies of their structural elements have tended to be lower than the operating speed, i. e. they are usually undertuned. The critical speed of the main shaft is, of course, always run through as quickly as possible so that, in practice, it is for a short interval that disturbing frequencies are set up during acceleration.

The situation is somewhat different when the machine is being brought to a standstill, an operation that usually takes from 40 to 60 minutes, during which the rotor may rotate for 1 to 2 minutes in or in the vicinity ($\pm 5\%$) of any range of frequency, a time sufficiently long for the natural frequencies of the undertuned elements to coincide with the actual r. p. m. and to set up resonant conditions for a few minutes. It is, therefore, possible that all structural elements will begin to vibrate with considerably increased amplitudes, be it owing to vibrations set up in them by the momentary r. p. m. of the rotor, be it because of disturbing forces becoming intensified when the rotor runs through its own critical speed. Accordingly, we cannot disregard the danger of strong vibrations which, for all their transitory character, may become the source of damages. Designers ought to take it into account, and it will be advisable to revise the methods of computation as contained in the present regulations. Recent experiments which included analyses concerning various turbogenerators have brought the existing problems a great deal nearer their solution. Suggestions for a simplified method of design which, made on the strength of the said experiments, reckons with dynamic forces that arise during acceleration and deceleration and have to be considered by designers, are contained in a book of the author, the English version of which is to be published shortly.* The experiments described in this paper are measurements of vibrations which extend to transitory resonance. Their object, means, the methods of evaluation, together with conclusions, form the subject matter of the following paragraphs.

Many simultaneous measurements of vibrations, and the method of analysis

The object of the present measurements was to obtain simultaneous records of vibrations set up at several points of the machine foundation and the surrounding buildings by a turbogenerator rotating at various speeds when accelerated and decelerated during the 40 to 50 minutes of its first test-run.

To solve this task with the usual methods would have required a rather great number of recording apparatuses as also a very numerous staff, while a

* MAJOR, A.: Stress Analysis and Design of Foundations for Machines and Turbines (1st ed. In Hungarian, Budapest 1956. 668 pp.)

synchronization of the measurements would have been more than difficult with the use of simple means. It was, therefore, necessary for us to devise a new process of synchronized vibration measurements which is described in the following.

It is not proposed to deal at this juncture with the usual methods in detail, they shall be mentioned and treated here only according to whether their description is necessary for the understanding and interpretation of our new method.

The commonly employed recording instruments are either mechanical or electrical. In the former, e.g. in GEIGER's well-known *vibrograph*, the characteristic curve of vibration is graphically registered by means of a suitable transmission gear. Instruments of the semi-electric type which use electricity for the purposes of magnification, but register the vibration itself by means of moving needles, may be regarded as belonging to this same category. Experiences made with instruments of this type have shown that their magnifying power is usually inadequate, further that considerable distortions are caused by the fact that, especially at higher frequencies, they are not sufficiently sensitive, such insufficient sensitivity being due to the comparatively great inertia of the registering appliance. As regards electrical instruments, their most typical representatives are cathode-ray oscilloscopes and galvanometer oscilloscopes. The potential induced by the movement of the receiving head of the cathode-ray oscilloscopes is transmitted, after electric amplification, to the magnets of the cathode-ray tube ; the changing path of the ray, as directed by the electromagnetic forces, becomes visible on a screen and admits of being photographed, so that the moving needle of the mechanically operated instruments is replaced by the cathode-ray in these oscilloscopes. Although satisfactory as regards both their magnifying power and sensitivity, these instruments are too bulky for our purposes and cannot, of course, register the movements of more than one point at a time.

The galvanometer oscillocopes, as is known, are based on the principle that the suitably amplified potential induced in the receiver generates a current in a loop-shaped conductor that is placed in a permanent magnetic field. The current, circulating in opposite directions in the two branches of the looped wire, causes one branch to move forward and the other backward, so that a small mirror, attached to the two branches and turned through a certain angle by these opposite movements, will deflect the incident rays. While the magnifying power and the sensitivity of this instrument are no less satisfactory than those of the cathode-ray oscillosope, the looped galvanometer has the great advantage of taking up considerably less room.

The above considerations have led us to the idea of solving our task by employing several galvanometer oscillographs placed side by side and registering on a common strip of film. Outfits of a similar nature have hitherto chiefly been used in geophysical measurements, expecially in the survey of profiles. We were successful in discovering an equipment of this kind in the possession of one of the local companies which seemed to be suitable for the measurement of synchronous vibrations without requiring major alterations.

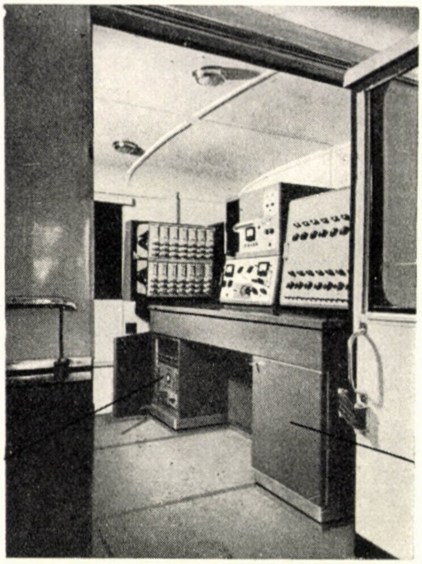


Fig. 1

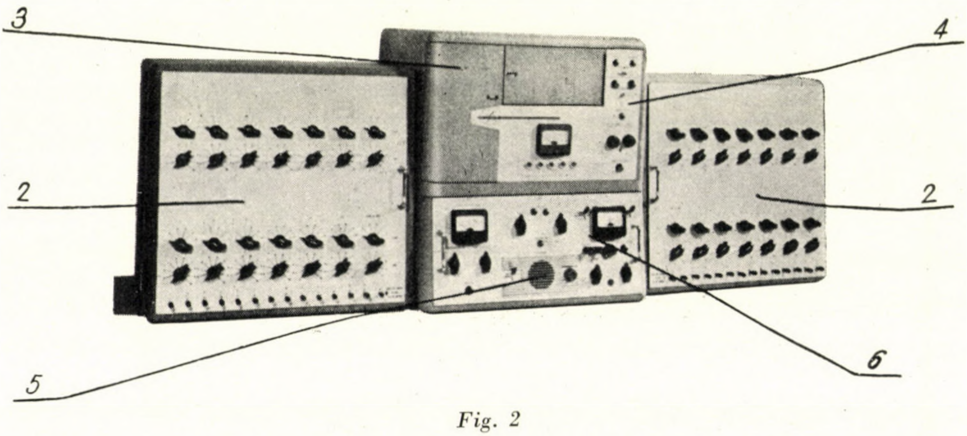


Fig. 2

The various parts of the equipment are mounted on a specially adapted motor lorry. The instrument table, the fuse board and the anode-voltage stabilizer are inside the car (Fig. 1). Likewise inside, in the middle part of the car body (Fig. 2), are the galvanometer oscillographs (3), with switches on their right for the mixing and tuning-fork units (4), underneath them are the control oscillator and impulse meter (6), while the switches of the amplifier installation are mounted right and left (2). Cable are used to connect the central installation with the receiving heads at the various points to be measured. There are 26 such receivers and cables to register synchronous vibrations. A telephone in the car, capable of being connected to any of the 26 cables, secures communication between the central operator and observers at any point of measurement. A telephone set, provided with loud-speaker and microphone (5), serves to identify the individual points of measurement.

Galvanometers and time signals transmit their records to a common sensitized paper-strip which moves with a speed of 35 cm/min. This is sufficient

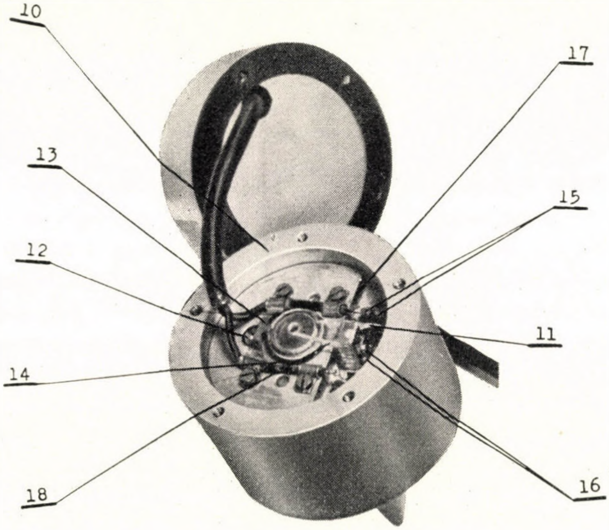


Fig. 3

to satisfactorily record even movements of 1/100 second duration. The vehicle also accomodates a photographic laboratory.

Geophones, usually employed in geophysical surveys, were used as receivers in the present experiments (Fig. 3). To assure a good transfer of the vibrations, we fixed the comparatively heavy casing of the geophones (10) to the elements to be measured by way of gypsum plaster. The casing holds a fixed permanent magnet (17) with an induction coil (14) which, placed in a plastic disc, moves in the magnetic field. The disc is attached to a stretched wire by means of a small arm and, owing to its inertia, does not follow the movement of the casing ; it recovers its state of rest through the torsional elasticity of the wire (11 and 15). A tangent screw between the magnetic circuit and the casing is indicated as (12) in the figure, while (13) illustrates the buffer which has to prevent the coil from excessive swings ; (16) marks the attachment of the oscillating part to the torsion-thread, and (18) the arm of the coil.

Our afore-mentioned three problems, i. e. the great number of necessary instruments, a reduced staff, and the synchronization of measurements, were all satisfacorily settled by the adoption of the above-described apparatus.

Disturbances

Before actually starting our measurements we had to tackle the problem of desturbing factors. Those of the various disturbing effects which had to be taken into account were :

a) inside disturbances of the instrument ; *b)* disturbances caused by other machines in operation ; *c)* disturbances caused by the passage of persons ; *d)* electrical disturbances.

We will examine these factors one by one :

a) Disturbances inherent in the instrument itself could be disregarded : as the apparatus was originally destined to register small amplitudes there was no need for us to make the utmost use of its amplifying power, so that — in actual practice — internal disturbances never exceeded the limit of negligibility.

b) Disturbances occasioned by other machines in operation could not be disregarded : in order to be able to eliminate them from our subsequent records, the "initial disturbance", i. e. vibrations existing prior to the particular ones we wanted to analyze, had to be measured at each intended point of observation.

c) Owing to the high sensitivity of the geophones unavoidable disturbances excited by the coming and going of persons had also to be accounted for ; since vibrations of this kind are aperiodic they cause only local disturbances and are easily eliminated from the final picture.

d) When dealing with disturbances caused by electrical factors we had to remember that in the alternating electromagnetic field both the geophones and the connected cables may behave as antennae, and that under induced voltage a surplus voltage may arise in them. While being run up, i. e. during the measurements, the generator itself was not excited electrically. All other electrical installations (the motors in particular) were connected to the main current of a 50 cycle-per-second frequency, so that the great difference between the various frequencies made it easy to distinguish between them. To indicate any extraordinary disturbances, one of the geophones, suspended in a vibration-proof manner, was used as antenna.

These measures proved sufficient to enable us to eliminate the effect of disturbing forces when evaluating the final diagrams of the synchronous vibrations.

Recording of vibrations

As has been mentioned, the present experiments were carried out on the building of a powerhouse. Its diagramatic cross-section is presented in Fig. 4. The higher part is the boiler house, the lower the engine room. Except

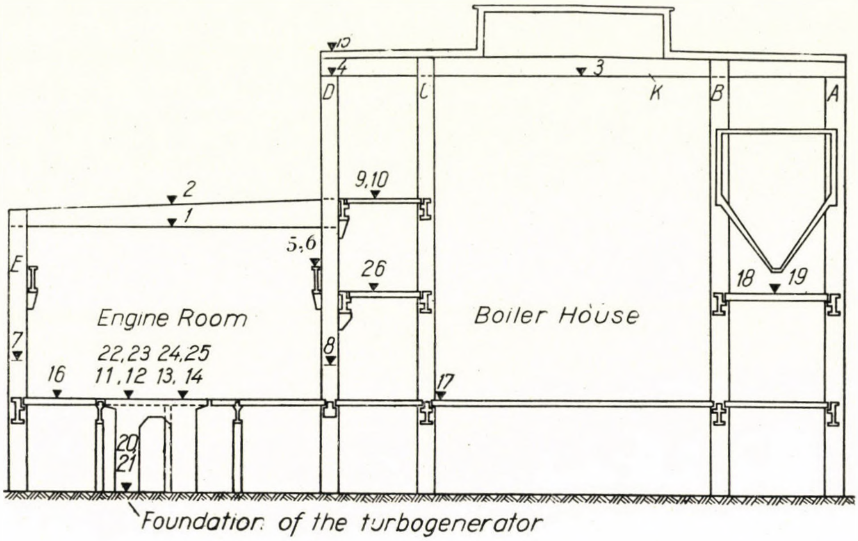


Fig. 4

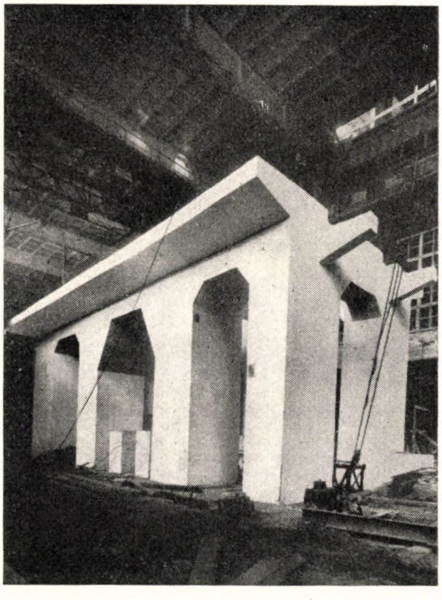


Fig. 5

some of the monolithic ceilings, the hall-structure is made of prefabricated elements. The members of the five ranges of pillars are rigidly built in the foundation, the roof girder of the engine house — an end-supported beam — reposes upon the pillars D and E. The roof girder of the boiler house, likewise an end-supported beam, is set upon the pillars B and C. The foundations of the turbogenerators are isolated from the surrounding buildings by means of joints.

Out of a total of 21 geophones, 19 served the purposes of the measurements proper, one was used to indicate possible extraordinary disturbances, and another to register r. p. m. As can be seen in the figure, geophone No. 1 was placed on the roof girder of the engine room, No. 2 on the floor of the roofing structure of the engine room, No. 3 on the middle part of the roof girder of the

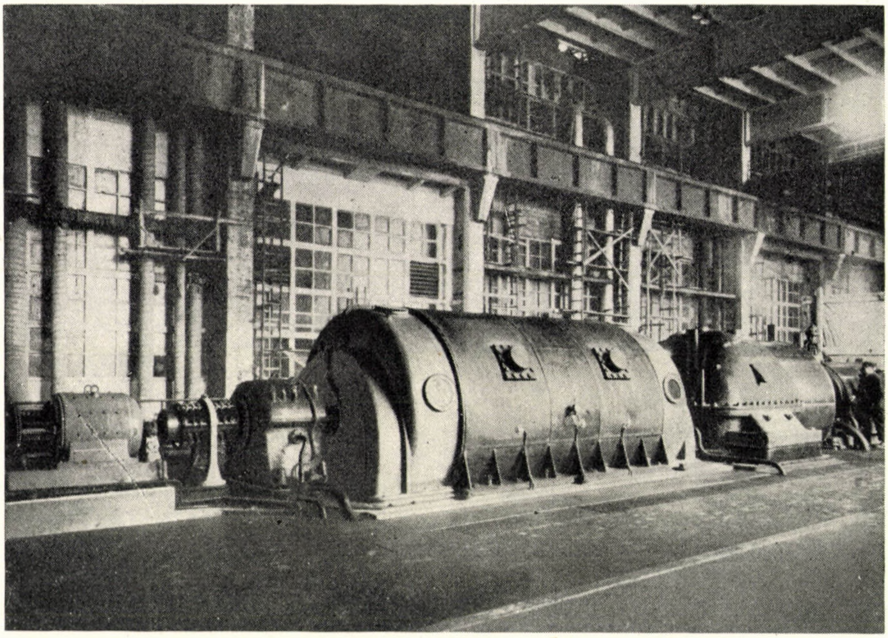


Fig. 6

boiler house, No. 4 on its projecting end, Nos. 5 and 6 on the craneway beams, No. 7 on pillar E, No. 8 on pillar D, Nos. 9 and 10 on the upper ceiling, Nos. 11 to 14 in the four corners of the turbine table (above the pillars), No. 16 on the monolithic structure beside the turbine table, No 17 on the boiler house, flush with No. 16, while Nos. 18 and 19 were placed on the ceiling below the bunker.

Subsequent single control measurements on the loaded turbine were made at the following points : Nos. 20 and 21 on the bedplate of the foundation, Nos. 22 to 25 on the turbine table, and No. 26 on an intermediate floor at the side of the engine house.

Mortar made of gypsum plaster was used to fix the geophones, and — before beginning with the measurements — each of the geophones was connected with the corresponding galvanometer oscillograph, the correct connection having been checked in each case by telephone.

Figs. 5 and 6 show the foundation of the turbine and the interior of the engine house, respectively.

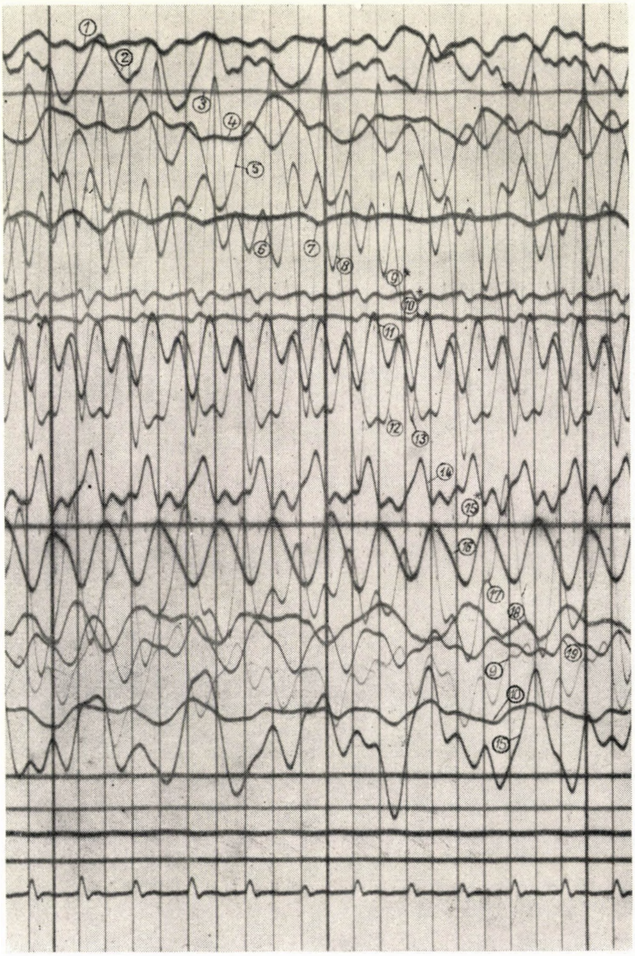


Fig. 7

After recording "initial disturbances", the turbogenerator was set going. During the first run we wanted to increase the speed in steps of 100 r. p. m., keep the machine at the given speed for a short time, and make our measurements before going a step higher. Although it was approximately possible to carry out this scheme, the actual increases in speed were a little more or less than 100 r. p. m. because the relatively low sensitivity of the revolution counter and the irregularities of steam pressure made it impossible for the successive steps to be intervalled with quite the desired accuracy. This, however, was not felt as a drawback, for the actual speed of the rotor at the moment of measurement could subsequently always easily be ascertained from the final characteristic curves of the vibrations and from the revolution counter connected with one of the galvanometers. The said stepping-up of the speed was practicable only until 1500 r. p. m. because, after this, we were approaching the critical speed of the rotor, i. e. about 2100 r. p. m. In order to pass through the critical speed as quickly as possible we had to accelerate at a more rapid rate until reaching the operating speed when a new measurement was made. Although this, of course, means that a certain region of r. p. m. had to be jumped over, it does not matter much as — according to the above-mentioned earlier vibration measurements — the natural frequencies of the structural parts under examination were, with the exception of the craneway beam with a natural frequency of 2100, generally in the region below 1500 r. p. m.

A photograph of the vibration records

Fig. 7 shows part of our records. The intervals between the thin vertical lines correspond to 1/100 sec. The record in question was made at a speed of 3000 r. p. m.

Evaluation of records

After developing the film strips in the laboratory of the car, the first step was to identify each characteristic curve as seen in the pictures with the corresponding geophones. This was followed by the determination of the amplitudes and frequencies of the recorded vibrations. It is known that periodic vibrations, however complicated their form, can be split up into simple harmonic ones which are divisible by the fundamental frequency, i. e. the frequency corresponding to the period of the complex vibration. The resolution in question is always possible, and each curve has but one possible resolution. Any known periodic function of the form $z = f(t)$ can be expanded as a Fourier series which will be the sum of harmonic functions with definite amplitudes and phases, all their frequencies divisible by the said fundamental.

$$f(t) = A_0 + A_1 \sin(\omega t + \varphi_1) + A_2 \sin(2\omega t + \varphi_2) + A_n \sin(\omega t + \varphi_n),$$

where

$$\omega = \frac{2\pi}{T} \quad \text{and} \quad n = 1, 2, 3 \ \ldots;$$

vibrations of the frequency $n \cdot \frac{1}{T}$ are the harmonics of the fundamental. Therefore, if the function $f(t)$ is known, Fourier's formulae will enable us to determine the constant A_0 as also the amplitudes A_1, A_2, A_3, and the phases φ_1, φ_2, φ_3, ... of the simple harmonic vibrations of which the complex vibration is composed.

The harmonic analysis, i. e. the reduction of a periodic function of this kind to harmonic functions can be performed by means of special instruments, the harmonic analyzers, which, besides saving lengthy and complicated analytical computations, have the advantage of permitting reduction in cases also — and this applies to our problem in particular — where the function $z = f(t)$ cannot be

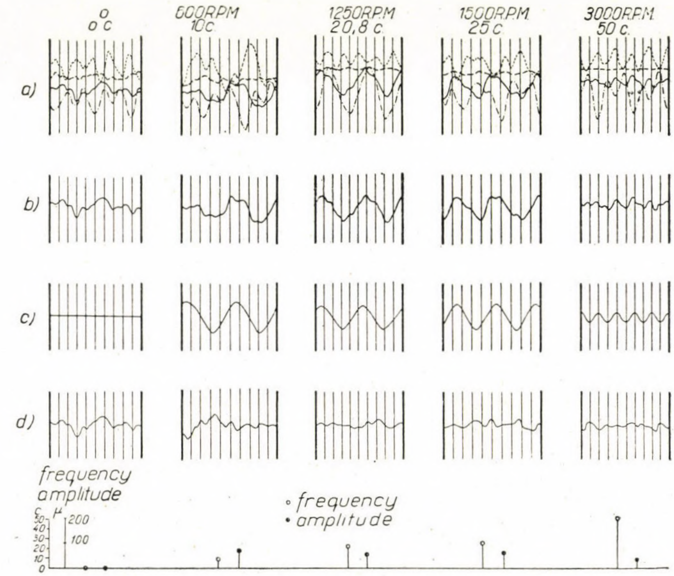


Fig. 8

expressed in mathematical terms. That we did not resort to this instrument had two reasons : first, to prepare the models of the various curves would have caused too much work and expense ; second, the irregular character of the disturbances made a very detailed and highly accurate analysis superfluous. What we actually did was to try, with the aid of Fourier's theorem, to isolate the fundamental vibration and at least its first harmonic from the complete picture. To achieve it we employed the simple but expedient method of approximation illustrated in Fig. 8 :

We traced the curves of the original record (a) ; from the four curves thus traced we isolated curve No. 3 (b) ; we plotted its sine curve which, as will be seen, follows the original with a good approximation (c) ; we then drew a curve (d) which corresponds to the residual ordinates obtained from the differences between the ordinates of curves (b) and (c) ; finally, we compared this curve with the record of the "initial disturbance" at a "speed" of zero r. p. m. The construction was regarded as correct and the sine curve (c) accepted as representing the true fundamental vibration if the amplitude in the curve of the disturbance was not conspicuously larger than that of the "initial disturbance". It is evident from the figure that as long as the machine is at rest it is only the "initial disturbance" which appears in the diagram, the fundamental vibration being zero at this stage. This simple procedure does not give rise to errors in dealing with the frequency because frequency is known from the readings of the revolution counter, further because the approximate sine curve has been plotted just so as to accord with it. As regards errors concerning amplitudes, they were quite negligible. The curves obtained by our method made it possible for us to determine

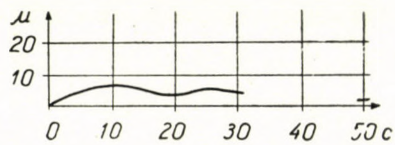


Fig. 9

the amplitude of the vibrations set up at various speeds and, having ascertained it, to plot for each point the curve of the amplitude as a function of the speed of rotation.

Fig. 9. shows that amplitudes were small at operating speed, and that, at this point of measurement, larger amplitudes arose at 10, further between 20 and 30 cycles per second.

To determine amplitudes we had to ascertain the magnifying power of the geophones at the given (and for all galvanometers identical) amplification, as also its ratio to the disturbing frequency. Too, the same relation had to be ascertained in respect of the galvanometers themselves. The problem was settled by specially testing each of the geophones : the rate of magnification thus obtained proved to be constant within a given range of frequency.

The characteristics of the galvanometers revealed linearity in the region between 20 and 200, and the necessity of correction blow 20 cycles/second. The records taken by the galvanometers disclosed the fact — one to which we shall refer later — that in the vicinity of 18 to 20 cycles/sec, i. e. below a speed of 1100 to 1200 r. p. m., frequencies were twice as high as the disturbing frequencies, so that no need for corrections arose since, apart from the "initial dusturbances" we made no measurements below a speed of 600 r. p. m. as it was not possible to run the rotor at lower speeds for any measurable length of time.

Results

To illustrate results, diagrams are presented in which the curves of amplitudes are plotted as functions of r. p. m.

Points of measurement Nos. 2 and 3 (Fig. 10)

Curves of vibrations as registered by geophones placed on the roof. Amplitudes at point 3, viz. in the middle part of the principal beam of the boiler house, appear to be quite negligible, a symptom which shows that the effect of vibrations was hardly perceptible at this point. While the shape of the curve which

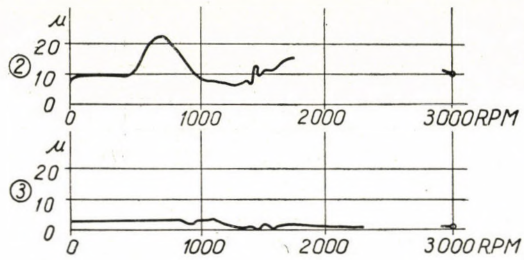


Fig. 10

illustrates vibrations registered at point 2, viz. the roof of the engine room, is similar to that of courve 3, it shows a double amplitude of 10 μ, i. e. a swing of 5 μ, at the operating speed of 3000 r. p. m. Preliminary measurements had shown the natural frequency of the elements at point 3 to be 15 cycles/sec which corresponds to a speed of about 900 r. p. m. Therefore, these elements are

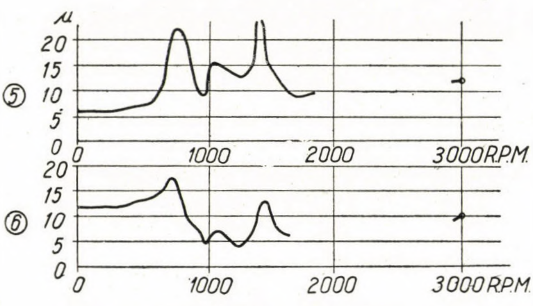


Fig. 10/a

undertuned, but, owing to the great distance, no vibrations with amplitudes coinciding with the r. p. m. of the generator could reach the roof girder. On the other hand, we see in curve 2, corresponding to a point where preliminary measurements disclosed a natural frequency of 1500, a peak in the region of about 700 r. p. m., and there is a further jump in the vicinity of 1500 r. p. m., i. e. in the region where actual and operating speeds coincide.

Points of measurement Nos. 5 and 6 (Fig. 10a)

Curves of vibrations as registered at two points of the craneway beams. One peak visible at a speed of 700, another at one of 1100, and a third at a speed of 1400 r. p. m. Double amplitudes about 10 μ at operating speed for both points. Natural frequency according to preliminary examination at 2100: this was within the range of critical speed so that no measurements could be performed.

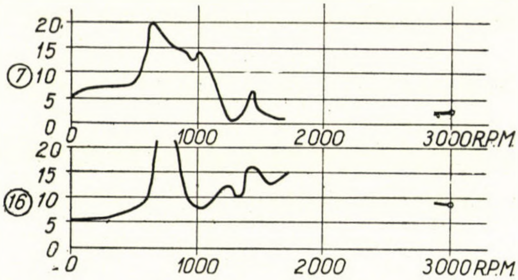


Fig. 10/b

Points of measurement Nos. 7 and 16 (Fig. 10b)

Curves of vibrations on pillars and floor-beams. Curve registered at point 7 (outside pillar of engine house) shows likewise peaks around 700 and 1000 r. p. m. Amplitude at operating speed negligible. At point 16 (floor beam) a sudden increase in amplitude at a speed of 800 r. p. m. As in the previous cases, amplitude at operating speed remains below 10 μ.

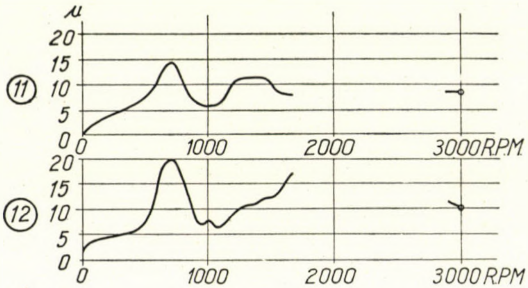


Fig. 10/c

Points of measurement Nos. 11 and 12 (Fig. 10c)

Curves of vibrations as registered in two corners of the turbine table. Preliminary measurements showed this element to be strongly overtuned at operating speed. As in the previous cases, conspicuous peaks around 700 and 1100 r. p. m. The fact that the other curves, too, show suddenly increased amplitudes in the region of these two speeds supports the assumption of a transitory resonance at one of these points. According to preliminary measurements, the natural frequency of the frame of the turbogenerator was 4000, a figure well above 3000, the operating speed. Accordingly, no resonance was set up at the latter. When making the said preliminary computations to determine natural frequency, we disregarded the elasticity of the bedding. Subsequent calculations in which due regard was paid to the joint deformation of frame and bedding gave 700 as the natural frequency of these combined elements, and it was this combined, true natural frequency to which resonant conditions set up at the first

Table 1

No. of the point	Location of the point	Synchronized amplitude measurement μ	Subsequent measurement at 3000 r. p. m. at singular points μ	Maximum measured amplitude: magnitude μ	Maximum measured amplitude: r. p. m.	Measured natural frequency m r. p. m.
1	In the middle of the beam	4		6	700	
2	On the roof of the engine room	5		11	700	1500
3	In the middle of the beam of the boiler house	0,5		2	almost continuously	900
4	On the cantilever of the beam of the boiler house	3		8	1400	900
5	On the crane girder	6	3,4	11 13	700 1400	2100
6	On the crane girder	5		9 6,5	700 1400	
7	On column E	3	2,2	16	650	
8	On column D	(3,8)		(9)	1300	
9	On level +23,00	only disturbances				
10	On level +23,00	only disturbances				
11	On the turbine table	4	5,6	7	700	
12	On the turbine table	5	4,8	10	700	
13	On the turbine table	13	5,0	15	650	
14	On the turbine table	4	4,1	6	700	
15	On the roof of the boiler house	5		11	700	
16	On level +7,30 beside the turbine	5	3,3	18	850	1800
17	On level +7,30 in the boiler house	only disturbances				1500
18	On level +16,00	only disturbances				1450
19	On level +16,00	only disturbances				1050

highest jump of the amplitude — on the foundation of the turbogenerator — were due. If we accept this assumption it will be easy to interpret the phenomenon of all observed resonances. Similar jumps of the amplitude at a speed of 600 to 700 at several points of the surrounding structure must have been due to a simple transfer via the soil of the said original resonance. The bedding coefficient with which the above-said figures are obtained is $10{,}4 \times 10^3$ t/m^3.

Table 2

No. of the point	Location of the point	Amplitude at 3000 r. p. m. in μ
20	On the bedplate	2,8
21	,, ,,	0,9
22	On the turbine table	3,9
23	,, ,,	6,0
24	,, ,,	6,3
25	,, ,,	5,0
26	On level of the intermediate floor	3,3

In order to ascertain the other factors responsible for increases in the amplitude it will be necessary to investigate conditions regarding the turbine or the generator shaft from the point of view of critical speed. That of the shaft is in the neighbourhood of 2100 r. p. m. and its harmonics often appear in the pictures. We have seen that nearly all vibration curves reveal peaks not only at a speed of 700 r. p. m. but also at one of about 1100 r. p. m. ; the latter represent the harmonics and must, therefore, be connected with a transitory increase in the disturbing force. The fact that there is no essential difference between the various amplitudes registered at the operating speed strengthens our confidence in the correctness of measurements made at points 20 to 26 (Table 2), i. e. those single measurements which were performed after the synchronized ones. Table 1 presents the results of the synchronous measurements together with maximum amplitudes and those at operating speed. The natural frequencies, determined by earlier measurements, are also indicated. While the curves show double amplitudes, only single values are indicated in the table. It is clear that most of the maximum amplitudes correspond to speeds of about 700 and 1100 r. p. m. In view of certain conspicuous amplitudes (e. g. those at point 7 which show a striking deviation from those at point 8) it seemed advisable to perform a number of individual (i.e. not synchronized) control measurements at additional points (20 to 26) : they were made by means of a cathode-ray oscilloscope and receivers of the Philips-type. The unusually large amplitudes as originally measured at point 8 were due to the fact that the amplifyer at this particular point happened to be adjusted to a tenfold measurement which was different from the adjustment applied at other points. Synchronized measurements have the advantage of making striking differences of this nature conspicuous, it being then easy to correct such errors by way of simple control measurements.

We can see that the figures obtained from the control measurements are not essentially different from those of the synchronized ones.

Table 3

Capacity in KW at 3000 r. p. m.	Doubled amplitude in mm at 3000 r. p. m.
6 000	0,030
6 000	0,021
12 000	0,030
16 000	0,060
16 000	0,056
16 000	0,042
16 000	0,025
17 500	0,066
25 000	0,058
25 000	0,040
25 000	0,060
25 000	0,020
25 000	0,030

On the strength of computations made in connection with finished machine foundations that had given no complaint it has been established that the largest amplitudes of vibrations in machines running at a speed of 3000 r. p. m. have usually values between 20 and 30 μ.

Amplitudes, registered in the course of the present experiments, have nowhere exceeded 20 μ, i. e. the figure obtained from measurements, as can be seen in the above tables.

Table 3 shows the double amplitudes of vibrations in 3000 r. p. m. — turbogenerators as the functions of capacity. It will be seen that single amplitudes (i. e. a half of the values indicated in the second column) are mostly under 30 μ. The figures obtained from a comparison with the other tables are in agreement with those yielded by control measurements.

Summary of results

The present investigations afford the following conclusions :

1. It is possible to determine the extent to which vibrations set up by turbogenerators are transmitted to surroundig structures. Measurements performed at points 2 and 3 have proved that vibrations do not spread beyond the engine room, and that their effect is practically imperceptible in the boiler house.

2. No structural element was found to be in resonance at the operating speed, a fact that could be checked up with the values of the previously-measured natural frequencies.

3. It was found in agreement with the observations of other authors, that frequencies up to a speed of 1100 to 1200 r. p. m. are twice as high as, and beyond that, equal to the disturbing frequency.

4. We have seen that amplitudes showed a sudden jump around the speed of 700 and 1100 r. p. m., respectively, at most points of measurement. The first of these jumps is apparently due to the transitory resonance set up by the elastic deformation of the bedding, while the second jump, i. e. that at 1100 r. p. m. is undoubtedly connected with the critical speed (2100 r. p. m.) of the turbine shaft. This is a phenomenon of harmony where it is not the building structures but the main shaft in which resonant conditions are set up.

5. As regards the values of the amplitudes, those observed in the present experiments are more or less in agreement with the results established by other authors.

6. When the rotation of the turbine shaft reaches a speed that coincides with the natural frequency, resonance is set up in undertuned structural elements, — disregarding the effect of the bedding's elasticity and the maximum vibrations due to disturbances. Resonances of this kind cannot be observed if natural frequency and critical speed are closely together, as it is necessary to pass over the critical speed as quickly as possible so that no time for measurements in its vicinity is left. It is obvious that, when dealing with undertuned elements, due regard must be paid to the effect which resonances, set up during acceleration and deceleration, exercise on the forces that are involved in the computations, and that they must not be disregarded even though the extent of the actual transitory amplitudes does not appear to be dangerous.

7. Vibrations should be investigated not only in respect of the machine foundations but also in that of the surrounding structures, especially if prefabricated or partly prefabricated elements had been employed in their construction. Our experiments have proved that a skilful use of correctly joined prefabricated structures is by no means incompatible with fully satisfying all requirements raised by considerations concerning vibration.

We hope to have demonstrated that the method described in this paper can be usefully applied to clearing up conditions of vibration in turbine foundations and the surrounding buildings.

SUMMARY

The rapid development of industry and transport in recent years has made it imperative that special attention be paid to dynamic forces affecting building structures, and it seems to be important that vibrations set up in them should be thoroughly analyzed.

Research work in this field requires analyses of the said kind in order to be able to check up the correctness of natural frequencies determined by theoretical computations, and to clear up the dynamics of supporting structures as far as they can be cleared up by way of vibration measurements.

The analysis of vibrations is of special significance in connection with machine foundations in general and the foundations of turbogenerators in particular, where it is important to examine not only vibrations set up at the constant operating speed but also frequencies and amplitudes at intermediate speeds; it is during the first run of the rotor that the latter are most reliably observable.

The paper describes a new method with which it is possible to simultaneously measure the characteristics of synchronous vibrations occurring at a number of points. An apparatus, comprising 26 geophones, mounted on a motor lorry has been found to satisfy the purposes of such measurements, and its operation during the first test-run of a turbogenerator is described and illustrated by the author.

Instead of using harmonic analyzers for the elimination of the effect of disturbances from the final records, the problem is solved in a simple manner by the determination of the "initial disturbances", i. e. those existing prior to the vibrations to be analyzed, and by the application of Fourier's theorem.

After evaluating the results of the measurements and surveying them by way of tabled data, it was possible to determine the range of effect of the vibrations, to analyze resonances set up at points where the known natural frequency of certain structural elements happened to coincide with the momentary r. p. m. of the rotor, and it was thus also possible to interpret the phenomenon of conspicuous peaks in the resonance, jumps in the amplitudes, which were found to be partly due to the critical speed of rotation and its harmonics.

The paper further discusses intermediate resonances observed in undertuned elements, as also the importance of all appreciable resonances for dynamical calculations; it arrives at the conclusion that by a skilful use of correctly joined prefabricated structural elements all requirements prescribed by considerations regarding vibrations can well be satisfied.

The outcome of the present experiments justifies the claim that the described analysis of synchronized vibrations may not only promote industrial seismology in general but may be also useful inasmuch as it offers the possibility of checking, by way of experiments, the correctness of preliminary dynamical and statical calculations made in respect of supporting structures.

NEUES SYNCHRONISIERTES SCHWINGUNGSUNTERSUCHUNGSVERFAHREN DER INDUSTRIELLEN SEISMIK

A. MAJOR
Doktor der technischen Wissenschaften

ZUSAMMENFASSUNG

Das dargestellte neue Schwingungsuntersuchungsverfahren löst die Aufgabe, gleichzeitig an mehreren Punkten erscheinende Schwingungscharakteristiken synchronisiert zu messen. Ein auf einen Kraftwagen aufmontiertes, 26 Geophone enthaltendes Instrument erwies sich als am geeignetesten, dessen erstmalige Verwendung zu solchem Zwecke beim ersten Probelauf eines Turbogenerators beschrieben wird.

Mit Anwendung des Fourierschen Prinzips, jedoch nebst Vermeidung des Gebrauches des harmonischen Analysators, werden die Störungsfaktoren auf einfache Weise auf Grundlage der Grundgeräuschaufnahme aus den Aufnahmen ausgefiltert.

Durch ausführliche Auswertung und tabellarische Darstellung der Messungsergebnisse war die Wirkungsweite der Schwingungen feststellbar; es war möglich beim Zusammentreffen mit der bekannten Eigenschwingungszahl der einzelnen Elemente, die Resonanz wahrzunehmen und somit die Ursachen der Resonanzausschläge festzustellen, die teils mit der kritischen Drehzahl und deren Harmonischen in Zusammenhang stehen.

Bei den abgestimmten Elementen war das Auftreten von Zwischenresonanzen und deren Bedeutung für die Festigkeitsberechnung infolge der in Betracht kommenden Resonanzen feststellbar. Es wurde festgestellt, dass den schwingungstechnischen Gesichtspunkten auch beim Einbau von fachmässig gekuppelten, abgestimmten, im Fertigbau hergestellten Konstruktionselementen Genüge geleistet werden kann.

Das synchrone Schwingungsuntersuchungsverfahren ist laut Versuchsergebnis sehr geeignet zur Förderung der industriellen Seismik. Damit können die auf Grund von dynamischen und statischen Voraussetzungen auftretenden theoretischen Probleme der Trägerkonstruktionen sehr erfolgreich auch versuchsmässig untersucht werden, bzw. können die theoretischen Überlegungen überprüft werden.

NOUVELLE MÉTHODE D'ÉTUDE DES OSCILLATIONS EN SISMOLOGIE INDUSTRIELLE

A. MAJOR

Docteur des sc. techn.

RÉSUMÉ

La nouvelle méthode d'étude des oscillations présentée par l'auteur résout le problème de la mesure en synchronisme des charactéristiques oscillatoires se présentant simultanément en plusieurs points. On fait usage d'un instrument contenant 26 géophones, et monté sur une automobile, dont l'application est démontrée à l'occasion du premier essai d'une turbo-génératrice.

Avec l'application du principe de Fourier, mais avec l'exclusion de l'usage d'un analyseur harmonique, les facteurs troublants sont filtrés des sismogrammes d'une manière très simple, sur la base de la réception du bruit fondamental.

Après l'évaluation détaillée des résultats des mesures et leur présentation par tableaux, on a pu déterminer la portée des oscillations. À la concordance avec les périodes propres connues des éléments individuels, on a pu observer la résonance et déterminer les causes des saillies de la résonance, en partie en rapport avec les nombres de tours critiques et leurs harmoniques.

Aux éléments baissés de ton, on a pu constater des résonances intermédiaires et, vu les résonances entrant en ligne de compte, leur importance au point de vue du calcul de la résistance des matériaux. Il s'est également avéré qu'on pouvait faire face aux points de vue oscillatoires lors de l'application d'éléments structuraux techniquement liés, baissés de ton et préfabriqués.

La méthode d'étude synchrone des oscillations peut fortement contribuer au développement de la sismologie industrielle. On peut ainsi examiner par la voie expérimentale, et d'une façon toujours plus efficace, les problèmes théoriques résultant de suppositions dynamiques et statiques concernant les ponts et charpentes, et proposer de nouvelles suggestions théoriques.

НОВЫЙ СИНХРОНИЗИРОВАННЫЙ ВИБРАЦИОННЫЙ МЕТОД ИССЛЕДОВАНИЯ В ПРОМЫШЛЕННОЙ СЕЙСМИКЕ

Др. техн. наук А. МАЙОР

РЕЗЮМЕ

Описываемый новый вибрационный метод исследований решает задачу синхронизированного измерения вибрационных параметров, возникающих в один и тот же момент в ряде точек. Наиболее подходящим для этого оказался прибор на автопередвижке, связанный с 26 геофонами. Первое применение этого прибора для этой цели показан на примере первого раскручивания некоторого турбогенераторного агрегата.

Исходя из принципа Фурье, но избегая применения гармонического анализа, на основе снятия основного шума простым методом фильтруются из съемок мешающие факторы.

На основе результатов измерений можно установить радиус действия колебаний, далее у отдельных элементов можно наблюдать резонанс при совпадении с известными

значениями собственных колебаний и, таким образом, определить причину скачков частоты, которые находятся в зависимости частично с критическим числом оборотов и его гармониками.

На основе проведенных исследований установлено, что в случае недостроенных элементов возникают промежуточные резонансы, далее вследствие приходящих во внимание резонансов значение их с точки зрения расчета механической прочности и доказательство того факта, что и при установке недостроенных сборных конструкционных элементов, соединенных технически грамотно, можно удовлетворить принципы вибротехники.

Синхронный вибрационный метод исследований, который по имеющимся в нашем распоряжении данным заграницей еще не применяется для такой цели, является очень подходящим — согласно данным проведенных исследований — для развития промышленной сейсмики и, таким образом, возможно эффективнее исследовать теоретические вопросы, возникшие на основе динамических и статических субпозиций несущих конструкций опытным путем, или же вносить теоретические предположения.

THE DRAG OF STREAMLINE BODIES OF REVOLUTION IN A WIND TUNNEL

G. S. VASY

[Manuscript received 26th May 1956]

It is known that the drag of bodies placed in a wind tunnel (D_w) is not equal (for the same flow characteristics) to the value measured in free air (D). Owing to the effect of the boundaries of the wind tunnel the velocity along the surface of the body, and thus the drag too, will be increased in a closed-jet wind tunnel while decreased in one of open-jet. Thus in general it will be :

$$D_w = n \cdot D , \qquad C_{Dw} = n \cdot C_D \tag{1}$$

where for a closed-jet wind tunnel $n > 1$, while for an open-jet one $n < 1$. On the assumption of irrotational flow it may be shown that the change (increase or decrease) of magnitude (u) of the local velocity of an unlimited flow (V) will take place to a good approximation in the same ratio to that velocity at all points on the surface of the body, except for regions of small extent near the stagnation point and the trailing point. That is :

$$\bar{u} = u/V = \text{constant} = u_1/V = \bar{u}_1 \tag{2}$$

(see [1], Part 1, Chapter III, § 6.[1]).

LOCK's approximate method of calculation (see [2], § 10.) gives for a body of revolution coaxial with the wind tunnel the formula :

$$\bar{u}_1 = u_1/V = \tau \cdot \lambda \cdot (s/S)^{3/2} \tag{3}$$

where s is the maximum cross-sectional area of the body, S is the experimental section of the wind tunnel, λ is a *shape coefficient*, and τ is a *wind tunnel coefficient*. According to LOCK for two-dimensional flow it will be:

$$\bar{u}_1 = \tau \cdot \lambda \cdot (s/S)^2 \tag{4}$$

If the drag may be taken proportional to the square of the velocity, its value in a wind tunnel will be equal to its free air value multiplied by $n = (1 + \bar{u}_1)^2$. However in case of non-streamline bodies, owing to the wake arising

[1] A. TOUSSAINT and C. N. H. LOCK use in [1] and in [2] respectively the ratio $m_1 = (u_1 + V)/V$ instead of $\bar{u}_1 = u_1/V$; $m_1 = 1 + \bar{u}_1$.

after the body, the values of u_1/V at the rear part of the body differ from those according to formula (3). This discrepancy is taken into account by LOCK by holding the theoretical value of $\bar{u}_1$ and introducing a *drag factor* K_1. Thus (for a body of revolution):

$$n - 1 = K_1 \cdot [(1 + \bar{u}_1)^2 - 1] = K_1 \cdot \{[1 + \tau \cdot \lambda \cdot (s/S)^{3/2}]^2 - 1\} \quad (5)$$

According to LOCK (loc. cit.) the variation of the value of K_1 in the function of C_D is that given in Fig. 1, i. e. for very small drag values (streamline bodies) it may be taken equal to 1 (cf. [3]).

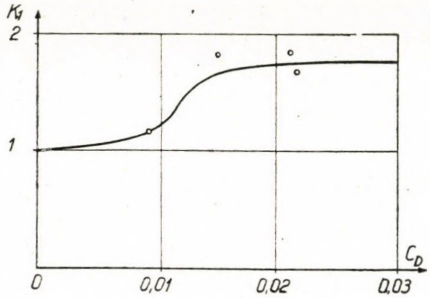


Fig. 1. The Variation of the drag factor K_1 after LOCK (from [2])

The value of the wind tunnel coefficient τ depends only upon the shape of the experimental section and how it is confined (open or closed). Its values for various cases are given in Table 1.

Table 1

Values of the wind tunnel coefficient τ according to LOCK

Flow	Shape of the Experimental Section	Closed-jet Wind Tunnel	Open-jet Wind Tunnel
Two-dimensional		0,82	—0,62
Three-dimensional	Circle	0,80	—0,20
	Square	0,81	—0,24
	"Duplex" Rectangle	1,03	

The shape coefficient λ depends upon the shape of the body and its fineness ratio.[2] LOCK has calculated it for six bodies of different shape; these were partly infinite cylinders, partly bodies of revolution. The sections of the cylinders considered taken normal to the generatrices (i. e. the profiles) were: ellipse,

[2] The finenes ratio (aspect ratio) is in case of infinite cylindrical bodies equal to the ratio of the profile length (chord length c) and the profile thickness (t), i. e.: $A = c/t$, while in case of spindle-shaped bodies it equals the ratio of the body length (l_B) and the circumference of the maximum section divided by π ($C_B/\pi = D_B$), i. e. $A = l_B/D_B$.

RANKINE oval,[3] simple symmetrical JOUKOWSKI aerofoil section, and a generalized symmetrical JOUKOWSKI aerofoil section (the latter one after [4]), while the bodies of revolution were : spheroid and RANKINE ovoid.[4] The profiles (and the axial sections respectively) of the bodies mentioned are shown (after [2]) in Fig. 2 for a fineness ratio of $A = 3{,}67$, while the corresponding shape coefficients are plotted against the fineness ratio in Fig. 3.[5]

Now neither the spheroid nor the RANKINE ovoid are shapes important in practice, on the other hand LOCK's method is unfortunately not applicable to streamline bodies of revolution whose outlines in the axial section are similar to those of a generalized symmetrical JOUKOWSKI aerofoil section. In practice

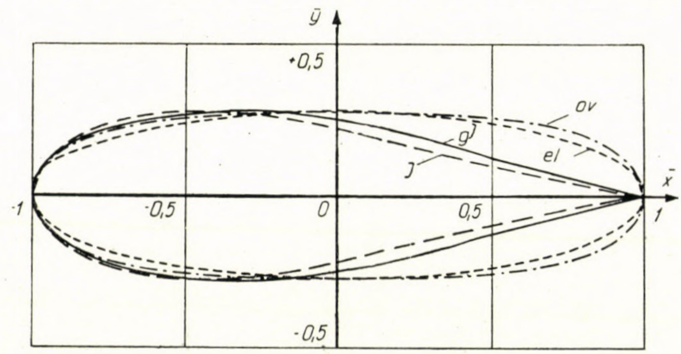


Fig. 2. The profiles examined by LOCK ($A = 3{,}67$)
Suffices used : ov = RANKINE oval, el — ellipse, gJ — generalized JOUKOWSKI aerofoil section J — simple JOUKOWSKI aerofoil section

usually the shape coefficients for spheroids or RANKINE ovoids are applied also to streamline bodies.

However, doing so is evidently not correct as the shape coefficient essentially depends upon the degree how the profile (and the axial section respectively) fills out the circumscribed rectangle. By comparison of Figs. 2 and 3 it may be stated that among the profiles plotted, the value of the shape coefficient is the largest for the RANKINE oval having the "fullest" shape, it is smaller for the ellipse and yet smaller for the JOUKOWSKI aerofoil sections having a tapered after part (it is the smallest for the simple Joukowski aerofoil section having a zero tail angle at the trailing edge). Similarly in case of bodies of revolution the value of

[3] The RANKINE oval is the $\psi = 0$ line (in the plane of the flow) of a flow being the resultant of a uniform flow and a two-dimensional source and a sink of equal strength behind it (ψ is the stream function).

[4] The RANKINE ovoid is the $\psi = 0$ surface of a flow being the resultant of a uniform flow and a three-dimensional source and a sink of equal strength behind it. See also foot-uote 6.

[5] A short description of LOCK's method may be found in [5] (on page 330). The curves are not given there ; it is only mentioned that the shape coefficient for ovoids roughly equals the ratio of the body length and its diameter which is true for slender RANKINE ovoids within an error of several percentage. In the formula published LOCK's factor K_1 is taken for ≈ 1.

the shape coefficient for the spheroids having more tapered nose is considerably smaller than that for the RANKINE ovoids.

In want of a value that could be evaluated theoretically, the value of the shape coefficient may be determined approximately in the following manner:

According to Fig. 3 the curves of $\lambda = f(A)$ all pass through the point $\lambda = 1$, $A = 1$; if the fineness ratio is large enough (about over $A = 3$) the variation

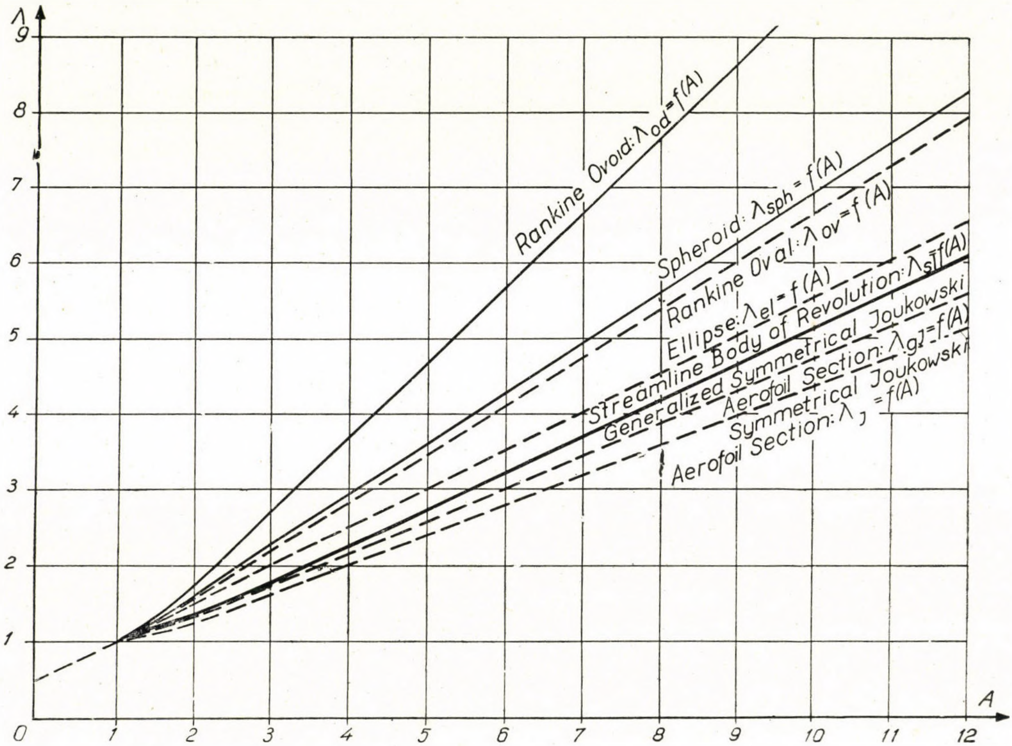


Fig. 3. The shape coefficient λ plotted against the fineness ratio A
——— bodies of revolution, — — — — cylindrical bodies

may be taken linear. It is probable that the course of the curve of $\lambda = f(A)$ for a streamline body of revolution is similar and its location is below the curve for the spheroids. Since the outlines of the axial section of streamline bodies applied in practice are similar to the outlines of the generalized JOUKOWSKI aerofoil section plotted in Fig. 2, on first consideration it seems obvious to take the curve of λ for a streamline body of revolution at the same fraction of the curve of λ for the spheroids (i. e. of its ordinates) as the curve of λ for the generalized JOUKOWSKI aerofoil section is to the curve of λ for ellipses. However, doing so would be incorrect as the ratios of the values of λ evaluated by LOCK for cylindrical bodies (RANKINE oval[6] and ellipse) and for bodies of revolution (RANKINE ovoid[6] and spheroid) of the same profile (axial section) respectively are not equal (i. e. $\lambda_{ov}/\lambda_{el} \neq \lambda_{od}/\lambda_{sph}$)[7]; the latter one is considerably larger (see Table 2). It may be assumed that a similar discrepancy exists also between the ratio of the values of λ for ellipses and the generalized JOUKOWSKI aerofoil section (λ_{el} and λ_{gJ}, respectively) and the ratio of the values of λ for the spheroids and the streamline body of revolution (λ_{sph} and λ_{sl}, respectively). It is more suitable to relate the discrepancy of λ_{sl} from λ_{sph} (expressed as the ratio $\lambda_{sph}/\lambda_{sl}$) to the discrepancy of λ_{od} and λ_{sph} (expressed as the ratio $\lambda_{od}/\lambda_{sph}$) and assume that their ratio is the same as that of the discrepancy of λ_{el} and λ_{gJ} (expressed as the ratio $\lambda_{el}/\lambda_{gJ}$) to the discrepancy of λ_{ov} and λ_{el} (expressed as the ratio $\lambda_{ov}/\lambda_{el}$). That is :

$$\frac{\lambda_{sph}/\lambda_{sl}}{\lambda_{od}/\lambda_{sph}} = \frac{\lambda_{el}/\lambda_{gJ}}{\lambda_{ov}/\lambda_{el}}. \tag{6}$$

Whence :

$$\lambda_s = \frac{\lambda_{sph}}{\lambda_{el}/\lambda_{gJ}} \cdot \frac{\lambda_{ov}/\lambda_{el}}{\lambda_{od}/\lambda_{sph}}. \tag{7}$$

The curve of $\lambda_{sl} = f(A)$ corresponding to the formula (7) is plotted in Fig. 3. It may be seen that it fits quite well to the set of the theoretically evaluated curves.

We may attempt the determination of the shape coefficient of a streamline body of revolution also in another way. Namely from the data in Table 2 it may be found that between the ratio of the coefficients λ for an ovoid and a spheroid of the same fineness ratio, and the ratio of the coefficients λ for the corresponding cylindrical bodies (i. e. of the same section), the following empirical relation exists :

$$\lambda_{od}/\lambda_{sph} = B_1 \cdot (\lambda_{ov}/\lambda_{el})^{3/2}. \tag{8}$$

Here $B_1 \approx 1{,}06$ if $A \geqq 4$; in case of $A < 4$ the value of B_1 diminishes, at $A = 1$ it will be $B_1 = 1$. It may be assumed that a similar relation may be extended to the coefficients λ of a streamline body of revolution and the generalized JOUKOWSKI aerofoil section respectively ; that is :

$$\lambda_{sph}/\lambda_{sl} \approx B_2 \cdot (\lambda_{el}/\lambda_{gJ})^{3/2}. \tag{8a}$$

[6] The outlines of the profile of a RANKINE oval and those of the axial section of a Rankine ovoid of the same fineness ratio are not identical, however considering the approximate character of the described method the discrepancy may be neglected.

[7] The meaning of the suffices used is :
el — ellipse, *ov* — RANKINE oval, *gJ* — generalized symmetrical JOUKOWSKI aerofoil section, *sph* — spheroid, *od* — RANKINE ovoid, *sl* — streamline body of revolution.

Table 2

Values of the shape coefficient λ

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Fineness Ratio A	λ_{od}	λ_{sph}	λ_{ov}	λ_{el}	λ_{gJ}	$\frac{\lambda_{od}}{\lambda_{sph}}$	$\frac{\lambda_{ov}}{\lambda_{el}}$	$\frac{\lambda_{el}}{\lambda_{gJ}}$	$1{,}06 \cdot \left(\frac{\lambda_{ov}}{\lambda_{el}}\right)^{3/2}$	B_1	$2 \cdot (\lambda_{ov}/\lambda_{el} - 1) + 1$	Values of λ_{sl} According to Formula (7)	(8a)	(9a)
	According to Lock													
1	1	1	1	1	1	1	1	1	1,06	1	1	1	1	1
2	1,76	1,60	1,56	1,50	1,30	1,10	1,057	1,153	1,125	1,037	1,08	1,333	1,187	1,177
3	2,68	2,24	2,18	2,00	1,72	1,196	1,09	1,164	1,218	1,041	1,18	1,756	1,71	1,688
4	3,67	2,91	2,81	2,50	2,15	1,26	1,125	1,163	1,263	1,057	1,25	2,235	2,20	2,195
5	4,66	3,58	3,44	3,01	2,59	1,30	1,143	1,161	1,295	1,063	1,286	2,71	2,695	2,71
6	5,65	4,24	4,08	3,51	3,02	1,33	1,16	1,162	1,325	1,063	1,32	3,18	3,19	3,205
7	6,64	4,91	4,72	4,02	3,45	1,352	1,175	1,165	1,35	1,062	1,35	3,66	3,68	3,695
8	7,63	5,58	5,36	4,52	3,88	1,367	1,187	1,166	1,368	1,060	1,374	4,16	4,185	4,19
9	8,62	6,24	6,00	5,03	4,31	1,38	1,192	1,166	1,381	1,060	1,384	4,625	4,67	4,68
10	9,61	6,91	6,64	5,53	4,74*	1,39	1,20	1,166	1,395	1,057	1,40	5,12	5,20	5,18
11	10,60*	7,58	7,28	6,04	5,17*	1,40	1,203	1,167	1,40	1,060	1,406	5,58	5,66	5,67
12	11,59*	8,24	7,92	6,54	5,60*	1,406	1,208	1,167	1,406	1,060	1,416	6,07	6,16	6,17

* Extrapolated values.

The values of λ_{sl} calculated using formula (8*a*) on the assumption of $B_1 = B_2$ are shown in Table 2.

Moreover, approximately there exists the following empirical relation too:

$$(\lambda_{od}/\lambda_{sph}) - 1 = 2 \cdot \left[(\lambda_{ov}/\lambda_{el}) - 1\right]. \qquad (9)$$

On this basis the following relation may be assumed :

$$(\lambda_{sph}/\lambda_{sl}) - 1 = 2 \cdot \left[(\lambda_{el}/\lambda_{gJ}) - 1\right]. \qquad (9a)$$

It may be found from Table 2 that the values of the shape coefficient for a streamline body of revolution calculated by formulas (7), (8*a*), and (9*a*) respectively differ only slightly ; if $A > 2$, the difference is negligibly small. As on the other hand the entire procedure of calculation based on Lock's method is rather approximate, the curve for λ_{sl} plotted in Fig. 3 may be taken sufficiently accurate for practical use.

As a final result it may be concluded that the shape coefficient of streamline bodies of revolution — above a fineness ratio of about A = 4 — approximately equals the half of the fineness ratio, thus it is about half as large as the value for ovoids.

Therefore the difference between the drag coefficients of a streamline body of revolution measured in a wind tunnel and in free air becomes smaller, according to formula (5) it will be about half as large as it would be when taking into account an ovoid. If the wind tunnel is closed, a smaller correction is to be subtracted from the value measured experimentally, thus the value for free air is higher than it would be when considering the body as an ovoid. On the other hand, in an open-jet wind tunnel the drag coefficient for free air calculated with the value of λ_{sl} will be smaller than with the shape coefficient for an ovoid.

The difference, especially in case of a closed-jet wind tunnel may attain a considerable value, and in general it is in order of magnitude higher than the experimental error. For example in case of the closed-jet wind tunnel of experimental section $0{,}50 \cdot 0{,}50$ m and a body of revolution of maximum diameter $D_B = 0{,}1$ m and length $l_B = 0{,}6$ m, calculated in [5] on page 330, if this body is a Rankine ovoid (or we apply the coefficient λ corresponding to it), the drag coefficient for free air will be smaller by 5,3 per cents[8] than the experimental value measured in the wind tunnel, while if it is a streamline body of revolution, the decrease will be only 2,9 per cents (the difference equals 2,4 per cents).

In case of an open-jet wind tunnel the absolute value of the coefficient τ is considerably lower. Therefore, the difference of the corrections in the two cases will be less too (in case of the preceding example it is only 1,7—0,85 = 0,85 per cent), and it may lie within the limits of experimental error. However, since the value of the correction ΔC_D increases rapidly with the value of s/S, for higher values of this ratio the difference ceases to be unimportant also for open-jet tunnels.

In practice the streamline bodies examined in a wind tunnel are frequently not bodies of revolution, but their cross-section is an ellipse or a shape not deviating much from it (f. e. aeroplane fuselages). In case of very flat cross-sections the flow approximates to a certain degree the two-dimensional flow, however, for cross-sections of usual proportions it will be rather similar to the flow along a body of revolution. In any case the error will be rather on the safe side when calculating the wind tunnel correction with the shape coefficient for a streamline body of revolution and taking as diameter the arithmetical mean value of the major and minor axes.

The method described is in principle applicable also to evaluate the drag of a Venturi (measuring) body.[9] Actually, however, then we have to take into consideration also some conditions neglected there, as the variation of the velocity in the cross-section of the tunnel (tube), moreover such simplifications of Lock's method that do not hold any more when the cross-section of the body is large in relation to that of the wind tunnel (see [6]).

[8] The value of 12 per cents given in [5] on page 330 is erroneous.

[9] A Venturi measuring body is a streamline (or approximately streamline) body placed in a tube of constant cross-section in order to throat it for the purpose of measuring the flow through it.

REFERENCES

1. W. F. DURAND : Aerodynamic Theory, Vol. III, Div. I (A. Toussaint, E. Jacobs : Experimental Methods — Wind Tunnels). Julius Springer, Berlin, 1935.
2. C. N. H. LOCK : The Interference of a Wind Tunnel on a Symmetrical Body. Reports and Memoranda No. 1275, British A. R. C.
3. A. FAGE : On the Two-dimensional Flow Past a Body of Symmetrical Cross-section Mounted in a Channel of Finite Breadth. Reports and Memoranda No. 1223, British A. R. C.
4. A. FAGE & V. M. FALKNER : Experiments on a Series of Symmetrical Joukowski Sections. Reports and Memoranda No. 1241, British A. R. C.
5. DR. GRUBER JÓZSEF—BLAHÓ MIKLÓS : Folyadékok mechanikája. Tankönyvkiadó, Budapest, 1952 (J. Gruber, Dr. & M. Blahó : Mechanics of Fluids).
6. VASY GÉZA : Venturi-mérőtestek alkalmazásával kapcsolatos kérdések; kéziratban (G. S. VASY : Some Problems Connected with the Application of Venturi Measuring Bodies; in manuscript).

SUMMARY

LOCK's method for the evaluation of the wind tunnel correction of the drag coefficient does not yield the correction factor for a streamline body of revolution (or rather, more strictly speaking, its shape coefficient). The paper describes several approximate methods for its evaluation. According to the results, the wind tunnel correction for a slender streamline body of revolution ($A \geqq 4$) is about half as large as that for a body of oval axial section (RANKINE ovoid).

DER WIDERSTAND VON STROMLINIENFÖRMIGEN UMDREHUNGSKÖRPERN IM WINDKANAL

G. S. VASY

ZUSAMMENFASSUNG

LOCK's Berechnungsmethode für die Windkanalberichtigung des Widerstandsbeiwertes gibt nicht den Berichtigungsbeiwert für einen stromlinienförmigen Umdrehungskörper (bezw. genauer seinen Formkoeffizient). Die Abhandlung beschreibt einige Annäherungsverfahren für dessen Berechnung. Nach den Ergebnissen ist die Windkanalberichtigung für schlanke stromlinienförmige Umdrehungskörper (Schlankheit $A \geqq 4$) ungefähr halb so groß wie für länglichrunde Körper (RANKINE'sches Ovoid).

LA RÉSISTANCE DE L'AIR DES CORPS DE ROTATION FUSELÉS DANS UNE SOUFFLERIE AÉRODYNAMIQUE

G. S. VASY

RÉSUMÉ

La méthode de LOCK pour le calcul de la correction à apporter au coefficient de résistance d'un corps experimenté dans une soufflerie aérodynamique ne fournit pas le facteur de correction pour un corps de rotation fuselé (ou plus précisément son coefficient de forme). Le travail décrit quelques procédés approximatifs pour son calcul. Selon les résultats, la correction à appliquer pour un corps de rotation fuselé assez allongé (allongement $A \geqq 4$) est d'environ la moitié de celle s'imposant dans le cas d'un corps ovoïde (ovoïde de RANKINE).

СОПРОТИВЛЕНИЕ ОБТЕКАЕМЫХ ТЕЛ ВРАЩЕНИЯ В АЭРОДИНАМИЧЕСКОЙ ТРУБЕ

Г. И. ВАШИ

РЕЗЮМЕ

Расчетная методика Лока, касающаяся коррекции аэродинамической трубы коэффициента сопротивления, не дает коэффициент поправки обтекаемого тела вращения (соответственно коэффициент формы этого тела). В работе описывается приближенная методика расчета вышеуказанного коэффициента поправки. Коррекция аэродинамической трубы статного тела вращения согласно результатам ($\lambda \geqq 4$) равна приблизительно половине коррекции элептического тела (овоида Ренкина).

THE CATION-EXCHANGE CAPACITY OF HUNGARIAN BENTONITES AND THE EXCHANGE PROCESS WHEN TREATED WITH SODA

J. BARNA

RESEARCH INSTITUTE OF MINING, BUDAPEST

[Manuscript received 25th June, 1956]

It is a generally known fact that clay minerals have, among others, the property of adsorbing in stoichiometric proportions, certain cations and even anions with the ability of retaining these in an exchangeable state. These exchangeable cations are held in general on edges and peaks on the outer surface of the elemental clay mineral crystal units, and between the flakes in montmorillonites. Electron micrographs by Endell ($40\,000\times$) show that when gold had been filled into the cation-exchangeable places of kaolin crystals, those parts have appeared in form of dots [1].

The exchange capacity is expressed in milliequivalents (meq.) per 100 g. The main exchangeable cations in clay minerals are, Ca^{++}, Mg^{++}, NH_4^+, K, Na^+, H^+. The so-called "S" value is the total of the Ca + Mg + K + Na cations, and the "T" value, the total of S + H + others.

The cation exchange capacity which is a fundamental characteristic of clay minerals is of extraordinary importance for whatever purpose the minerals may be used. In soils f. i. it plays a significant part in retaining the nutritive matter and the usability of any given soil depends upon the character of exchangeable cations present therein.

Also in the field of geology, there are many examples showing the influence of exchange reaction. In weathering processes, for instance, the retention of liberated alkalies and alkaline earth metals is always a matter of the cation-exchange capacity.

Even in industrial usage, the qualitative and quantitative distribution of the cations present in the clay minerals is of primal importance.

Exchange capacity in bentonites is a matter of vital importance as montmorillonite, the characteristic clay mineral thereof, has a cation-exchange power far exceeding that of any other of the more common kinds of clay minerals.

In general, the cation-exchange capacity is attributed to three main causes, namely [2]:

1. The so-called "*broken bonds*" occurring at the edges of crystal units of the clay minerals. In montmorillonite, f. i., they account for about 20 per cent of the cation-exchange capacity.

2. *Unbalanced state due to isomorphous substitutions.*

3. In certain *more exposed hydroxyl groups* even the hydrogen cation may be substituted by other cations.

One of the characteristics of the cation-exchange capacity is its considerable increase as a result of grinding [3].

Another fact of interest is the effect of temperature on the cation-exchange capacity of montmorillonite and sárospatakite. HOFMAN and KLEMEN [4] have shown that a decrease of the cation-exchange capacity due to the influence of heat is by far greater in Ca than in Na montmorillonites and, further, that a deterioration in the swelling capacity caused by heat-treatment is decidedly smaller than the decrease in the cation-exchange capacity.

No suitable explanation is available as yet for the high cation-exchange capacity of montmorillonites as well as for the slight variations observed in the bentonites of various origin and of varying compositions [5].

There are great differences in test data about the relationship of the cation-exchange capacity and the colloidal properties of Na montmorillonites which show swelling. Thus, when two alkaline montmorillonites having "T" values of 98 and 82, respectively, were tested, BUZÁGH [6] has found that the montmorillonite with the higher "T" value had the more favourable colloidal properties (i. e., greater stability of the suspensions and increased resistance to electrolytes). On the other hand, FOSTER [7] testing twelve montmorillonites saturated with Na ions has shown that no distinct correlations can be discovered between their cation-exchange capacities ranging from 77 to 115 and their volume of swelling ranging from 21 to 66 ml. There was found, however, a relationship between the volume of swelling and the octahedral substitutions, in so far as an increase of substitutions involves a decrease of the swelling capacity.

Determination of the cation-exchange capacity

No generally accepted method of determination is known as yet. In fact it varies according to the p_H value, the method of *exchange* and the quality as well as the degree of concentration of the solution. An exchange solution in common use chiefly in the USA, is acetate of ammonia [8]. A comprehensive survey of the base-exchange capacity of clay minerals has been compiled by DEUEL and HOSTETTLER [9].

In Hungary, the Research Institute of Mining, and the author respectively, were the first to recognize the importance of this problem in relation to bentonites, and already in 1951, contact was established with the Agrochemical Research Institute where for some time already, systematic investigations had been going on in respect to the cation-exchange capacity of soils. The method applied by the latter institute is the MEHLICH process using an 0,1 n solution of $BaCl_2$ working with triethanolamine buffered at p_H 8,2 [10].

Table I

Calcium bentonites

Bentonite	Montmorillonite %	Exchangeable cations mg equ./100 g at 140° C							Apparent*) viscosity cp after	
		Ca	Mg	K	Na	"S"	H	"T"	24 h	max.
Istenmezeje average	65	51	21	3,3	4,6	80	9	94	settles	
Istenmezeje cream yellow ..	63	35	22	0	9,5	67	10	83	settles	
Nagytétény	86	106	17	0	0,9	124	4	128	settles	
Bánd	75	71	34	0,9	2	108	4	118	settles	
Mád—Koldu......	39	38	18	0,4	0,4	57	3	62	16	16
Mád—Vasbánya ..	64	66	50	2,5	5,8	124	3	130	13	15
Mád—Rátka	38	22	20	3,2	4,2	50	3	60	settles	
Várpalota	75	77	23	0,3	0,6	100	6	110	22	—
Ódörögdpuszta....	83	73	18	0,6	3,3	95	6	105	45	—
Gyöngyöspata (1)	78	74	33	2	2,7	112	—	119	settles	
Göncz	72	61	49	4,3	15	129	6	140	16	18
Pákozd (2)	63	55	43	1,5	4,3	105	11	123	settles	
Eger 1.	—	69	13	0,6	12	95	9	105	settles	
Tállya III. (1) ...	55	56	7	tr.	3,4	67	7	74	16	18
Kismaros (3)	60	73	18	0,3	1,7	92	6	120	settles	
Hajmáskér (1) ...	—	49	27	2	2,7	81	3	90	settles	
Rány (1)	42	44	22	0,5	0,5	67	10	79	settles	
Komlóska hard white	50	42	24	1,8	2,3	70	—	74	settles	
Komlóska soft white	56	32	29	3	0,5	64,5	6	79	20	
Komlóska green ..	66	30	28	2	0,2	61	8,5	78	16	
Komlóska average	48	30	27	2,5	0,2	60	5,5	77	16	
Sima	55	67	14	0,3	1,8	83	16	99		
Gánt-Bagolyhegy (3)	55	48	39	0,5	0,5	88	7,5	95		
Végardó X. borg...	37	35	9	1,5	4	49,5	4	58	8	8
Tolcsva R. I. (1) ..	75	77	24	1,8	4,3	107	8	119		
Golop II.........	63	49	15	0,6	2,2	66	4,5	73	25	
Ruman. (Erdély) (9)	—	82	45	0,3	7	134	7	149		
Chinese (4)	—	98	27	0,3	0,2	126	11	147		
Indian (Giridih) (4)	72	58	49	0,9	0,1	108	23	140		
Yugoslav Petrovac (10) I.	62	43	41	0,9	13	98	6,5	105		
II.	—	46	17	0,6	17	81	5,5	97		
III.	—	48	9	0,8	24	82	3,5	91		
Cyprian (4)	62	42	30	0,6	28	100	5	109	settles	

*) NOTE. The viscosity of bentonite dispersions with an optimum of soda content was measured at 25°C and 600 r. p. m. in a Marschalkó viscosimeter [12] after the elapse of 24 hours, with the procedure repeated later until a maximum value could be obtained.

The bentonite samples tested were of the following origin : 1. Collected by Gy. Varju. 2. A. Gallov. 3. L. Reich. 4. *Chemolimpex*. 5. L. Tokody. 6. T. Kilényi. 7. *Silicate Section of NEVIKI* (Research Institute of the Heavy Chemical Industry). 8. J. Barna, Salgótarján. 9. V. Bauma. 10. *Ministry of Public Construction*. 11. *Shaft-sinking Company*, Komló.

Since the effect of the exchange solution of $BaCl_2$ is obviously more favourable than that of the univalent acetate of ammonia [11], the author too has applied the Mehlich process. In the case of bentonite, however, only 1 to 2 g of the substance could be measured instead of 5 to 10 g, which is the customary quantity for soils, and also the SCHACHTSCHABEL funnel had to be elongated considerably. A pipe of the size 20 by 350 mm and a sand (bentonite ratio of 1 : 30) has proved to give satisfactory results.

Other factors of import are, the fineness of the bentonite under test (—60 micron) and a most intimate mixture with the sand. A special problem arose when bentonites with soda content were to be investigated. Here, the excess of soda could be successfully removed when prior to leaching, the material was treated twice or three times with 80% alcohol.

The general practice was to run simultaneous investigations which when reproduced at various instances were, generally, in good agreement, although some inexplicable deviations were encountered too. It may be stated, however, that every precaution was taken that *tests be carried out always under identical conditions.*

Occasional differences occurring between the "S" and "T" values ar waiting for further explanation. (The cation-exchange tests were carried out by B. PATAKY.)

The data covering the cation-exchange capacity values for Hungarian and foreign bentonites established since 1951 and compiled in Tables I, II and III, are classified according to the amount of the cations into groups of bentonites with Ca, Mg, resp., Na cations. This is of course a perfectly arbitrary classification, since Ca and Mg contents, as a rule, are rather close in quantity, like, f. i.

Table II

Magnesium bentonites

Bentonite	Montmorillonite %	Exchangeable cations mg equ./100 g at 140° C							Apparent*) viscosity cp after	
		Ca	Mg	K	Na	"S"	H	"T"	24 h	max.
Komló I. (5)	—	38	56	3,7	11,2	108,7	8,9	132	settles	
Komló III. (11) ...	—	29	40	0,6	1,2	70,8	13,0	85		
Monostorapáti (1) .	80	34	42	0,2	1,2	78	4	90	35	35
Eger 2.	63	52	54	2,2	16	124	7	132	settles	
Bükkösd (1)	—	18	24	3	8	53	8,9	72	settles	
Nagymányok (7) ..	90	51	55	—	1,2	107	6,9	125	34	—
Nagybélverő	—	48	50	1,3	5	104	3,4	113	settles	
Tarnaszentmária ..	75	34	42	0,3	4,2	80,5	14	97	settles	

*) Note. See: Note to Table I.

Table III

Natural sodium bentonites

Bentonite	Montmorillonite %	Exchangeable cations mg equ./100 g at 140° C							Apparent viscosity cp after	
		Ca	Mg	K	Na	"S"	H	"T"	24 h.	max.
Little Rock USA (7)	91	12	36	3,4	78	130	7	140	settles	
Wyoming I. USA (4)	80	39	30	2	28	99	5,3	107	14	48
Wyoming II. USA (4)	70	13	7	1	50	71	3	76	10	45
USA (4)	75	15	23	3	53	92	5,3	100	13	
"C" from Dutch market (4)	60	29	16	1,4	64	111	—	118	35	
Greek (4)	35	6	17	7	20	50	9	71	settles	
Salgótarján original (8)	40	15	16	1	20	52	4	58	2	—
Salgótarján *concentr. by water*	concentrated	7	12	2	50	71	6	95	180	
Concentrated sodium bentonites (Saturated with natrium kation)										
Istenmezeje cream yellow ...	concentrated	24	16	1,3	87	128	7	135	92	
Nagytétény	,,	22	18	0,4	93	134	7	147	52	
Mád—Koldu	,,	8	13	0,3	91	116	—	128	216	
Komlóska soft green	,,	33	3	—	71	107	14	123	100	
Komlóska soft white	,,	30	8	0,3	60	98	11	114	120	
Ódörögdpuszta	,,	21	9	1	87	118	8	127	33	
Monostorapáti	,,	44	21	0,5	44	109	4	128	7	
Salgótarján *concentrated with soda solution*	,,	25	6	11	73	114	13	128	286	
Bentonites treated with wet soda solution										
French "C" (4) ...	65	20	33	0,8	68	122	1	126	12	20
Italian S. p. M. (4) ..	55	52	15	3	44	114	3	123	6	
Bentonite hot-treated with wet soda solution										
Istenmezeje cream yellow ...	80	40	20	0,3	86	146	1	147	17	30

in the bentonites of Komlóska, Eger 2, Nagybélverő etc. Judging from experiences available so far, differences of a more essential type in the properties of bentonites have been identified only when Mg cations were present in larger quantities ; f. i., in the bentonites of Komló and Monostorapáti.

Special studies were devoted to the process of cation-exchange in order to investigate the effect of *single* soda treatment commonly applied. For this purpose, pure, resp., concentrated montmorillonites were prepared and the exchange of cations determined. For montmorillonites prepared from bentonites of Istenmezeje, Nagytétény, Mád—Koldu, Komlóska — both soft white and green, Ódörögdpuszta and Monostorapáti, the Buzágh—Szepesi method [13]

Table IV

The process of cation-exchange

	Exchangeable cations mg equ./100 g at 140° C							Montmorill. content %
	Ca	Mg	K	Na	"S"	H	"T"	
Istenmezeje cream-yellow original	35	22	0	10	67	10	83	64
conc. montmor. established	24	16	1,3	87	128	7	137	concentrated
computed*	55	34	0	15	104	16	130	concentrated
Nagytétény original ..	106	17	—	0,9	124	4	128	86
conc. montmor. established	22	18	0,5	93	134	—	147	concentrated
computed	123	20	—	1	144	5	149	concentrated
Mád—Koldu original..	38	18	0,4	0,4	57	3	62	39
conc. montmor. established	8	13	0,3	91	116	—	120	concentrated
computed	74,5	37,6	—	—	110,5	8	119	concentrated
Komlóska soft white, original	32	29	3	0,5	64,5	6	79	56
conc. montmor. established	33	3	—	71	107	14	123	concentrated
computed	39,5	52	5	0,9	97	13,9	121	concentrated
Komlóska green original	30	28	2	0,2	61	8,5	78	66
conc. montmor. established	30	8	0,3	60	98	11	114	concentrated
computed	45,5	42,5	3	0,3	92	13	118	concentrated
Ódörögdpuszta original	73	18	0,6	3,3	95	6	105	83
conc. montmor. established	21	9	1	87	118	8	127	concentrated
computed	88	21,7	0,7	4	115	4	127	concentrated
Monostorapáti original	34	42	0,2	2	78	4	90	80
conc. montmor. established	44	21	0,5	44	109	4	118	concentrated
computed	42,5	52,5	0,6	2,5	98	5	112	concentrated

* The computed values refer to a state without soda treatment

of determination, and for the montmorillonite prepared from Salgótarján bentonite, a simple water solution was used (Table III).

In order to discover the extent of cation-exchange actually taking place, comparisons were drawn between the cation-exchange values of concentrated montmorillonites and the cation-exchange capacity of the original bentonites on one hand, and the computed values corresponding to the concentrated montmorillonite content without soda treatment, on the other hand (Table IV). The proportion of the exchangeability of Ca and Mg cations is shown in Table V.

Table V

Exchange of alkaline earth metal cations due to soda treatment

Bentonite	Ca %	Mg %
Istenmezeje	56,3	14,5
Nagytétény	82,2	53
Mád—Koldu	89,3	59,7
Komlóska, soft white	19	94,2
Komlóska, green	44	85,5
Ódörögdpuszta	71	50
Monostorapáti	0	60

The cation-exchange capacity of the non-montmorillonite constituents in bentonites were considered only in the case of the Mád—Koldu and the soft white Komlóska bentonites. In all other kinds, the cation-exchange capacity of such constituents was taken to be of no significance.

In order to facilitate comparisons, in Tables I and III data of several foreign bentonites and in Table VI, data on the cation-exchange capacity of other clay minerals, all examined and established by the author, have been included.

For the majority of the bentonites listed, also montmorillonite content has been quoted. In some of the cases, this was determined by X-ray examinations (carried out by E. Nemecz), most of the samples, however, were tested by the Buzágh—Szepesi method [13].

Table VI

Other clay minerals

	Exchangeable cations mg equ./100 g at 140° C						
	Ca	Mg	K	Na	"S"	H	"T"
Zettlitz kaolin	2,8	8,1	0	0,5	11,4	0,5	12
Pilisszentiván clay (1)	7	4,5	0	1	12,6	1,3	14
Füzérradvány illite	13,5	12,6	2	2,6	30,7	1	36
Komlóska, soft white, dead rock	22,5	—	—	1	23,5	—	25,8
Mád—Koldu dead rock	13,5	5,2	1	1	20,7	2	24

Discussion of the results

From the point of view of the amount of exchangeable cations present, the majority of Hungarian bentonites apparently belong to the group of Ca bentonites, for this is the cation prevalent in them. It is striking, however, to find that in a considerable number of bentonite occurrences, Mg cation are dominating. Some of these latter are of great commercial and industrial importance due to both the extension of the deposits and the excellence of the properties.

Although some of the bentonites mined in Hungary contain 10 to 15 mg of Na and have an "S" value of 12 to 13 per cent, for the time being, however, Salgótarján bentonite is the only recognized quality with the comparatively highest Na content and an "S" value of approx. 40% (Table III).

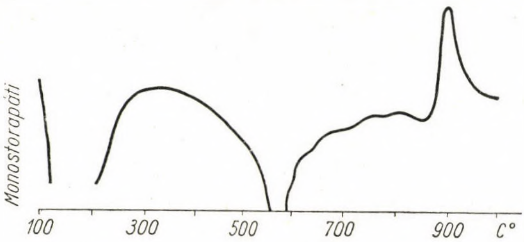


Fig. 1

Some of the bentonites in the group characterized by very high exchangeable Mg cation content have certain remarkable attributes. Komló bentonite, f. i., which according to Tokody's investigations [14] shows the characteristic X-ray lines of montmorillonite, when tested by the Buzágh—Szepesi process [13] can neither be peptized, nor can its montmorillonite content be precisely determined. Tokody has found further that in the differential thermal curve for Komló bentonite the second endothermic peak is missing, though it is known to be otherwise one of the essential characteristics of montmorillonites.

Tests by the author have revealed a similar behaviour of the Monostorapáti bentonite, where the second endothermic peak in the d. t. a. curve (Fig. 1) is likewise missing.

A matter for further consideration is a statement by Page [15] on this behaviour of bentonites. On investigation of the d. t. a. curves fcr, muscovite, biotite and pyrophyllite Page has found, namely, that while muscovite, which contains aluminium in its three-layer structure, does show the endothermic peak, in the d. t. a. curve for biotite containing magnesium in its octahedral sheet, the peak does not appear, and a loss of water occurs at temperatures beyond 1000° C, only. Herefrom, he came to the conclusion that in all the three-layer clay minerals containing aluminium in the octahedral sheet, the water is lost around 700° C with an endothermic peak appearing in the d. t. a. curve. When, however, the magnesium content is the predominating one, the water is bounded much stronger and may become lost at high temperatures, only. According to PAGE, the same must be true for montmorillonites, too. Recently, EARLEY *and colleagues* [16] have not confirmed this assumption of PAGE. The Komló bentonite "as mined" has a magnesium content of 8,8%, that of Monostorapáti 2,3%. The amount of magnesium in octahedral coordination has not been determined by the author.

Table III contains data on the cation-exchange capacity of montmorillonites prepared according to the BUZÁGH—SZEPESI method [13]. They show clearly that with the Buzágh—Szepesi procedure even such a forceful method consisting of a single soda treatment is unable to produce a replacement of all the alkaline earth metal cations by Na, and also that bentonites show widely varying properties in this respect.

The maximum exchange recorded has taken place in the bentonites of Ódörögdpuszta and Mád—Koldu, whereas the minimum was experienced in the Monostorapáti bentonite containing Mg as the predominating exchangeable cation.

A further characteristic is that Ca and Mg cations are exchangeable to entirely different degrees. The percentage of the exchange capacity of various cations is shown in Table V.

From a comparison of the cation-exchange data of pure (concentrated) montmorillonites with those of natural Na bentonites in Table III, it seems likely that one of the main prerequisites of a good swelling capacity is a smallest possible content of Ca and Mg cations and a largest possible content of Na cations. This postulate is well-supported by the extraordinarily high viscosity of the pure montmorillonite of Mád—Koldu reaching a maximum of 216 cpoises and that of the natural Na bentonite of Salgótarján. The concentrated Na bentonite produced by *water extraction* from the latter one is also very low in Ca and Mg cations and the viscosity of its 6% dispersion amounts to 180 cpoises.

In a concentrated montmorillonite produced with *soda extraction* from Salgótarján bentonite, the total of exchangeable Ca and Mg cations was — as can be seen from Table III — higher than that of the montmorillonite concentrated by water extraction. Besides, the amount of Na cations rose from 50 to 73 mg and along with it the viscosity also increased from 180 to 286 cpoise.

Cation-exchange capacity and viscosity of concentrated montmorillonite dispersions

A study of the viscosity figures of concentrated montmorillonites of high-cation-exchange capacity, reveals striking variations. Taking the bentonite of Monostorapáti which in its normal state, with an optimum of soda and 80%

of montmorillonite content, is having a viscosity of 35 cpoises whereas that of the pure montmorillonite is no more than 7 cpoises, it is obvious that pure montmorillonite when produced by the Buzágh—Szepesi method [13] loose under the prescribed conditions the major part of its peptizing capacity. The bentonite of Monostorapáti can be peptized even *without addition of soda.* It is then treated a dilute solution of acid, washed until swelling and charged from a near-isoelectric point. The viscosity of its 6% dispersion amounting to 30 cpoises is completely destroyed already by a simple evaporation to dryness over water bath, as it loses its peptizing capacity entirely.

A similar phenomenon occurs in one of the most promising Hungarian types, the bentonite of Ódörögdpuszta. While the natural bentonite which has a montmorillonite content of 84%, shows a viscosity of 45 cpoises, that of the pure montmorillonite is no more than 33 cpoises. No doubt, the method of producing pure dry montmorillonite by evaporating it twice over water bath is causing even here a considerable decrease in the peptization capacity.

The sensibility to heat of the concentrated montmorillonite produced from Ódörögdpuszta bentonite has been studied more thoroughly and the data obtained are shown in Table VII.

Table VII

Variations in the viscosity of a 6% dispersion of concentrated montmorillonite of Ódörögdpuszta

Method of preparing the dispersion	Viscosity 600/M cpoise 25° C
Natural bentonite treated with an optimum of soda and the obtained sol evaporated to dryness over water bath	33
Heated to swelling with an optimum of soda, the sol condensed at room temperature	108
Cold treated with an optimum of soda, the sol condensed at room temperature	143

Similarly, a reduction of the peptizability must be assumed in the Nagytétény ben tonite since its viscosity of 52 cpoises in entirely out of proportion with its cation-exhange capicity.

It is obvious beyond any doubt that cation-exchange when carried out at room temperature, that is, by a cold process, and when the sol is merely condensed to 6 per cent dry content, high viscosities up to 143 cpoises can be reached.

Of all that has been said so far, very valuable informations may be derived in respect to the preparation of Hungarian bentonites.

Whenever the cation-exchange capacity of a bentonite is to be used commercially the only kinds to be employed are those characterized by a cation-exchange capacity ensuring under ordinary conditions the greatest possible exchange of the alkaline earth metals.

From a viewpoint of the conditions of industrial usage of bentonites, it is essential to know the heat sensitivity of the available montmorillonites since the viscosity of heat-treated bentonite dispersions (evaporated to dryness over water bath) shows, as we have seen, considerable variations. Among the qualities tested so far, the Mád—Koldu bentonite has proved to be most resistant and that of Monostorapáti the most sensitive to heat.

A deterioration of viscosity due to decrease of peptization may to an appreciable degree be influenced also by the "optimum" content of soda which cannot be precisely determined by measuring the viscosity [13].

Experiments to prepare montmorillonite under less severe conditions, further, to define the effect of soda content on the heat sensitivity of bentonite dispersions and finally, to investigate their rheological conditions, are in progress.

Rather interesting is the behaviour of the cream-yellow bentonite of Istenmezeje when wet-treated with warm soda. It adsorbs an amazing quantity of Na cations and shows an increased "T" value, although there is a reduced exchange of alkaline earth metals. In all probability, the soda becomes molecularly bounded and that may account for the minor viscosity of its dispersion in comparison to the viscosity of the concentrated montmorillonite of Istenmezeje.

Several kinds of bentonites, chiefly those of Mád—Vasbánya, Kismaros, Pákozd, the Yugoslav and Cyprian bentonites (Table I), the Eger 2 (Table II), the Dutch "C" type, the French "C" type (Table III) when treated according to the BUZÁGH—SZEPESI method [13], have proved to have a considerably smaller montmorillonite content than could be expected from their cation-exchange capacity and "T" value.

The mixed clay minerals present may play here an important role. Deposits of all the combinations of mixed clay minerals of the order 2 : 1 (namely, illite, montmorillonite, chlorite, vermiculite) are very common. WEAVER [17] found f. i., that more than 70% of some 6000 sedimentary rock samples collected from all over the United States representing all ages from the Cambrian to recent times, were containing mixed clay minerals.

Clay minerals originating from marine diagenesis are more frequently of the mixed type than pure deposits and since the irregularly mixed ones with 10—15 layers of montmorillonite to 1—5 layers of illite are the more common kind, very little has been reported so far on the regularly mixed minerals [18].

Clay minerals of this type, naturally, do not display the characteristics of pure clay minerals since owing to the still unknown separability of the mixed-layer clay minerals, the amount of the pure montmorillonite content cannot be determined by peptization, for instance, and even the analytical data are insufficient to draw the necessary conclusions.

REFERENCES

1. Endell, J.: Gestaltung und Struktur der Tonmineralien. Tonindustrie Z. 1939. p. 13·
2. Grim, R. E.: Clay Mineralogy (1953) p. 129.
3. Kelley, W. P. and H. Jenny, Soil Sci. 41. pp. 367—382 (1936).
4. Hofmann, U. and R. Klemen, Z. anorg. Chem., 262. pp. 95—99 (1950).
5. Edelman, C. H. and J. C. L. Favejee, Z. Kristallogr. 102, pp. 417—431 (1940).
6. Buzágh, A.: Stabilität und Thixotropie der Montmorillonit Suspensionen. Kolloid. Zeitschr. 139, H. 1/2, 1954.
7. Foster, M. D.: Geochemical Studies of Clay Minerals: II. Relation Between Ionic Substitution and Swelling in Montmorillonites. Amer. Mineralogist, pp. 994—1006, 1953.
8. Graham, R. P. and J. D. Sullivan: Critical Study of Methods of Determining Exchangeable Bases in Clays. (1938).
9. Deuel, H. and F. Hostettler: Experientia. 6. pp. 445—456. 1956.
10. Mehlich, A.: Rapid Estimation of Base-exchange Properties of Soils. Soil Sci. pp. 1—14, (1942).
    Mehlich, A.: Determination of Cation and Anion-exchange Properties of Soils. Soil Sci. pp. 429—445 (1948).
    Schachtschabel, P.: Untersuchungen über die Sorption der Tonmineralien und organischen Bodenkolloide und die Bestimmung des Anteils dieser Kolloide an der Sorption im Boden. Kolloid Z. Beihefte, Bd. 51, p. 199. 1940.
    Az adszorpciós komplexus és a reakció állapot meghatározása. (The adsorption complex and determination of the state of reaction.) Agrokémiai Kutató Intézet kiadása. Manuscript.
    Klimes-Szmik, A.: Zeitgemässes Verfahren zur Bestimmung des Adsorptionsvermögens der Böden und der Menge der austauschfähiger Kationen. Kongress für Bodenkunde. 1955. Budapest.
11. Hanna, W. J. and Fielding Reed, J.: A Comparison of Ammonium Acetate and Buffered $BaCl_2$ Methods for Determining Cation-exchange Properties of Limed Soils. Soil Sci. pp. 447—458 (1948).
12. Barna, J.: Rotationsviskosimeter nach B. Marschalkó zur Untersuchung zähflüssiger und strukturviskoser Substanzen. Acta Technica 1954. pp. 361—368.
13. Buzágh, A. and K. Szepesi: Über eine kolloidchemische Methode zur Bestimmung des Montmorillonits in Bentoniten. Acta Chimica 1955. pp. 287—298.
14. Tokody, L.: Der Bentonit von Komló. Acta Geologica 1955. pp. 185—205.
15. Page, J. B.: Differential Thermal Analysis of Montmorillonite. Soil Sci. pp. 273—283 (1943).
16. Earley, J. W., J. H. Milne and W. J. McVeagh, American Mineralogist, 1953. 9/10, 782.
17. Weaver, C. E.: The Distribution and Identification of Mixed-layer Clays in Sedimentary Rocks. American Mineralogist, 1956. 3/4, 202.
18. Earley, J. W., G. W. Brindley, W. J. McVeagh and R. C. Van den Heuvel, American Mineralogist, 1956. 3/4, pp. 258—268.

SUMMARY

The exchangeable cation predominating in Hungarian bentonites is the Ca cation. There are, however, several other commercially important deposits with Mg and one with Na cations prevailing.

In a cation-exchange reaction effected under rather severe conditions, with single warm soda treatment, for instance, there is only a partial exchange of the alkaline earth metal cations and even the exchange capacity of the Ca and Mg cations varies in the different types of bentonite.

High viscosity values are found in bentonites with a possibly high exchange of the alkaline earth metal cations accompanied by an accumulation of the Na cations, wherever an exchange is taking place. A good example hereof is given in the Mád—Koldu bentonite.

It has been found that the apparent viscosity of concentrated montmorillonites produced from Hungarian bentonites, when tested under identical conditions, show great variations chiefly because in the course of the production process their peptizability is essentially handicapped by the accumulated effect of even a relatively mild heat treatment (evaporation to dryness over water bath) and of the "optimum soda content".

When bentonites are treated for the commercial utilization of their cation-exchange capacity, the possibility and the technology of an exchange must always be borne in mind, since with the montmorillonites of some Hungarian bentonites there is a permanent danger of loosing in consequence of even a mild heat treatment a significant part of the valuable colloidal properties of their water dispersions.

The extraordinary diversity in quantity and rate of the exchangeable cations present in bentonites, the process of cation-exchange resulting from an addition of soda and varying according to the kind of the bentonite available, and finally, the differences in the peptizability of pure, i. e. concentrated, montmorillonites being contingent on the joint effect of the soda content and of heating the water dispersions, — are as many evidences of the "individual character" of bentonites, or montmorillonites, respectively.

DAS KATION-AUSTAUSCHVERMÖGEN UNGARISCHER BENTONITE UND DER AUSTAUSCHVORGANG BEI SODAZUGABE

J. BARNA

ZUSAMMENFASSUNG

Ungarische Bentonite enthalten im allgemeinen an austauschfähigen Kationen in grösster Menge das Kalziumkation, es gibt jedoch auch solche einheimische Bentonite von industrieller Bedeutung, die das Magnesiumkation in überwiegender Menge enthalten; der neuerdings bei Salgótarján gefundene Bentonit enthält sogar überwiegend Natriumkation.

Der Kationaustausch unter dem Einfluss von Soda geht bei den einzelnen Bentoniten verschieden vor sich, und eine hohe Viskosität zeigt sich dort, wo Ca bzw. Mg in grösserem Masse durch Na ersetzt werden.

Die bei optimaler Sodazugabe hergestellten Suspensionen konzentrierter Montmorillonite hohen Kationaustauschvermögens ergeben sehr abweichende Viskositäten, indem einzelne Montmorillonite infolge ihrer Wärmeempfindlichkeit an Peptisationsfähigkeit mehr oder weniger einbüssen.

LE POUVOIR D'ÉCHANGE DE CATIONS DES BENTONITES HONGROIS ET LE PROCESSUS D'ÉCHANGE AVEC DOSAGE DE SOUDE

J. BARNA

RÉSUMÉ

Comme cation échangeable, les bentonites hongrois contiennent en plus grande quantité le cation Ca^{++}, mais il y a aussi des bentonites hongrois intéressant l'industrie, qui contiennent le cation Mg^{++} en quantité prépondérante. Le bentonite récemment trouvé aux environs de Salgótarján contient surtout le cation Na^{+}.

L'échange de cations sous l'effet de la soude se passe différemment chez les diverses sortes de bentonites. Une haute viscosité apparaît chaque fois que le Na se substitue au Ca ou Mg dans une plus large mesure.

Les dispersions de montmorillonites concentrés à haut pouvoir d'échange de cations, produites avec dosage optimum de soude, donnent des viscosités très différentes, les divers montmorillonites perdant plus ou moins leur aptitude à la peptisation à cause de leur sensibilité à la chaleur.

КАТИОНООБМЕННОСТЬ ОТЕЧЕСТВЕННЫХ СОРТОВ БЕНТОНИТОВ И ПРОЦЕСС КАТИОНООБМЕНА ПОД ВОЗДЕЙСТВИЕМ СОДЫ

Я. БАРНА

РЕЗЮМЕ

Отечественные сорта бентонитов в качестве обменного катиона вообще в наибольших количествах содержат катионы кальция, у нас имеются также бентониты, обладающие свойствами промышленного значения, которые содержат в преобладающем большинстве магниевые катионы, а бентонит, найденный в последнее время в районе Шалготарьяна, — натриевые катионы.

Катионообмен, происходящий при воздействии соды, в случае различных бентонитов протекает различным образом и высокая вязкость имеет место там, где CaMg обменивается в больших масштабах с натрием.

Дисперсии монтмориллонитов, обладающих высокой катионообменностью и полученные при оптимальной обработке содой, имеют сильно отличные значения вязкости, так как отдельные монтмориллониты вследствие их термочувствительности теряют в большей или меньшей мере пептизационные свойства.

Стабильность водных бентонитных дисперсий имеет большое практическое значение.

CORRELATION BETWEEN THE CRYSTAL STRUCTURE OF DOLOMITE AND ITS APTNESS TO MAGNESIUM RECOVERY

T. G. GEDEON
CAND. OF MINERAL & GEOLOG. SC.
RESEARCH INSTITUTE OF METALS, BUDAPEST

[Manuscript received 5th July, 1956]

There are two methods used the world over for producing magnesium. The different countries put up their plants with a view to the nature of the given raw material, and so we may distinguish electrolytic and thermic processes. In Hungary magnesium oxyde is present only in the form of dolomite and therefore magnesium industry had to be built up on this raw material.

Silicothermic magnesium metallurgy represents a highly developed state of metallurgical industry and is a characteristic example of vacuum metallurgy. Caracteristic of this branch of industry is that from the material processed no gaseous byproducts escape, only metal-vapour precipitates on the colder (cooled) part of the vacuum space.

The first step in establishing Hungarian magnesium metallurgy was the detailed geologic mapping of dolomite occurrences and the chemical and physical examination of each occurring material. We examined the dolomites of Gánt, Iszkaszentgyörgy, Nyirád, Pilisvörösvár (i. e. Trans-Danubian) then specimens found in the Bükk Mountains at Hámor. According to their chemical constitution, they contain small amounts of alumina (0,38%), silica (0,72%), iron oxyde (0,86%). The composition of our dolomites differs little from the theoretical mol-rate

$$CaCO_3 : MgCO_3 = 1 : 1$$

The dolomite as a double salt built in a crystal behaves in all physical respects otherwise than its constituent minerals separately (magnesite and calcite). This can be well observed when investigating into the processes of thermal decomposition. This physical behavior changes, however, if we also detect an external change on the dolomite due to geological circumstances, although this may not be proved in its chemical composition. During our investigation we were able to fix such a well-observable and characteristic change which facilitates evaluation of the material of the individual dolomite occurrences for magnesium metallurgy.

Calcite and magnesite crystallize in the space group D_{3d}^{6}—$R\bar{3}c$ whereas dolomite as a double salt may be classed into the space group of C_{3i}^{2}—$R\bar{3}$ — reduced in its symmetry elements. Bond distances of the single ions are C—O

1,31 Å, Ca—O 2,34 Å in calcite and C—O 1,31 Å, Mg—O 2,06 Å in magnesite. These bond distances become evident if we consider the radii of Ca ang Mg ions (Ca^{++} 1,06 Å, Mg^{++} 0,78 Å). In case of dolomite as a double salt the lattice link is not as close as that of calcite. Development of the MgO group comes into being during heating, therefore sooner than that of CaO with its greater bond distance.

Physical examination of Hungarian dolomites was extended to DTA tests, also by the Habicht thermogram apparatus, and finally by determination of CO_2 loss. Besides there were made X-ray patterns by the Debye—Scherrer

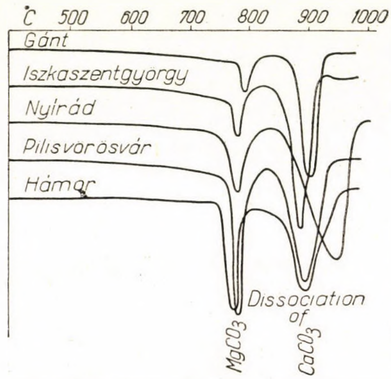


Fig. 1. DTA-curves of Hungarian dolomites. Prepared by Hungarian Geological Survey

method. Then followed the experimental recovery of metallic magnesium in a laboratory vacuum furnace to receive practical data on the amount of recovery.

The peaks of the received DTA curves (Fig. 1) were observed at the following temperatures :

	$MgCO_3$	$CaCO_3$
Gánt	790 °C	920 °C
Iszkaszentgyörgy.......	770 ,,	890 ,,
Nyirád	780 ,,	950 ,,
Pilisvörösvár	800 ,,	910 ,,
Hámor	790 ,,	890 ,,

The following peak values were found by means of the Habicht apparatus, the principle of which is that the electro-motive force induced by temperature rises is periodically mechanically compensated :

	$MgCO_3$	$CaCO_3$
Gánt	730 °C	885 °C
Iszkaszentgyörgy.......	722 ,,	898 ,,
Nyirád	725 ,,	908 ,,
Pilisvörösvár	700 ,,	885 ,,
Hámor	690 ,,	850 ,,
Kassa magnesite	610 ,,	750 ,,

The thermal decomposition of pure magnesite $MgCO_3$ 95% will take place at a temperature of 100°C lower than that of dolomite. The fall of the curves of Habicht's thermogram (Fig. 2.) in case of $MgCO_3$ decomposition is so vigorous that the peak, indicating the consumption of heat, becomes very high. This is

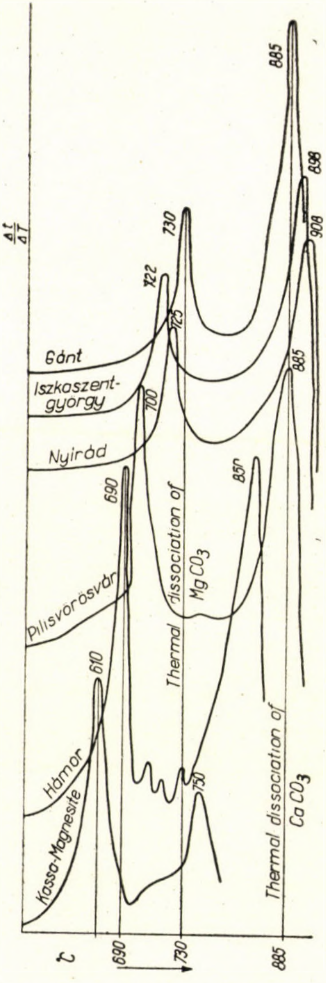


Fig. 2. Thermal dissociation of Hungarian dolomites
(Registered by Habicht-app.)

striking in case of the dolomites of Pilisvörösvár and Hámor. On the other hand the feature of the dolomites of Gánt, Iszkaszentgyörgy and Nyirád is the height of their decomposition peak of $CaCO_3$. Similar observations were made with DTA—thermograms (Fig. 1).

The difference between the decomposition temperatures is due to the differences of the structural set up of the various apparatuses and to the quantity of material used for the test as well as to the thickness of the pyrometer wires (inertness).

A definite difference was observed in the dolomite of Hámor where the peak of decomposition appeared at 530°C. We shall return to this later.

Investigations on thermal decomposition of dolomite were also made in a laboratory tube furnace in search for the point of decomposition of $MgCO_3$. The analysis was made in steps of 20°C by measuring the loss of CO_2 and it

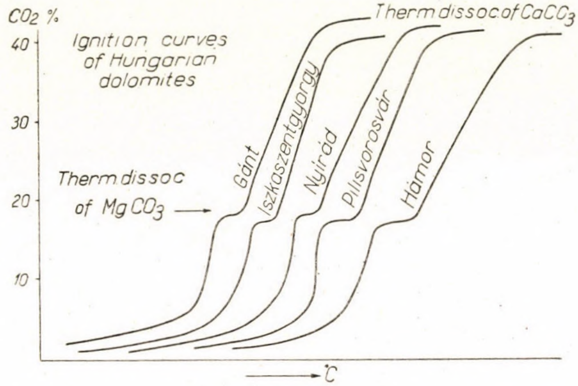


Fig. 3. Ignition curves of Hungarian dolomites

was found that the time of decomposition of $MgCO_3$, the section of standstill-respectively, seen on the thermogram, is wider in the dolomites of Pilisvörösvár and Hámor than in the case of the other three species (Fig. 3).

Debye—Scherrer X-ray patterns in case of the dolomites of Pilisvörösvár and Hámor show three intense diffracting lines typical of $MgCO_3$ appearing in identical breadth of magnesite (Fig. 4). G. BIDLO demonstrated nesquehonite $MgCO_3 \cdot 3H_2O$ and gypsum halfhydrate $CaSO_4 \cdot 1/2H_2O$ in the dolomite of Pilisvörösvár on the base of X-ray patterns.

Of the examined dolomites those of Gánt, Iszkaszentgyörgy and Nyirád originate from the Triassic main dolomite cut up by simple faults. The dolomite area of Pilisvörösvár is penetrated by hot springs which made the dolomite crumbling. The constitution of crumbling dolomite does not differ in anything from the solid kind which falls to pieces of 2—3 cm length when quarried. Its age is identical with the former. The presence of nesquehonite and gypsum halfhydrate in dolomite make the hot spring activity evident. Gypsum halfhydrate is stable only above 50°C up to 120°C. Its presence proves the hot spring activity on this particular spot.

The dolomite of Hámor is also of Triassic age originating from a strongly faulted — disturbed — area. Its color is dark gray discoloured by coal and a

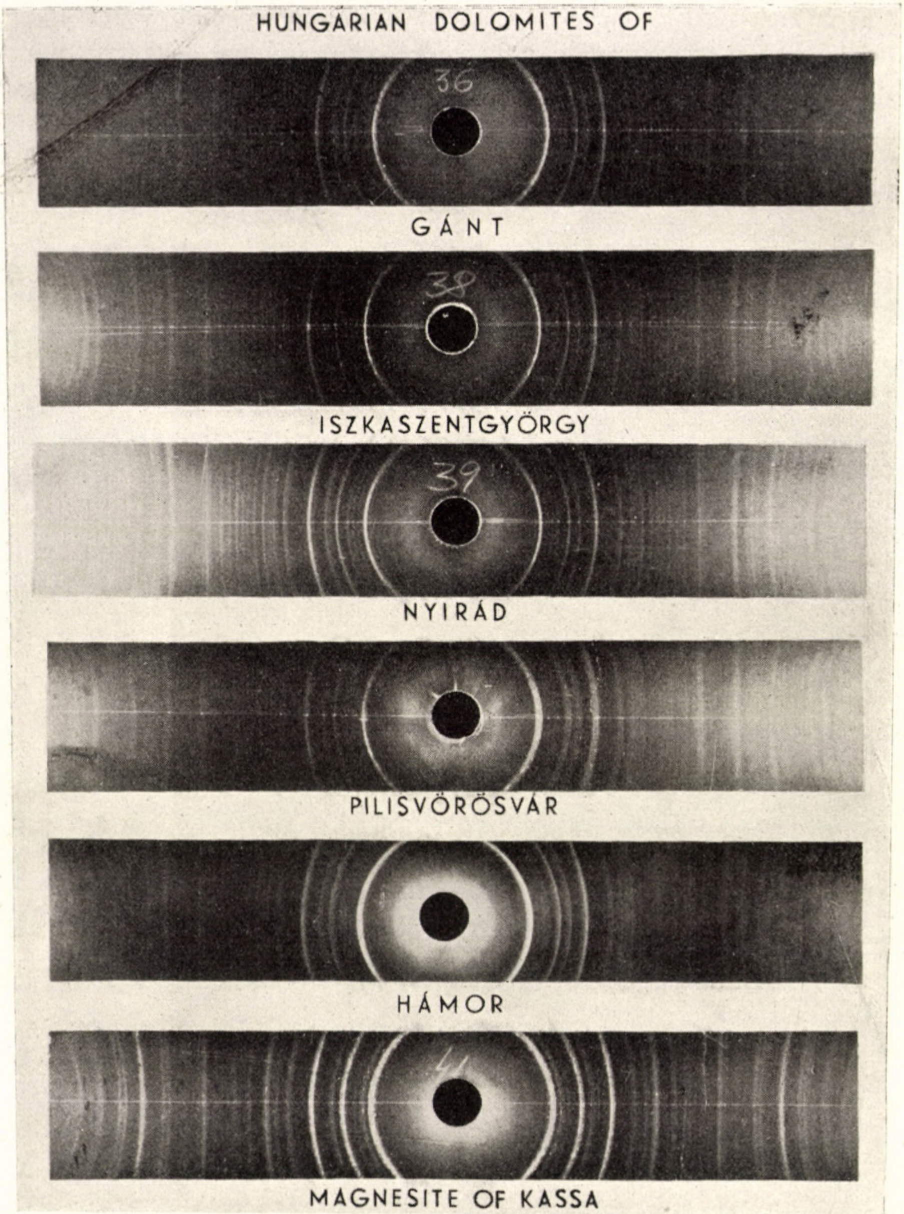


Fig. 4. X-ray diffraction patterns

small amount of pyrite. Heating the dolomite above 300°C, this coal particles will burn with a typical sparkling. The detrital gray dolomite which crumbled during faulting is breccialike cemented by precipitated high-lime dolomite (Fig. 5).

Experiments on recovery were made in a laboratory vacuum furnace. It was heated by four silite-rods, a refractory steel retort connected with a condenser being placed in the heated space. The capacity of it was 100 to 120 gr

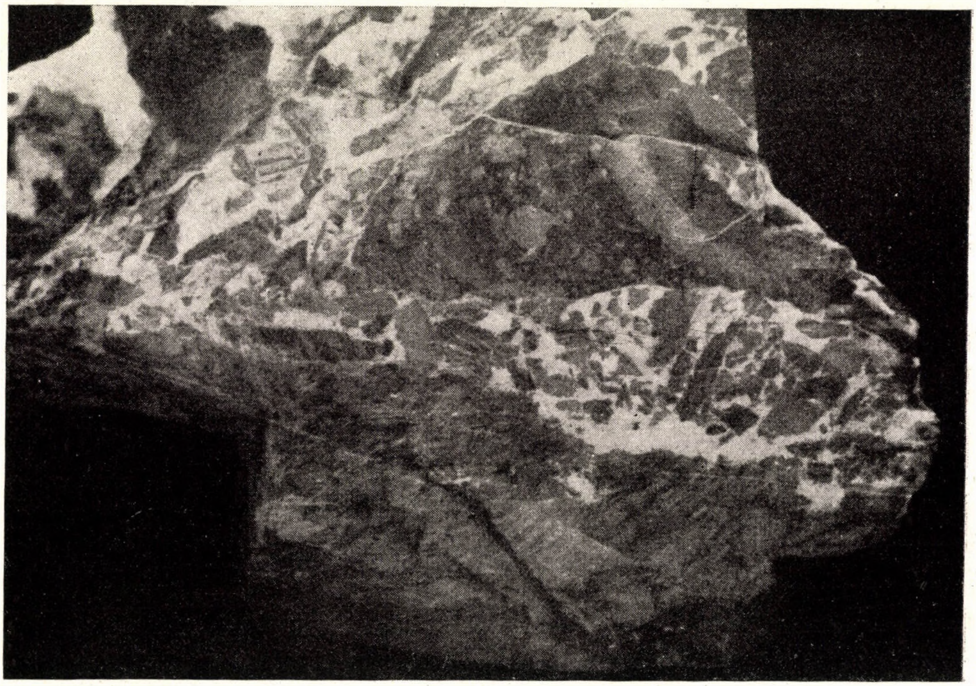


Fig. 5. Brecciated vein in dolomite of Hámor (Hungary)

matter worked to tablets. The vacuum in the space of the furnace was kept below 1 mm. The composition of mixture used for the recovery of Mg was always the same.

100 gr pulverised dolomite glowed at 950°C
20 gr pulverised ferrosilicon (80% Si)
5 gr calciumfluoride (CaF_2)

The mixture was worked to tablets of 12 mm diameter and 3 mm height by a hand press. There were always exactly 100 gr put into the retort. The circumstances of recovery were as follows :

Dolomite:		Temperature °C	Recovery of Mg %
Gánt	1 h 30 min	1180	75,23
Iszkaszentgyörgy	1 h 30 min	1170	71,69
Nyirád	1 h 30 min	1170	66,81
Pilisvörösvár	1 h 20 min	1210	90,41
Hámor	1 h 40 min	1180	84,86

The results of recovery show that under identical circumstances we achieved a greater quantity of metallic Mg from the Pilisvörösvár and Hámor dolomite than from the other compact rocks.

We examined also the dross which formed at the recovery. The analysis was in accordance with the recovery of Mg. It is ascertained from the Debye—Scherrer X-ray diffraction patterns that the dross contains mainly dicalciumsilicate and tricalciumsilicate. The pattern of the dross sample of Iszkaszentgyörgy indicates the presence of equal number of lines, while in that of Pilisvörösvár and Hámor dicalciumsilicate is significant.

Dross of dolomite:	Number of X-ray lines:
Iszkaszentgyörgy	Alfa and gamma-$Ca_2SiO_4 \simeq Ca_3SiO_5$
Pilisvörösvár	gamma-$Ca_2SiO_4 \gg Ca_3SiO_5$
Hámor	gamma-$Ca_2SiO_4 \gg Ca_3SiO_5$

It was concluded from tests and observations that, identical technical circumstances supposed for the production of magnesium, such kind of dolomite is to be used whose thermogram shows a higher peak of $MgCO_3$ than that of the $CaCO_3$ or is of similar height. The X-ray pattern of the formed dross should have numerically more gamma-dicalciumsilicate diffraction lines than tricalciumsilicate lines. Examining the dolomite occurrence, geologic circumstances, traces of hot spring activities and significant tectonic movements should be followed with attention. The last two factors may cause such alteration in the crystal structure of the dolomite, which would influence the double-salt type of dolomite, by freeing Mg ions in its crystal lattice to approach the magnesite structure. In these dolomites translation within the molecule must be supposed.

Bradley, Burst and Graf investigated the change of structure as the function of its grinding fineness in dolomite and found that after a certain duration of grinding (25 hours) the thermal differential curves gave already three thermal decomposition peaks: the magnesite at 580°C, the $MgCO_3$ bound in dolomite at 740°C, the $CaCO_3$ at 950°C. After grinding for 400 hours again only two thermal decomposition peaks were obtained, namely of magnesite at 570° C and of calcite at 940°C. The grinding process is seen on the following table:

	$MgCO_3$	$MgCO_3$ bound in dolomite	$CaCO_3$
3 hours grinding.........		740 °C	910 °C
25 ,, ,, ...	580 °C	740 ,,	950 ,,
50 ,, ,, ...	580 ,,	720 ,,	950 ,,
125 ,, ,, ...	580 ,,	720 ,,	950 ,,
400 ,, ,, ...	570 ,,		940 ,,

Having made the DTA of the Hámor dolomite we observed that the peak is at 790°C. Although this value does not differ from that of dolomites of lower recovery the geologic circumstances already contributed to the intermolecular lattice rearrangement as shown by the vigorous of thermal decomposition of the same type of curve as that of the Pilisvörösvár dolomite.

The reduction of this kind of calcined dolomite is performed more advantageously under identical circumstances than that from dolomite of normal pure double salt structure.

Translation in the molecule can be enhanced if it is calcined in current of water vapour. MacIntire and Stansel demonstrated by experiments the catalysing effect of water vapour on the lattice translation as dolomite decomposes already at 550°C in a steam space to $CaCO_3 + MgO + CO_2$. However, this process has been known long since it was explained by diminishing the partial pressure of CO_2 in the gas-space above the dolomite.

The performed analyses, the experimental reductions, geologic observations, also references to literature, are marking the way of the most favourable and profitable preliminary preparation of ore for the reduction of magnesium. Bischoff established by experiments that to the complete calcination of dolomite in air current twice as much quantity of heat is needed as when the process is made in steam current.

Required heat by air current	$\Delta H = 44{,}238$ cal/gmol
,, ,, ,, aqueous current	$\Delta H = 26{,}670$,, ,,

Thus, if we perform the calcination of dolomite in vapour current with the exclusion of air, the advantageous intermolecular rearrangement of lattice will take place, necessary for the reduction, which at the same time means saving of heat energy.

These experiments constitute only a small part of the work we have done to put into effect magnesium metallurgy in this country. Careful selection of raw materials and their proper dressing are the main conditions for successful metal production.

REFERENCES

G. L. CLARK and R. S. SPRAGUE: Anal. Chemistry 24. 688. 1952.
D. L. GRAF: The Amer. Mineralog. 37. 1. 1952.
H. T. S. BRITTON, S. J. GREGG and G. W. WINSOR: Transac. of the Faraday Soc. 48. I part: 63. II part: 70. 1951.
R. A. ROWLAND and G. W. BECK: Expl. and Prod. Research Div. Shell Oil Co. Publ. No 13. 76. 1952.
W. F. BRADLEY, J. F. BURST and D. L. GRAF: The Amer. Mineralog. 38. 207. 1953.
G. T. FAUST: Economic Geology 39. 142. 1944.
A. RICHTER and P. VALLET: Revue de Métallurgie 50. 597. 1953.
G. F. HÜTTIG and H. HEINZ: Ztschr. f. anorg. Chem. 255. 223. 1948.
FR. BISCHOFF: Ztschr. f. anorg. Chem. 262. 288. 1950.
KULP, KENT and KERR: The Amer. Mineralog. 36. 643. 1951.
W. H. MACINTIRE and T. B. STANSEL: Ind. and Eng. Chem. 45. 1548. 1953.
R. MALDAU and R. H. S. ROBERTSON: Nature 172. 998. 1953.
E. THILO and H. FUNK: Ztschr. f. anorg. u. allgem. Chem 273. 26. 1953.
SZTRELEC, TAIC, GULJANICKIJ: Magnesium Metallurgy 1951 (Hungarian).
M. FÖLDVÁRI—VOGL and V. KOBLENCZ: Acta Geologica Hungarica 3. 15. 1955.
DR. E. NEMECZ (Veszprém): Silicate Minerals and their Geology I. 1953 (Hungarian).

SUMMARY

Hungarian magnesium metallurgy can be based only on dolomite, because there are immense reserves available of this raw material.

On the basis of chemical analysis of Hungarian dolomites can not be estimated their fitness for the reduction process. From some of our dolomites magnesium can be very favourably produced by the silicothermic process, from others this is impracticable.

Investigation of the physical structure of dolomite was carried out by the Debye—Scherrer X-ray method which gave no definitely appreciable differences between the several grades.

Thermic decomposition curves gave characteristic divergences between the individual kinds of dolomite on the basis of DTA, as well as investigation by the Habicht apparatus.

Conclusion drawn on thermal decomposition of dolomite, speeding up decomposition by adding salt or by heating in a stream of water vapour. Influence of the fineness and of the duration of grinding on reducibility.

DER ZUSAMMENHANG ZWISCHEN DER KRISTALLSTRUKTUR UND DER REDUZIERBARKEIT DES DOLOMITS

DR. Ing. T. G. GEDEON

Kand. der mineral. und geol. Wissenschaften

ZUSAMMENFASSUNG

Die Grundlage einer ungarischen Magnesiumverhüttung kann nur der Dolomit sein, da eine fast unbegrenzte Menge dieses Rohstoffes im Lande zur Verfügung steht.

Auf Grund der chemischen Analyse der ungarischen Dolomite lässt es sich nicht bestimmen, ob sich der betreffende Dolomit zur Verhüttung eignet. Aus einzelnen ungarischen Dolomiten kann das Magnesium nach dem siliko-thermischen Verfahren günstig gewonnen werden, aus anderen wieder nicht.

Die Untersuchung der physikalischen Struktur des Dolomits erfolgte nach dem Debye—Scherrer-Verfahren, das aber keine gut auswertbaren Unterschiede zwischen den einzelnen Sorten aufzeigte.

Durch Bestimmung der sich beim Zerfall in der Hitze ermittelten Kurven konnten dagegen bereits charakteristische Unterschiede zwischen den einzelnen Dolomitsorten festgestellt werden, u. zw. sowohl mit der Differenzialthermoanalyse als auch mit den Untersuchungen mit dem Habicht-Apparat.

Die Habicht-Kurven lassen Folgerungen auf folgende Eigenschaften des Dolomits zu: Einfluss fremder Stoffe auf den Zerfall des Dolomits bei Hitze, die Beschleunigung dieses Zerfalls durch Zugabe von Salzen oder durch Glühen im Wasserdampfstrom. Einfluss der Mahlfeinheit bzw. der Mahldauer auf die Reduzierbarkeit.

LES RELATIONS ENTRE LA STRUCTURE CRISTALLINE DES DOLOMITES ET LEUR REDUCTIBILITÉ

T. G. GEDEON
Candidat des sciences mineral. & geolog.

L'analyse chimique des dolomites hongroises ne permet pas d'évaluer si la dolomite convient ou non au traitement métallurgique du magnésium. Certaines de nos dolomites permettent d'obtenir avantageusement du magnésium par la méthode silico-thermique, d'autres non.

La métallurgie du magnésium en Hongrie doit être basée exclusivement sur les dolomites, matière première dont on possède des quantités presque illimitées.

L'examen physique de la structure des dolomites a été effectué par rayons X suivant la méthode de Debye—Scherrer, laquelle n'a pas mis en évidence des différences bien nettes entre les différentes sortes de dolomites examinées.

Les courbes de décomposition thermique montraient déjà des différences caractéristiques entre les différentes sortes de dolomites, aussi bien pour les mesures des différences de température (DTA), que lors des relevés avec l'appareil de Habicht.

Des diagrammes de Habicht, on peut déduire certaines conclusions, a savoir influence des matières étrangères sur la décomposition thermique de la dolomite, accélération de la décomposition thermique par adjonction de sel ou chauffage dans un courant de vapeur d'eau, influence de la finesse de mouture (de la durée du mouture) sur la réductibilité.

ЗАВИСИМОСТЬ МЕЖДУ КРИСТАЛЛИЧЕСКОЙ СТРУКТУРОЙ И ФРИШУЕМОСТЬЮ ДОЛОМИТА

Т. ГЕДЕОН
Канд. минер. и геол. наук

РЕЗЮМЕ

На основе химического анализа венгерских доломитов нельзя установить пригодность данного вида доломита для металлургии магния. Отдельные сорта доломита позволяют получать магний силикотермическим методом удовлетворительным образом, а другие непригодны для этой цели.

Основу металлургии магния в Венгрии может представлять собою лишь доломит, так как это сырье имеется в неограниченных количествах.

Физическое исследование структуры доломита выполнено при помощи рентгеновского анализа по Дебюе и Шерреру и при этом не были получены хорошо оценимые отклонения между отдельными сортами.

Снятием кривых теплового разложения были получены уже характерные отклонения между отдельными сортами доломита, как на основе измерения разности температур (ДТА), так и при съемках с помощью прибора Хабихта.

Выводы, которые можно сделать на основе кривых Хабихта : влияние посторонних веществ на тепловое разложение доломита, интенсификация теплового разложения добавлением соли или прокаливанием в токе водяного пара. Влияние на фришуемость тонины помола и, соответственно, времени помола.

CONTRIBUTION TO THE KINEMATICS OF THE HYDROCYCLONE

Prof. G. TARJÁN

CORRESPONDING MEMBER OF THE HUNGARIAN ACADEMY OF SCIENCES

INSTITUTE OF MINERAL DRESSING, TECHNICAL UNIVERSITY, SOPRON

[Manuscript received 21st December, 1956]

The fluid flow in the hydrocyclone is very complicated ; its exact mathematical formulation is hopeless. KELSALL [1] observed stroboscopically tangential v_t, axial v_a and radial v_r velocity components in the conical part of a hydrocyclone ; the results of his observations are presented in Fig. 1 and 2. (The half apex-angle of the cyclone was $\alpha = 10°$, its diameter $2r_1 = 3'' = 7{,}62$ cm, its vortex finder $2r_0 = 1/2'' = 1{,}27$ cm, its apex $(2r_a)$ was in case of Fig. 1 $1/8'' = 0{,}32$ cm, in case of Fig 2 $1/2'' = 1{,}27$ cm ; at 40 lb/sq. in. = 2,81 at internal pressure in the case of Fig 1 0,18 l/min underflow and 49,22 l/min overflow (a total of 49,40 l/min of slurry) in the case of Fig. 2 33,10 l/min under flow and 26,72 l/min overflow (a total of 59,82 l/min = 3,58 cb. m/hour of slurry) were obtained.) In Fig. 1 and 2 d = const curves are also shown. These indicate orbits of particles of equal size revolving in equilibrium in the cyclone. Grain size d is calculable from pertinent values of v_t and v_r at any place of the cyclone, centrifugal force

$$C = \frac{d^3 \pi (\delta - \gamma) v_t}{6 g r}$$

and the Stokes resistance of the medium $S = 3 \pi \eta \, d v_r$ equated,

$$d = \sqrt{\frac{18 \eta g}{\delta - \gamma}} \; \frac{\sqrt{r v_r}}{v_t} .$$

(η is viscosity of the medium, γ its specific gravity, δ the specific gravity of the particle, g the gravity acceleration, r the distance from the cyclone axis of the particle revolving in equilibrium.)

From Fig. 1 and 2 it is evident that lines v_t = const are parallel to the cyclone axis. Near the air core formed in the axis line v_t varies linearly with the radius ; $v_t(r-a)^{-1} = C$; it reaches its maximum at $r = (0{,}7-0{,}9)\, r_0$, thereupon with the increase of the radius it decreases according to the function $v_t r^n = C$, where $0{,}5 < n < 1$. In Fig 1 $n = 0{,}84$, in Fig 2 $n = 0{,}77$. In the case of $2r_a = 1/2''$, when the total amount of feed of 52,15 l/min was discharged at the apex $n = 0{,}75$ was valid. DRIESSEN [2] found by investigations on a gas cyclone $n = 0{,}64$; TRAWINSKI [3] found $n = 0{,}5$—$0{,}7$. In case of "free vortex" $n = 1$. It appears probable that at high turbulence the value of n approaches 0,5, at low turbulence it approaches 1. The degree of turbulence is probably determined by proportions of the cyclone, α, r_1, r_0, r_a and the relative size of the cylindrical section, the depth of immersion of the vortex finder etc., and the velocity of entry (pressure) of the feed. In harmony with KELSALL's experimental data $n = 0{,}8$ appears to be a practically acceptable mean value.

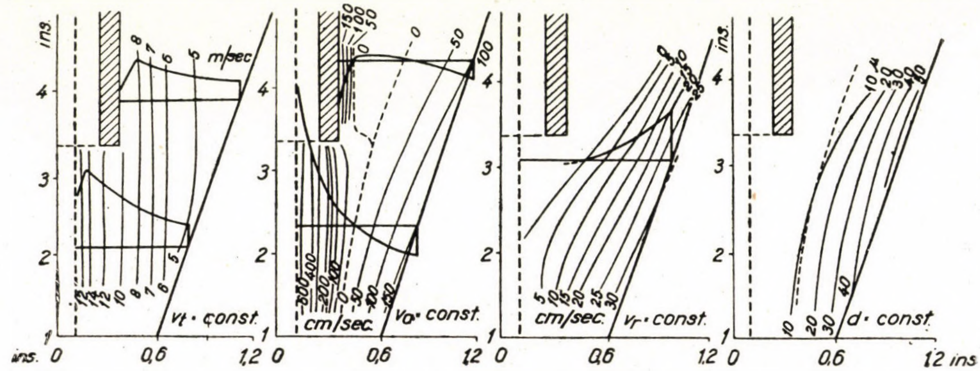


Fig. 1

Lines v_r = constant include in the conical section of the cyclone with the axis of the cyclone an angle greater than the half apex-angle α. Radial velocity component v_r itself diminishes according to Kelsall's investigations approximately linearly with the decrease of the radius, about according to the function

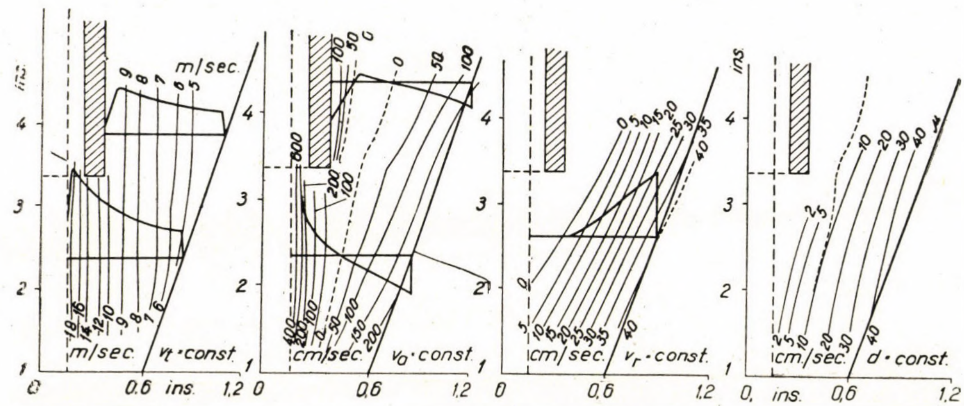


Fig. 2

$v_r(r-a)^{-1} = C$. In the environs of the end of the vortex finder negative v_r values appear too ; here the medium is flowing from the axis of the cyclone towards its shell. If axial flow did not occur and the fluid flow were free from turbulence in the cyclone, the radial velocity in its conical section would be calculable by the formula $v_r = \dfrac{Q}{2\pi r\,(h_1 + h)}$, where Q is the rate of feed $\left(Q = \dfrac{e^2\pi}{4} v_{t1}\text{, if } e \text{ is the diameter of the orifice of entry}\right)$, h_1 is the length of the cylindrical section and $h = (r_1 - r)\operatorname{cotg}\alpha$ the height of the conical section at radius r. (See middle sketch in Fig. 4). Thus "theoretically" the function $v_r\, r[h_1 + (r_1 - r)\operatorname{cotg}\alpha] = C (=$ parabola) is valid, and v_r cannot be negative or zero. v_r has its minimum at $r = \dfrac{h_1 + r_1 \operatorname{cotg}\alpha}{2\operatorname{cotg}\alpha}$, (in case of $h_1 > 0$ at $r > \dfrac{r_1}{2}$;

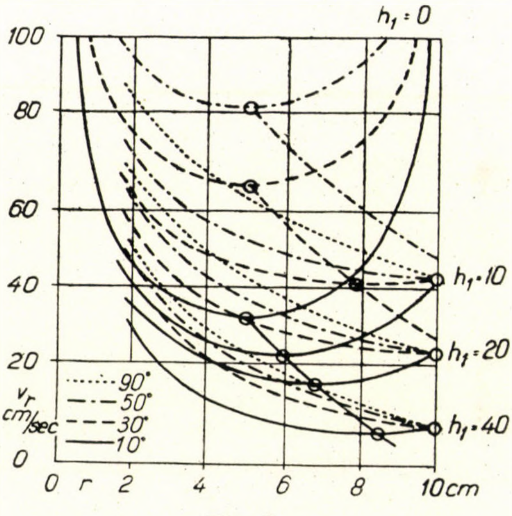


Fig. 3

in case of $h_1 > r_1 \operatorname{cotg}\alpha$ at $r > r_1$). Fig. 3 gives the variation of v_r as a function of r at different apex half-angles and h_1 values for $r_1 = 10$ cm and $Q = 25$ m³/hr.

Lines $v_a =$ const (Fig. 1 and 2) form in the conical section of the cyclone a bunch of rays radiating from a point near the apex. Along the conical shell of the cyclone, as well as along the outer wall of the vortex finder, the medium is flowing downward, near the axis, beside the central core of air it is flowing upward. $v_a =$ const lines of the axial slurry flow, along the axis and beside the vortex finder, are nearly parallel to the axis. $v_a =$ const lines beside the conical shell include with the axis an angle greater than half apex-angle α. The relation

$v_{a1} \cong v_{r1}$ cotg α is also valid approximately. Line $v_a = 0$, which separates downward and upward slurry currents in the cyclone, includes with the axis an angle somewhat smaller than the half apex-angle. The vortex finder generally reaches as far down as the junction of the cylindrical and of the conical sections of the cyclone. At this height line $v_a = 0$ bifurcates and includes a wider zone in which $v_a \cong 0$. In this zone and along the line $v_a = 0$ of the conical section, grains revolving in equilibrium remain for a longer time in the cyclone. The farther off this line falls the orbit of particles revolving in equilibrium, the more rapidly they are discharged from the cyclone ; grains positioned near the axis upward through the vortex finder, those beside the wall of the cyclone down-

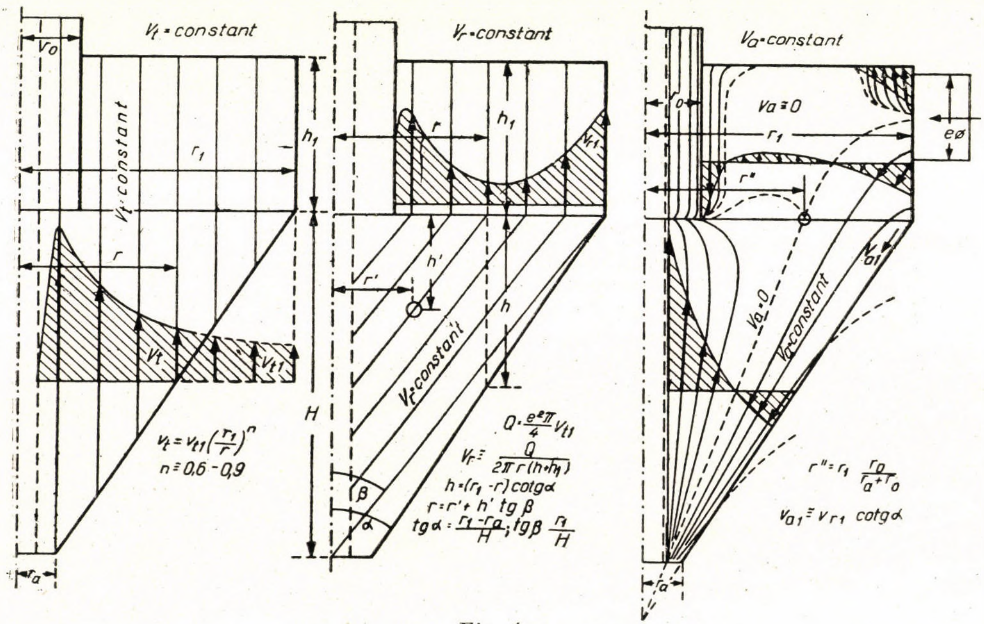


Fig. 4

ward through the apex. The grain size of the particles revolving on line $v_a = 0$ is thus at the same the limit grain size of classification executed in the cyclone.

In the diagram of $d =$ const, lines $v_a = 0$ are also drawn in Fig. 1 and 2 ; as evident, in both cases classification was effected at grain size of 10 μ, grains above 10 μ got into the underflow, while the undersize was discharged in the overflow.

The grain size of particles revolving in different places of the cyclone, or the limit grain size of classification executed by the cyclone cannot be precisely determined because of the complicated process of flow of the medium, but the approximate grain sizes can be determined by choosing conditions that more or less approach the actual flow of the medium. The values of v_t, v_r and v_a necessary for the calculation can be chosen, for instance, according to *Fig.* 4 : $v_t r^n = v_{t1} r_1^n$; $n = 0{,}8$, $Q = \frac{e^2 \pi}{4} v_{t1}$; $v_r = \frac{Q}{2 \pi r (h_1 + h)}$; $h = (r_1 - r) \operatorname{cotg} \alpha$. Lines v_r=const are parallel to the axis of the cyclone in the cylindrical section of the latter, and in the conical section of it they include with the axis the angle of $\beta = \operatorname{arc\,tg} \frac{r_1}{H}$; line $v_a = 0$ connects the apex of the cyclone with the point at the junction of the cylindrical and the conical sections, at the distance of $r'' = r_1 \frac{r_0}{r_a + r_0}$ from the axis. At locus r', h' of the conical section of the cyclone $v_r' = v_r$ where $r = r' + h' \operatorname{tg} \beta$.

Substituting the corresponding values into the formula

$$d = \sqrt{\frac{18 \eta g}{\delta - \gamma}} \frac{\sqrt{r v_r}}{v_t}$$

in the conical section of the cyclone the formula

$$d = \frac{80 e^2}{\sqrt{(\delta - \gamma) Q}} \left(\frac{r'}{r_1}\right)^{0,8} \sqrt{\frac{r' \operatorname{tg} \alpha}{(r' + h' \operatorname{tg} \beta)(h_1 \operatorname{tg} \alpha + r_1 - r' - h' \operatorname{tg} \beta)}}$$

or

$$d = \frac{80 e^2}{\sqrt{(\delta - \gamma) Q}} \left(\frac{r'}{r_1}\right)^{0,8} \sqrt{\frac{r'}{\left(r' + \frac{h' r_1}{H}\right)\left(h_1 + \frac{H (r_1 - r') - h' r_1}{r_1 - r_a}\right)}}$$

in the cylindrical section the formula

$$d = \frac{80 e^2}{\sqrt{(\delta - \gamma) Q}} \left(\frac{r}{r_1}\right)^{0,8} \frac{1}{\sqrt{h_1 + (r_1 - r) \operatorname{cotg} \alpha}}$$ is obtained,

where d is in microns, $\eta = 10^{-5}$ g sec cm^{-2}, $g = 981$ cm sec^{-2}, δ, γ in g cm^{-3} Q in m^3/hr, $e, r, r', r_1, r_a, h', h_1, H$ in cm, $\operatorname{tg} \alpha = \frac{r_1 - r_a}{H}$, $\operatorname{tg} \beta = \frac{r_1}{H}$. H cm is the height of the conical section. (If Q is expressed in l/sec instead of m^3/hr, instead of 80, the figure of 42 stands in the formulas). At $h' = 0$, $r' = r$, and the formula of the conical section passes into that of. the cylindrical part.

By substitution of $h_1 = a r_1$ the equation of the cylindrical section can be brought to the form

$$d = \frac{80\,e^2}{\sqrt{(\delta-\gamma)\,Q}} \left(\frac{r}{r_1}\right)^{0,8} \frac{1}{\sqrt{r_1\left[a + \left(1 - \frac{r}{r_1}\right)\operatorname{cotg}\alpha\right]}}$$

In the cylindrical section of the cyclone lines $d = \text{const}$ are parallel to the axis. The state of equilibrium corresponding to grain size $d = \infty$ is at the cylindrical section of the cyclone (beyond the shell of the cyclone) at distance $r_\infty = r_1 + h_1 \operatorname{tg}\alpha$ from the axis ; at the conical section the line, on which the grain of $d = \infty$ revolves in equilibrium, includes with the axis the angle of β (Fig. 5).

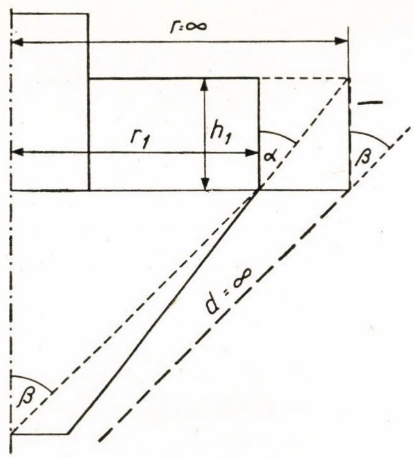


Fig. 5

In the cylindrical part of the cyclone to radius r_1 pertains the grain size of $d_1 = \frac{80\,e^2}{\sqrt{(\delta-\gamma)\,Q\,h_1}}$; the limit grain size occurring at radius $r'' = r_1 \frac{r_a + r_0}{r_0}$ [in the cylindrical section] is calculable by the formula

$$d_l = \frac{80\,e^2}{\sqrt{(\delta-\gamma)\,Q}} \left(\frac{r_0}{r_a + r_0}\right)^{0,8} \frac{1}{\sqrt{h_1 + r_1\left(1 - \frac{r_0}{r_a + r_0}\right)\operatorname{cotg}\alpha}}$$

In hydrocyclones often $r_1 = 4\,r_0 = 8\,r_a$; then

$$\frac{r_0}{r_a + r_0} = \frac{2}{3} \quad \text{and} \quad d_l = \frac{58{,}5\,e^2}{\sqrt{(\delta-\gamma)\,Q\left(h_1 + \frac{r_1}{3}\operatorname{cotg}\alpha\right)}}$$

$$\text{If } h_1 = r_1 \text{ and } e = \frac{r_1}{3}, \quad d_l = \frac{11{,}2\,r_1^{3/2}}{\sqrt{(\delta-\gamma)\,Q\,(3 + \operatorname{cotg}\alpha)}}$$

or transformed

$$d_l = 63 \sqrt{\frac{r_1}{(\delta - \gamma)\, v_{t1}\, (3 + \operatorname{cotg} \alpha)}}\,, \text{ where } v_{t1} \text{ is in m/sec.}$$

(This formula is valid in the case of $h_1 = r_1$, $e = r_1/3$, $r_0 = r_1/4$, $r_a = r_1/8$, n $= 0{,}8$). For given values of r_1 and α, $d_l = a/\sqrt{v_{t1}}$, where

$$a = 63 \sqrt{\frac{r_1}{(\delta - \gamma)\,(3 + \operatorname{cotg} \alpha)}}\,.$$

Table 1 shows limit grain sizes d_l (μ) in case of $\delta = 2{,}65$ and $\gamma = 1$, for $r_1 = 10$ cm, calculated at different half apex-angles α and velocity of entry v_{t1} m/sec. At other r_1 values the multiplicator $\sqrt{r_1/10}$ has to be made use of. On the left diagram of Fig. 6 the variation of values $(r/r_1)^n$ is shown

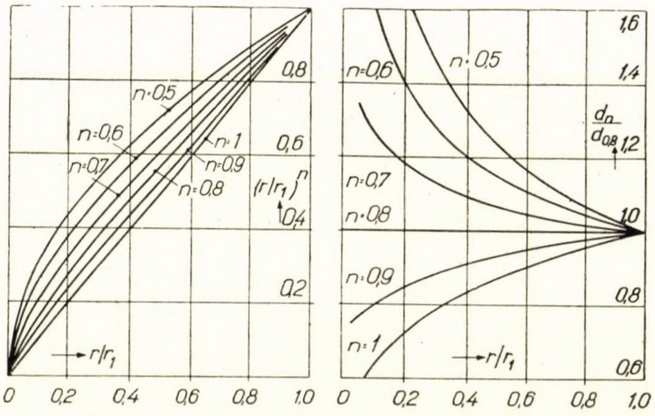


Fig. 6

as function of r/r_1. On the right diagram the trend of values of $(r/r_1)^n/(r/r_1)^{0,8} = (r/r_1)^{n-0,8}$ is presented. This value is moreover equal to the quotient $d_n/d_{0,8}$, that is, shows the relation of grain sizes pertaining to values n other than $n = 0{,}8$, to those pertaining to the exponent $n = 0{,}8$, at different values of r/r_1.

The last two lines of Table 1 show the pressure drop of ΔH m slurry column in the cyclone, pertaining to different velocities of entry v_{t1}, and the p at pressure of entry approximately corresponding to the former.

This pressure drop is calculable by the formula $\Delta H = \frac{v_{t1}^2}{2gn}\left[\left(\frac{r_1}{r_0}\right)^{2n} - 1\right]$

With $n = 0{,}8$ and $r_1/r_0 = 4$, the formula of $\Delta H = 0{,}524\, v_{t1}^2$ is obtained.

The deduction of the formula itself is as follows : on the elemental particle of the medium of dA cross-sectional area, of thickness dr and specific gravity γ revolving in the cyclone on radius r at velocity v_t, centrifugal force

$C = \frac{dA\,\gamma}{g} v_t^2 \frac{dr}{r}$ is acting, which is balanced by pressure $P = dA\, dp$ directed toward the axis of the cyclone. From equality $C = P$ the equations $dp = \frac{\gamma}{g} v_t^2 \cdot \frac{dr}{r}$ and $p = \frac{\gamma}{g} \int v_t^2 \frac{dr}{r}$ are obtained. The substitution of value $v_t = v_{t1} \left(\frac{r_1}{r}\right)^n$ yields

$$p = \frac{\gamma\, v_{t1}^2\, r_1^{2n}}{g} \int \frac{dr}{r^{1+2n}} = - \frac{\gamma\, v_{t1}^2\, r_1^{2n}}{2\, ngr^{2n}} + C\,.$$

If at radius r_1 the statical pressure is p_1, $C = p_1 + \frac{\gamma v_{t1}^2}{2gn}$

that is $p = p_1 + \frac{\gamma v_{t1}^2}{2gn} \left[1 - \left(\frac{r_1}{r}\right)^{2n}\right]$.

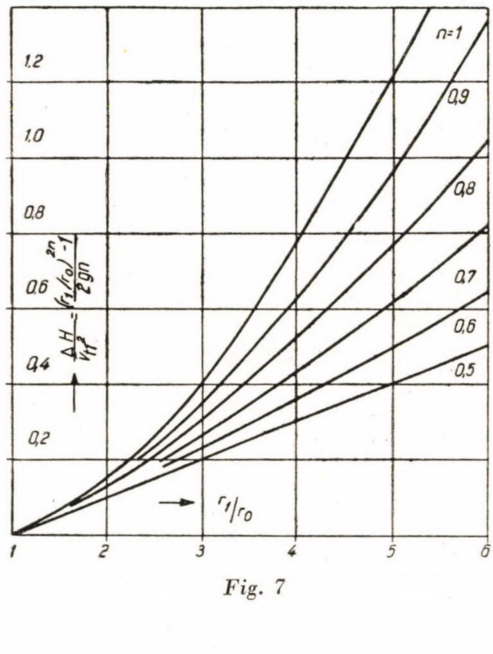


Fig. 7

From this

$$\frac{p_1}{\gamma} - \frac{p}{\gamma} = H_1 - H = \frac{v_{t1}^2}{2gn} \left[\left(\frac{r_1}{r}\right)^{2n} - 1\right], \text{ that is,}$$

$$H_1 - H_0 = \Delta H = \frac{v_{t1}^2}{2gn} \left[\left(\frac{r_1}{r_0}\right)^{2n} - 1\right]. \text{ The variation of}$$

$\frac{\Delta H}{v_{t1}^2} = \frac{1}{2gn} \left[\left(\frac{r_1}{r_0}\right)^{2n} - 1\right]$ for different values of n is presented in Fig. 7. (In case of $n = 0{,}8$ and $r_1/r_0 = 4$, $\Delta H/v_{t1}^2 = 0{,}524$, $v_{t1} = 1{,}38 \sqrt{\Delta H}$. At $e = r_1/3$,

$Q = 1{,}2\, r_1^2 \sqrt{\Delta H}$, where, Q is in m³/sec, r_1 and ΔH in m. Or $Q = 0{,}43\, r_1^2 \sqrt{\Delta H}$, where Q is in m³/hr, r_1 in cm, ΔH in m. DAHLSTROM's empirical formula for the quantity of overflow, at $\alpha = 10°$, $Q = 0{,}49 \sqrt{\Delta H}\,(2\, r_0 e)^{0,9}$; herefrom in the case of $r_0 = r_1/4$ and $e = r_1/3$ $Q' = 0{,}1 r_1^{1,8} \sqrt{\Delta H}$ is obtained, where Q' is in m³/hr, r_1 in cm, ΔH in m. [$Q/Q' \cong 4{,}3\, r_1^{0,2}$!?]

The diameter of the feed pipe of the cyclone of $\alpha = 10°$, $r_1 = 3{,}81$ cm of Fig. 1 and 2 was 5/8″ = 1,58 cm. To Fig. 2 belongs the quantity of slurry of $Q = 3{,}58$ m³/hr (= 1000 cm³/sec) that is, here $v_e = \dfrac{4\,Q}{e^2 \pi} = \dfrac{4 \cdot 1000}{1{,}58^2 \cdot 3{,}14} = 510$ cm/sec is the velocity of entry. Approximately $v_{t1} \cong v_e$. (For more exact calculation $v_e = 5{,}1$ m/sec is approximately equals not v_{t1} belonging to radius $r_1 = 3{,}81$ cm, but v_t pertaining to radius $r \cong r_1 - e/2 = 3{,}81 - 0{,}79 = 3{,}02$ (=1,2″). See also Fig. 2 So that more exactly $v_{t1} = 5{,}1 \left(\dfrac{3{,}02}{3{,}81}\right)^{0,77} = 4{,}25$ m/sec.) In Fig. 2 by extrapolation is obtained that at $r_1 = 3{,}81$ cm approximately $v_{r1} = 32$ cm/sec. Then $h_1 = \dfrac{Q}{2\pi\, r_1\, v_{r1}} = \dfrac{1000}{6{,}28 \cdot 3{,}81 \cdot 32} = 1{,}3$ cm (!?). Approximately $v_{a1} \cong v_{r1} \operatorname{cotg} \alpha = 32 \cdot 5{,}67 = 180$ cm/sec.

Calculated with values of $Q = 3{,}58$ m³/hr, $\alpha = 10°$, $r_1 = 3{,}81$, $h_1 = 1{,}3$, $e = 1{,}58$ cm, $\delta = 2{,}65$, further $r_a = 0{,}32$, 0,64 and 0,96 cm, grain sizes d obtained at different values of h' and r' (Table 2.) and lines d = const plotted therewith are presented in Fig. 8. Lines $v_a = 0$ pertaining to various values of $r_0 = 0{,}32$; 0,64 ; 0,96 and 1,28 cm are also drawn in dashed line. In the corresponding part of the middle diagram ($r_a = 0{,}64$ cm) lines d = const of Fig. 2 are also transferred, indicating agreement or divergence of experimental and of calculated values. The experimental line $v_a = 0$ is to be compared to line $v_a = 0$ pertaining to $r_0 = 0{,}64$ cm.

From the figures it is evident that the limit grain size that can be read off at the junction of the cylindrical and the conical sections is the maximum

Table 1

d_l μ

v_{t1} m/sec	4	6	8	10	12
$\alpha = 7{,}5°$	24	19	17	15	14
10°	27	22	19	17	15
30°	36	29	25	22	21
50°	40	32	28	25	23
ΔH m	8	19	33	52	75
~p at	1	2,3	4	6	8

Table 2

$d\ \mu$

h' cm	r_a cm	r' cm 3,81	2,81	1,81	1,31	0,81	0,31
	0,32						
0	0,64	72,0	24,3	12,7	8,9	5,6	2,4
	0,96						
5	0,32	—	44,7	13,6	8,4	4,5	1,4
	0,64	—	54,3	13,9	8,5	4,5	1,4
	0,96	—	69,0	14,2	8,6	4,5	1,3
10	0,32	—	—	24,1	10,5	4,8	1,3
	0,64	—	—	37,3	11,6	5,0	1,3
	0,96	—	—	—	14,5	5,4	1,4
15	0,32	—	—	—	—	8,0	1,6
	0,64	—	—	—	—	17,0	1,8
	0,96	—	—	—	—	—	3,0

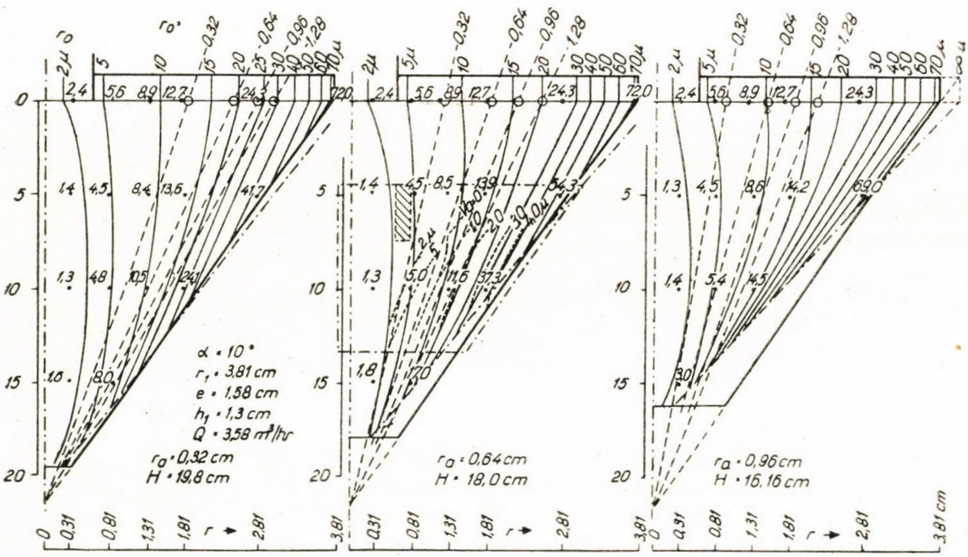


Fig. 8

grain size that gets into the overflow. Along line $v_a = 0$ proceeding toward the apex of the cone gradually finer sizes fall on line $v_a = 0$, indicating that the part of the finer grains, which reach their state of equilibrium only in the conical section of the cyclone, are also discharged in the underflow. Around the apex the line of $d = \infty$ also falls inside of the cyclone, and in the middle and the right diagram it also comes to the left side of lines $v_a = 0$ in the case examined.

Table 3

r_a cm	r_0 cm			
	0,32	0,64	0,96	1,28
0,32	13	19	25	30
0,64	9	13	16	20
0,96	6	10	13	16
ΔH m	83,5	27,0	13,4	8,0
$\sim p$ at	9	5	1,5	1

$Q = 3{,}58$ m³/hr, $\alpha = 10°$, $\delta = 2{,}65$
$r_1 = 3{,}81$, $h_1 = 1{,}3$, $e = 1{,}58$ cm

This would mean that at the apex of the cyclone the axial flow of slurry would transport quite large particles too, upward, toward the vortex finder. The coarse grains, however, having arrived at the upper regions of the cyclone, moving toward the line corresponding to their state of equilibrium get again on the right side of line $v_a = 0$, that is, back into the downward current of the slurry. It is more probable, however, that in consequence of divergences between conditions supposed at the deduction of the formula and the actual situation, the line of $d = \infty$ in reality never falls into the inside of the cyclone, and thus

Table 4

$\Delta H =$ constant

e cm	1,0	1,3	1,58	1,9	2,2
Q m³/hr	1,43	2,43	3,58	5,15	6,91
d_1 μ	46	59	72	87	100
d_l μ	8	11	13	16	18

the circulation of coarser grains around the apex of the cyclone of longer or shorter duration does not really take place, which would produce there a dense suspension of particles.

Limit grain sizes d_l (μ) pertaining to various values of r_a and r_0, which may be read from the diagram too, that is, the maximum grain sizes getting into the overflow, are shown in Table 3. Data ΔH m at the bottom of the table have been computed from formula

$\Delta H = \frac{v_{t1}^2}{2gn}\left[\left(\frac{r_1}{r_0}\right)^{2n} - 1\right]$ with values of $v_{t1} = 5{,}1$ m/sec and $n = 0{,}8$. [For $r_0 = 0{,}64$ cm, where $\Delta H = 27$ m, according to experimental results $p_e = 2{,}81$ at was the pressure of entry ($= 28{,}1$ m of water column). p at is about the necessary pressure of the pump.]

ΔH, and p respectively, vary much with r_0 if at constant orifice of entry (e) an invariable amount of slurry (Q) is to be fed to the cyclone ; limit grain size d_l varies simultaneously only slightly. (For instance, at $p = 9$—3—1,5 at, $d_l = 9$—13—16 μ.)

If at constant orifices of entry and of discharge pressure is reduced, while n remains invariable, the velocity of entry or the quantity of feed changes in proportion to the square root of the ratio of pressures. ($\Delta H = cv_{t1}^2$; $Q = kv_{t1} = K\sqrt{\Delta H}$). For instance, at KELSALL's experiments, when instead of 40 lb/sq. in. entry pressures of 30, 20 and 10 lb/sq. in. were applied, the amount of slurry was reduced from 59,82 l/sec to 52,31, 43,27 and 31,51 l/sec, respectively, in lieu of the "theoretical" values of $59{,}82 \cdot \sqrt{3/4} = 51{,}8$; $59{,}82 \cdot \sqrt{2/4} = 42{,}2$ and $59{,}82 \cdot \sqrt{1/4} = 29{,}9$ in the same order. Simultaneously d varies in inverse ratio to the radical of order 4 of the ratio of pressures $(d = C/\sqrt{Q} = C/\sqrt[4]{\Delta H})$. Therefore, if in any cyclone, keeping orifices of entry and of discharge constant, the limit grain size has to be reduced, for instance, to one half, the velocity of slurry entry or its amount has to be increased to four times its former value, the pressure has to be boosted 16-fold. The power demand will then rise to 64-times the former value (16-times referred to the feed unchanged).

It is more economical in such case to employ, instead of a single large cyclone, a set of m small ones tied up in parallel (multicyclone), whose linear dimensions are $1/\sqrt{m}$ times those of the big cyclone. Each of the small cyclones fed with 1/m times the original Q quantity of slurry, velocity of entry v_{t1} remains unvaried, but the grain size of separation is reduced to $1/\sqrt[4]{m}$ times the former. Since values r_1/r_0 and n also remain unaltered, the pressure drop in the small cyclones will be the same as that of the big one ; theoretically, the power demand of the multi-cyclone plant remains the same as that of the single big cyclone classifying at $\sqrt[4]{m}$ times, larger grain size. (If values v_{t1}, r_1/r_0 and n remain unchanged, in the big and the small cyclones at the places of equal r/r_1 values the same velocities v_t and v_r present themselves and the resistance S of the medium is the same, but the centrifugal force is $\sqrt{m}$-times greater in the small cyclone than in the big one.) If, for instance, the limit grain size of classification is to be reduced to one half, $m = 2^4 = 16$ small cyclones are required whose all dimensions are $1/\sqrt{m} = 1/4$ of those of the big cyclone. This multicyclone plant processes the unchanged quantity of feed "theoretically" with the same power demand (with the seam pump and motor), but with the limit grain size of classification reduced to one half. In reality, the power demand rises slightly because of greater pipe friction, but may be also because of the change of the n-value.

From Table 3 it appeared that in case of unvaried Q and e, that is, of v_{t1}, the change of r_0 is accompanied by a strong alteration of the necessary pressure of entry. In practice it is preferred to keep pressure (ΔH or p) constant and the magnitude r_a or r_0 is varied. Let be examined how the grain size of classification varies in this case. For example, let $\Delta H = 27$ m, ($p \simeq 3$ at), $r_1 = 3{,}81$ cm, $h_1 = 1{,}3$ cm, $a = 10°$, $\delta = 2{,}65$, $n = 0{,}8$; let further 1/ at $r_0 = r_a = 0{,}64$, $e = 1{,}0$; 1,3 ; 1,58 ; 1,9 ; 2,1 cm ; 2/ at $e = 1{,}58$ cm and $r_0 = 0{,}64$ cm $r_a = 0{,}32$, 0,64, 0,96 cm ; 3/ at $e = 1{,}58$ cm and $r_a = 0{,}64$ cm, $r_o = 0{,}32$, 0,64, 096, and 128 cm.

1. If e changes, but ΔH, n, r_1/r_0 and all other enumerated data remain unchanged, v_{t1} also remains unvaried (in the case on hand 5,1 m/sec), but Q varies proportionally to e^2, and the value of d changes in ratio to e, as may be read directly from formulas of Q and d. The values computed are listed in Table 4.

2. If r_a changes and all other data enumerated remain unchanged, v_{t1} and Q remain unvaried and the location of lines $d =$ const also remains unchanged in the cylindrical section of the cyclone, but line $v_a = 0$ and $d = \infty$ are displaced, wherefore the value of d_l and the location of lines $d =$ const also changes in the conical section of the cyclone. In the case on hand $d_1 = 72\ \mu$ remains unchanged, the values of d_l will be at $r_a = 0{,}32$; 0,64 and 0,96 cm 19, 13 and 10 μ, respectively, as listed in column $r_0 = 0{,}64$ of Table 3.

Table 5

$\Delta H =$ constant

r_0 cm	0,32	0,64	0,96	1,28
v_{t1} m/sec	2,87	5,10	7,26	9,45
Q m³/hr	2,01	3,58	5,10	6,64
d_1 μ	96	72	60	53
d_l μ	12	13	13	15

3. If r_0 changes but all other data enumerated remain unvaried, with change of r_1/r_0 — at ΔH and n unvaried — v_{t1} changes, and so do also Q and d. The value of $v_{t1} = \sqrt{\dfrac{2\,gn\,\Delta H}{(r_1/r_0)^{2n} - 1}}$; that of Q changes proportionally to v_{t1}, that of d in inverse ratio to $\sqrt{Q}$. Line $v_a = 0$ is shifted. Results of calculation are listed in Table 5.

4. If not pressure ΔH (or p) but the quantity of slurry Q remain constant (3,58 m³/hr), with change of e — other data enumerated ($r_1 = 3{,}81$ cm, $r_0 = r_a = 0{,}64$ cm, $h_1 = 1{,}3$ cm, $a = 10°$, $\delta = 2{,}65$, $n = 0{,}8$) remaining unchanged — v_{t1}, ΔH and d will change. That is, the value of v_{t1} varies inversely to e^2 ($v_{t_1} = 4Q/e^2\pi$), that of ΔH in inverse ratio to e^4 ($\Delta H = cv_{t_1}^2 = c'/e^4$), the value of d in direct ratio to e^2. The location of lines $d = \infty$ and $v_a = 0$ does not change. Results of the calculation are listed in Table 6.

Q = constant **Table 6**

e cm	1,0	1,3	1,58	1,9	2,2
v_{t_1} m/sec	12,75	7,54	5,10	3,54	2,64
ΔH m	168,8	59,2	27,0	13,0	7,2
d_1 μ	29	49	72	104	139
d_l μ	5	9	13	19	25

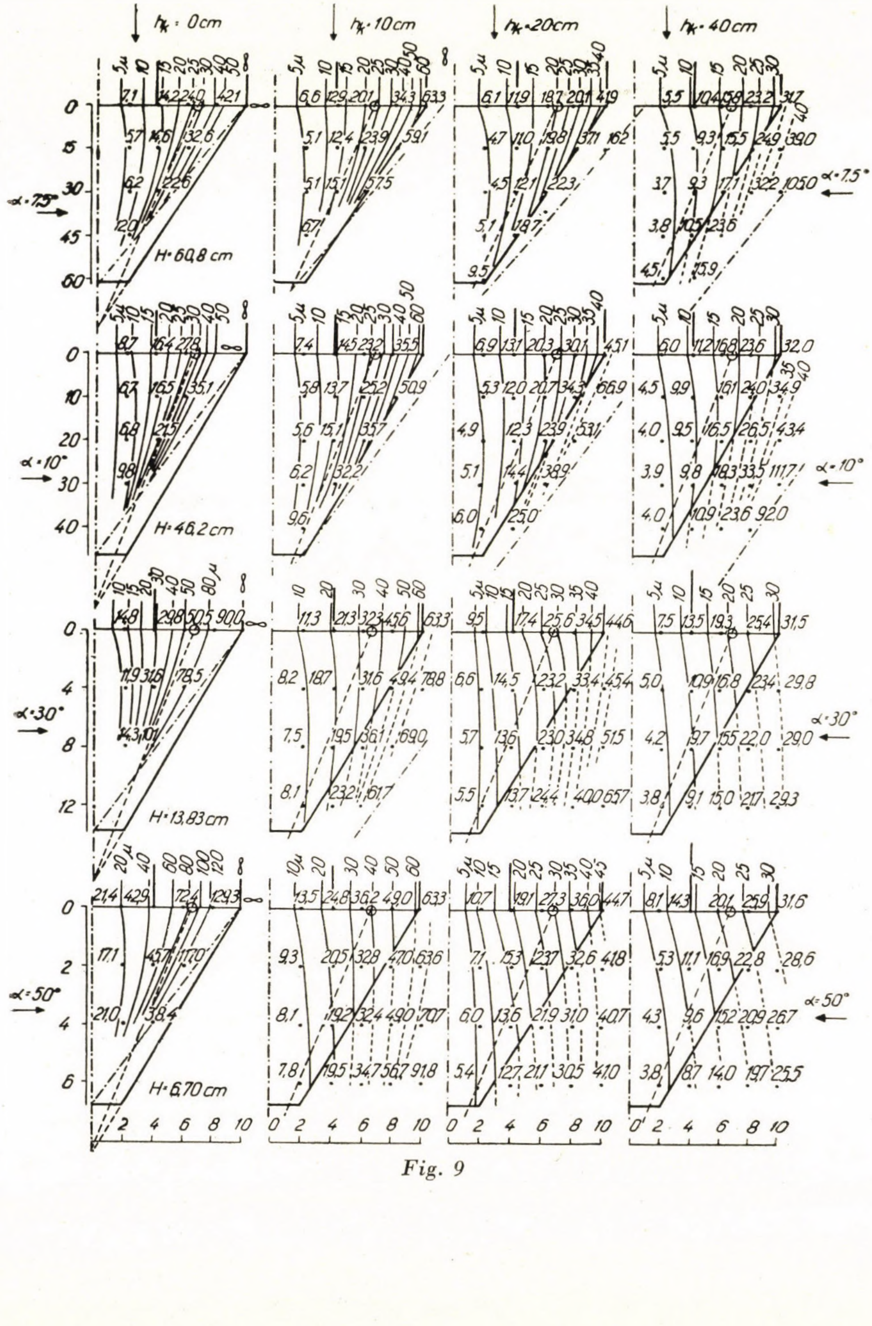


Fig. 9

Table 7

h' cm	$h_1 = 0$ cm				$h_1 = 10$ cm				$h_1 = 20$ cm					$h_1 = 40$ cm				
	0	15	30	45	0	15	30	45	0	15	30	45	60	0	15	30	45	60
$r' = 10$	∞	$\alpha = 7{,}5°$			63,3	—	—	—	44,9	162,2	—	—	—	31,7	39,0	105,0	—	—
8	42,1				34,3	59,1	—	—	29,1	37,1	—	—	—	23,2	24,9	32,2	—	—
6	24,0	32,6	—	—	20,8	23,9	57,5	—	18,7	19,8	27,3	—	—	15,8	15,5	17,1	23,6	—
4	14,2	14,6	22,6	—	12,9	12,4	15,1	—	11,9	11,0	12,1	18,7	—	10,4	9,3	9,3	10,5	15,9
2	7,1	5,7	6,2	12,0	6,6	5,1	5,1	6,7	6,1	4,7	4,5	5,2	9,5	5,5	4,1	3,7	3,8	4,5
h' cm	0	10	20	30	0	10	20	30	0	10	20	30	40	0	10	20	30	40
$r' = 10$	∞	$\alpha = 10°$			63,3	—	—	—	45,1	66,9	—	—	—	32,0	34,9	43,4	111,7	—
8	49,7				35,5	50,0	—	—	30,1	34,3	53,1	—	—	23,6	24,0	26,5	33,5	92,0
6	27,8	35,1	—	—	23,2	25,2	35,7	—	20,3	20,7	23,9	38,9	—	16,8	16,1	16,5	18,3	23,6
4	16,4	16,5	21,5	—	14,5	13,7	15,1	22,2	13,1	12,0	12,3	14,4	25,0	11,2	9,9	9,5	9,8	10,9
2	8,2	6,7	6,8	9,1	7,4	5,8	5,6	6,2	6,9	5,3	4,9	5,1	6,0	6,0	4,5	4,0	3,9	4,0
h' cm	0	4	8		0	4	8	12	0	4	8	12		0	4	8	12	
$r' = 10$	∞	$\alpha = 30°$			63,3	78,8	—	—	44,7	45,4	51,5	65,7		31,6	29,8	29,0	29,3	
8	90,0				45,6	49,4	69,0	—	34,5	33,4	34,8	40,0		25,4	23,1	22,0	21,7	
6	50,5	78,5	—		32,3	31,6	36,1	561,7	25,6	23,2	23,0	24,4		19,3	16,8	15,5	15,0	
4	29,8	31,6	101,0		21,3	18,7	19,5	23,3	17,4	14,5	13,6	13,7		13,5	10,9	9,7	9,1	
2	14,8	11,9	14,3		11,3	8,2	7,5	8,1	9,5	6,6	5,7	5,5		7,5	5,0	4,2	3,8	
h' cm	0	2	4		0	2	4	6	0	2	4	6		0	2	4	6	
$r' = 10$	∞	$\alpha = 50°$			63,3	63,6	70,7	91,8	44,6	41,8	40,7	41,0		31,6	28,6	26,7	25,5	
8	129,3				49,0	47,0	49,0	56,4	36,0	32,6	31,0	30,5		25,9	22,8	20,9	19,7	
6	72,4	117,0	—		36,2	32,8	32,4	34,7	27,3	23,7	21,9	21,1		20,1	16,9	15,2	14,0	
4	42,4	45,7	384,0		24,8	20,5	19,2	19,5	19,1	15,3	13,6	12,7		14,3	11,1	9,6	8,7	
2	21,4	17,1	21,1		13,5	9,3	8,1	7,8	10,7	7,1	5,9	5,4		8,1	5,3	4,3	3,8	

Let the computation of grain sizes revolving in equilibrium at various values of h' and r' beexecuted, for instance, in case of $r_1 = 10$ cm, $r_a = 2$ cm, $r_0 = 4$ cm, ($r'' = 6{,}67$ cm), $e = 4$ cm, $Q = 25$ m^3/hr ($v_{t1} = 5{,}53$ m/sec, $\Delta H =$ 6,4 m, $p = 0{,}8$ at), $\delta = 2{,}65$, $n = 0{,}8$ at $h_1 = 0$, 10, 20, 40 cm and $\alpha = 7{,}5°$, $10_\circ$, 30°, 50°. Results are shown in Table 7 and Fig. 9. Table 8 lists limit grain sizes d_l computed by formula

$$d_l = \frac{80 \cdot 4^2}{\sqrt{1{,}65 \cdot 25}} \left(\frac{2}{3}\right)^{0{,}8} \frac{1}{\sqrt{h_1 + 3{,}33 \operatorname{cotg} \alpha}} = \frac{144}{\sqrt{h_1 + 3{,}33 \operatorname{cotg} \alpha}}$$

From Table 8, as well as from individual diagrams of Fig. 9 is evident that the limit grain size, that is, the maximum grain size getting into the over-

Table 8

d_l μ

h_1 cm	0	10	20	40
$\alpha = 7{,}5°$	29	24	21	18
10°	33	27	23	19
30°	60	36	28	21
50°	86	40	30	22

$Q = 25$ m^3/hr, $\delta = 2{,}65$, $r_1 = 10$, $r_0 = 4$, $r_a = 2$, $e = 4$ cm

flow at invaried half apex-angle α is the smaller, the greater is h_1, the height of the cylindrical section of the cyclone ; at unchanged h_1 it diminishes the more, the smaller is α, the apex-angle of the cyclone. Table 9 shows the distance $r_\infty - r_1 = h_1 \operatorname{tg} \alpha$ in the cylindrical section of the cyclone pertaining to grain size $d = \infty$, at different values of α and h_1 ; this continues in the conical section with direction tangent β. If distance $r_\infty - r_1$ is small (at small apex-angle and low h_1 value), line $d = \infty$, to which fit closely lines $d =$ const, it passes near the wall of the cyclone. In that case lines $d =$ const cling more or less to the conic

Table 9

$r_\infty - r_1$ cm

h_1 cm	0	10	40	S
$\alpha = 7{,}5°$	0	1,3	2,6	5,3
10°	0	1,8	3,5	7,1
20°	0	5,8	11,5	23,1
50°	0	11,9	23,8	47,7

wall of the cyclone or to line $v_a = 0$ more or less closely. If line $d = \infty$ is far from the wall of the cyclone (great apex-angle, great h_1) lines $d =$ const do not fit to the conic wall of the cyclone or to line $v_a = 0$, but intersect these at the

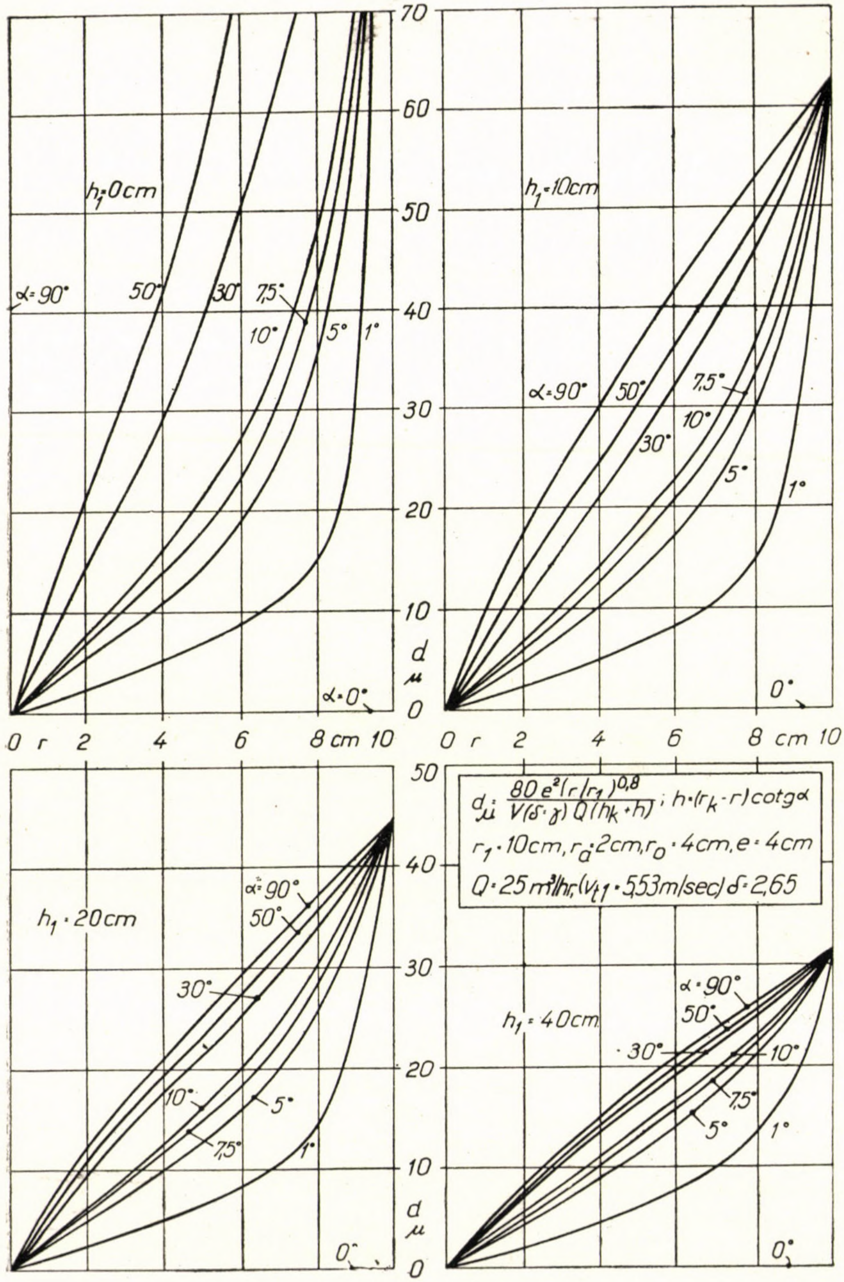


Fig. 10

greater angle, the higher is the value of $r_\infty - r_1$. Cyclones of small apex-angle and small cylindrical section are according to this fit for *classification;* in these the size of particles revolving in equilibrium on line $v_a = 0$ does not vary much, and only grains little smaller than the maximum grain size d_l discharged in the overflow will get into the underflow. Cyclones with great apex-angle and large cylindrical section, on the other hand, are more suited for heavy media *concentra-*

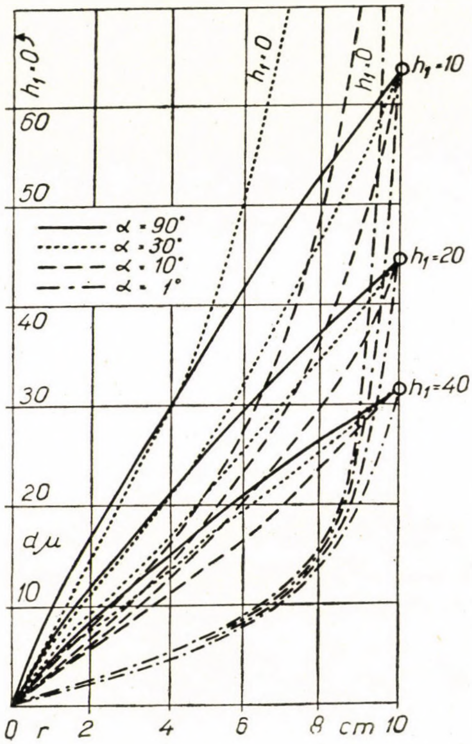


Fig. 11

tion. The large cylindrical section with its broad zone of $v_a \cong 0$ is very fit for producing the heavy suspension, since particles revolving therein in equilibrium have a long time of residence in the cyclone. Along the $v_a = 0$ line of the conical part to particles representing a proportionately wide grain size range take position and stay a larger time in that cyclone. But the stability of the heavy suspension, the constancy of its specific gravity, is favourably affected also by the fact that in the hydrocyclone of great apex-angle and large cylindrical section grains of the size fraction $d_1 - d_1/2$ or $d_1 - d_1/3$ are distributed in a broader zone than in cyclones of small apex-angle and small conical section. Tables 10 and 11 and Figures 10, 11, and 12 plotted from their data give information thereon. (The data refer to $Q = 25$ m³/hr, $\delta = 2{,}65$, $r_1 = 10$, $r_a = 2$, $r_0 = 4$, $e = 4$

Table 10

r cm	$h_1 = 0$ cm							$h_1 = 10$ cm						
	$\alpha = 1$	5	7,5	10	30	50	90°	1	5	7,5	10	30	50	90°
10	∞	∞	∞	∞	∞	∞	∞	63,3	63,3	63,3	63,3	63,3	63,3	63,3
8	15,6	35,0	43,0	49,7	90,0	128,7	∞	14,9	29,2	33,4	36,5	45,9	48,9	52,9
6	8,8	19,6	24,1	27,8	50,4	72,4	∞	8,6	17,8	20,9	23,2	32,3	36,2	41,9
4	5,2	10,8	14,2	16,4	29,8	42,5	∞	5,1	10,2	12,9	14,5	21,3	24,7	30,4
2	2,6	5,8	7,1	8,2	14,8	21,3	∞	2,6	5,5	6,6	7,1	11,3	13,5	17,5
	$h_1 = 20$ cm							$h_1 = 40$ cm						
10	44,7	44,7	44,7	44,7	44,7	44,7	44,7	31,6	31,6	31,6	31,6	31,6	31,6	31,6
8	14,4	25,6	28,2	30,0	34,6	35,9	37,4	13,4	21,2	22,5	23,4	25,4	25,9	26,4
6	8,4	16,4	18,7	20,3	25,6	27,5	29,6	8,1	14,3	15,8	16,8	19,4	20,2	20,9
4	5,0	9,7	11,9	13,9	17,4	19,2	21,4	4,9	8,8	19,4	11,2	13,5	14,3	15,2
2	2,5	5,2	6,2	6,8	9,5	10,7	12,3	2,5	4,8	5,5	6,0	7,6	8,1	8,7

cm, $n = 0{,}8$.) Table 10 gives d (μ) values computed at different values of α and h_1 by the formula valid for the cylindrical section of the cyclone. Table 11 gives per cent values of these grain sizes referred to $d_1 = 100\%$. Fig. 10 and 11 are graphical representations of Table 10, Fig. 12 that of Table 11 Table 12 indicates to what percentage of the cyclone radius extends the zone in which particles of the grain size fraction $d_1 - d_1/2$ and $d_1 - d_1/3$ are revolving in equilibrium. The zone of grain size fractions d_1—d_1/x is about equal in cyclones of $\alpha = 10°$, $h_1 = 40$ cm and of $\alpha = 30°$, $h_1 = 10$ cm. The last row of Table 11 gives the full heights of the cyclones.

The wear of the conical section of the cyclones is the greater, the farther line $d = \infty$ falls from the wall of the cyclone. On stubby cyclones of great apex-angle and large cylindrical section wear is therefore greater than on slender cyclones. In the latter particles somewhat below d_1 no more press against the

Table 11

α / h_1 cm	5°			10°			30°			50°		
	10	20	40	10	20	40	10	20	40	10	20	40
$r =$ 10	100	100	100	100	100	100	100	100	100	100	100	100
8	46,1	57,1	67,0	57,6	67,0	74,0	72,5	77,4	80,4	77,1	80,3	82,0
6	28,1	36,6	45,7	36,6	45,4	53,1	51,0	57,2	61,4	57,4	61,5	64,0
4	16,1	21,6	27,8	22,9	29,0	35,4	33,7	38,9	42,7	39,0	43,0	45,2
2	8,7	11,6	15,2	10,2	15,2	19,0	17,8	21,2	24,0	21,3	23,9	25,6
$H + h_1 =$	101,5	111,5	131,5	56,2	66,2	86,2	23,8	33,8	53,8	16,7	26,7	46,7

Table 12

$100 \frac{r_1 - r}{r_1}$ %

α	10°			30°		
h_1 cm	10	20	40	10	20	40
$d_1 - d_1/2$	25	35	43	41	47	52
$d_1 - d_1/3$	46	56	64	61	67	71

wall of the cyclone, and the line of equilibrium position (d = const) of particles pressing against the wall of the cyclone also passes at small distance beyond the wall of the cyclone, not so as in case of great α and height h. However, the

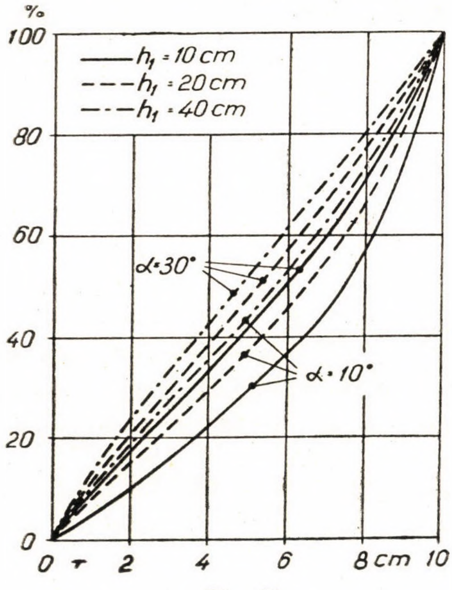


Fig. 12

farther the particle is from its d = const line, at the higher velocity and with the greater effort it tends to move toward this line, and the stronger it presses against the cyclone shell impeding its motion.

In diagram v_a = const of Fig. 4 (in conformity with Fig 1 and 2) was indicated that the axial velocity of downward flow of the slurry along the conic wall of the cyclone increases a little in progression toward the apex. It is also known that at the junction of the cylindrical and of the conical sections $v_{a1} \cong v_{r1} \operatorname{cotg} \alpha$. Instead of the axial velocity increasing a little along the wall, calculated with constant velocity v_{a1}, along the conic wall of the cyclone the slurry flows during a time period of $t \cong H/v_{a1} = \frac{r_1 - r_a}{v_{a1} \operatorname{tg} \alpha} = \frac{r_1 - r_a}{v_{r1}}$. (In the space between the shell and the line $v_a = 0$ the time of residence of the slurry will become gradually the longer, the nearer it comes to line $v_a = 0$ or the farther it is from the wall.) The value of $v_{r1} = \frac{Q}{2\pi r_1 h_1}$ the formula of $t \cong 2\pi (r_1 - r_a) r_1 h_1 / Q$ is obtained for the duration of slurry flow along the conic wall of the cyclone *(independently* of α or of H. For instance, for $Q = 25$ m³/hr = 6950 cm³/sec, $r_1 = 10$ cm, $r_a = 2$ cm and $h_1 = 10, 20, 40$ cm in the same order the values of $t = 0{,}72$; 1,45 ; 2,89 sec are obtained, however great be the apex-angle or the length of the conical section). That is, at the same quantity of slurry, the axial velocity of flow at the conic wall is the lower the higher is h_1 and the greater is α, that is the stubbier is the cyclone. At low velocity of flow the wear is less too. From the point of view of wear the axial flow of slurry is more favourable in stubbier cyclones than in slender ones. This is opposite to the former finding that at the conical section of stubby cyclones wear is stronger. However, the favourable effect of lower axial velocity along the wall of stubby cyclones plays no part, because of tangential velocities much higher than axial ones, the former being in stubby and in slender cyclones at equal Q and e of equal magnitude. [Fig. 1 and 2 refer to slender cyclones ($\alpha = 10°$, $h_1 = 1{,}3$ cm $\cong r_1/3$), axial velocities along the conic wall (1,5—2 m/sec) amount yet but to a fraction of tangential velocities (5—10 m/sec and still higher at the apex). The tangential velocity along the wall increases toward the apex, this causes the apex to wear off soonest.]

Let the problem of heavy media separation in the hydrocyclone be investigated hereafter. Let the volume of the heavy media be $Q = 25$ m³/hr ; the volume of the raw material (for instance coal) is usually $^1/_3$—$^1/_6$ of the former. Let the proportion be, for instance, $^1/_5$ then the quantity of coal is 5 m³ = 8 t/hr (at average specific gravity of 1,6). Let the specific gravity of the make-up medium (for instance quartz dust) be 2,65, the specific gravity of the suspension fed be $\gamma' = 1{,}2$. The volume proportion of solids in the suspension will be then $\sigma = \frac{\gamma' - \gamma}{\delta - \gamma} = \frac{1{,}2 - 1}{2{,}65 - 1} = 0{,}121$. The quantity of quartz dust is thus $25 \cdot 0{,}121 = 3{,}0$ m³/hr = 0,8 t/hr. Let the specific gravity of separation be 1,85. To this pertains $\sigma = \frac{0{,}85}{1{,}65} = 0{,}515$. Such a dense suspension has to be produced along line $v_a = 0$ and in the zone $v_a \cong 0$ of the cylindrical section in order that refuse particles of sp. gravity higher than 1,85 be discharged in the underflow (maybe in a suspension of substantially higher density than that), and the coal particles of lower specific gravity than that — viewed in the direction of the centrifugal force — float on the suspension of 1,85 sp. gr. stagnant in the cyclone and leave it in the overflow, in a suspension of much lower density than the feed. Let the coal recovery be for instance 70%, the average sp. gr. of washed coal 1,47, that of refuse 2,0, then the quantity of washed coal is $8 \cdot 0{,}70 = 5{,}6$ t/hr $= 3{,}8$ m³/hr, and that of refuse $8 \cdot 0{,}30 = 2{,}4$ t/hr $= 1{,}2$ m³/hr. Let the cumulative grain size distribution of the make-up medium of 2,65 sp. gr. be according to Table 13. In cyclones also figuring in Fig. 9 of $Q = 25$ m³/hr, $\delta = 2{,}65$, $r_1 = 10$, $r_a = 2$, $r_i = 4$, $e = 4$, $h_1 = 10$ cm, $d_1 = 63\ \mu$. Such a cyclone is to be chosen for the medium of given grain size. In case of $h_1 < 10$ cm $d_1 > 63\ \mu$: particles coarser than d_1 press against the cyclone shell and play no part in producing the suspension, they only wear the wall of the cyclone. In case of $h_1 > 10$ cm $d < 63\ \mu$: along the wall of the cyclone a suspension-free zone is formed, in which also coal grains of less than 1,85 sp. gr. can remain and get into the underflow as loss of coal. A cyclone of $h_1 = 10$ cm, $\alpha = 10°$ chosen (Fig. 9), in the cylindrical section into an about $r = 5$—8 cm area falls the region $v_a \cong 0$, where about the grains of 18—37 μ revolvent in equilibrium. On line $v_a = 0$ of the conical section, in the upper $^2/_3$ of the cone,

Table 13

$d\mu$	60	40	30	20	10	0
Weight %	5	25	45	70	90	100
t/hr	0,4	2,0	3,6	5,6	7,2	8,0
m³/hr	0,15	0,75	1,35	2,1	2,7	3,0

between h' = 0—30 cm, grains of about 16—27 μ can revolve in equilibrium. The quantity of grains of 18—37 μ is about 43% of the total suspension material, grains of 16—27 μ make about 25%. A substantial part of the suspension material thus takes part in the formation of the heavy suspension.

Spheres of uniform size contacting one another in hexagonal arrangement fill 52% ($\cong \pi/6$) of the space, in tetrahedral arrangement they fill about 74%. In the hydrocyclone grains of the suspension material arrange themselves according to size, shearing forces arising through differential tangential velocity of coaxial layers impedent the densest (tetrahedral, $\sigma \cong 0{,}74$) arrangement of contiguous particles only the looser (hexagonal $\sigma = 0{,}52$) arrangement can come about. (This just corresponds to the volume density of $\sigma = 0{,}515$ required for a suspension of 1,85 sp. gr. A heavy suspension of higher sp. gr. than this could not even be produced from a separation medium of 2,65 sp. gr. in the hydrocyclone.) (Shearing forces also strongly reduce the structural viscosity of relatively dense suspensions, therefore in the hydrocyclone fine-sized materials can be successfully separated even in a suspension of density $\sigma > 0{,}5$.)

The suspension material pressing against the cyclone wall does not consist of grains of uniform size, but a layer of coarser grains developed on the cylindrical section is joined by finer and finer particles on the conical section, and the smaller grains finding room in the interstices between coarser ones reduce the pore volume of the layer ; on the other hand, upon the grains of the layer is acting a force directed toward the cyclone wall, the intensity of which is the greater, the farther lies outside of the cyclone wall the line $d = \infty$. No such force is acting upon particles revolving in their state of equilibrium (on line $d =$ const, at locus $v_a = 0$). Therefore the density of the suspension pressing against the cyclone wall and discharged in the underflow can be even higher than the value of $\sigma = 0{,}74$ corresponding to the densest arrangement of uniform spheres, especially in stubby cyclones where, line $d = \infty$ lying far, a greater force is pressing against the wall the grains of the layer sliding down the conical section. Shearing forces too, which are smaller along the wall, than in the inside of the cyclone, do not hinder but promote the thickening of the layer,

Table 14

r cm	8	6	4	2
d microns	53	42	33	27
weight %	8	21	39	53
m³/hr	0,24	0,63	1,17	1,59
q cm³/sec	67	175	325	441
q/σ cm³/sec	122	318	591	804
q' cm³/sec	456	652	925	1138
$\sim v_a'$ cm/sec	65	75	90	110
$\Delta r'$ cm	0,14	0,23	0,41	0,82
z cm	2,7	2,0	1,3	0,6
$\sim v_a$ cm/sec	63	71	76	73
Δr cm	0,14	0,24	0,48	1,28

because they change the position of particles in contact with one another. (For instance, at $\sigma = 0{,}74$, in case of $\sigma = 2{,}65$, the sp. gr. of the suspension discharged in the underflow is 2,22, its water content 11,7%). In the case on hand ($a = 10°$, $h_1 = 10$ cm) line $d = \infty$ is near to the cyclone wall and even intersects it above the apex. Therefore here no noteworthy force presses the grains of the underflow pulp against each other, therefore in consequence of shearing forces, due to differing tangential and axial velocities of contiguous layers sliding down, the density σ of the underflow will be nearer to 0,52 than to 0,74. (For instance, σ may be 0,55, when the sp. gr. of the suspension will be 1,90, its water content 23,6%.)

From the Fig. 9 may be read that at $r = 8$, 6, 4 cm (at $h' = 12$, 23, 34 cm of the cone) the lines $d = 53$, 42, 33 μ in the same order, cling to the cyclone wall, further that $d_l = 27$ μ. In Table 14 are visible : the quantity of grains of the suspension coarser than these d sizes (in m³/hr and q cm³/sec) and their "loose" volume (q/σ cm³/sec) computed with volume density $\sigma = 0{,}55$, as well as the cumulative quantity ($q' = q/\sigma + q_1$) of the latter and of refuse of $q_1 = 1{,}2$ m³/hr $= 334$ cm³/sec ; the approximate axial velocity (v_a' cm/sec) appearing at the wall, which "slightly" increases from

$$v_{a1} = v_{r1} \operatorname{cotg} \alpha = \frac{Q \operatorname{cotg} \alpha}{2\,\pi\, r_1\, h_1} = \frac{6950 \cdot 5{,}67}{628} = 62{,}7 \text{ cm/sec at } h' = 0$$

in passing toward the apex ; value $\Delta r' = q'/2r\pi v_a'$ yields in first approximation the thickness of annular layer of thick pulp sliding down the conic wall at distance r from the axis ; z cm shows the horizontal distance — measurable from the figure — between the conic wall (r) and line $v_a = 0$; $v_a = \dfrac{v_a'}{2}\left(1 + \dfrac{z - \Delta r'}{z}\right)$ gives the approximate axial velocity of the pulp flowing in the layer $\Delta r'$, provided that the axial velocity reduces linearly from v_a at radius r to velocity 0 of line $v_a = 0$. In Fig. 1 and 2 in the middle and the upper part of the cone the axial velocity component changes about linearly between $v_a = 0$ and the conic wall, in its bottom part this change takes place about according to a parabolic law. In case of $z < \Delta r'$, change according to a parabolic law supposed, the average value of $v_a = 2\, v_a'/3$ may be reckoned with. $\Delta r = q'/2\pi r v_a$ is the approximate thickness of the layer computed with the average v_a value. (The calculation would be more exact if the values of r_2 or of $\Delta r = r_1 - r_2$ were calculated by substituting the linearly or parabolically varying function of v into the formula $q' = 2\pi \int_{r_1}^{r_2} vr\, dr$. Thus in the case of v varying linearly a cubic, in the case of its variation according to a parabolic law a fourth-degree equation would be obtained. The Δr calculable therefrom, however, would not be an exact value either, because of uncertainties of the parameter of the equation.) At $r_a = 2$ cm the calculation gives the value of $\Delta r = 1{,}28$ cm, accordingly the radius of the air core in the cyclone narrows to 2—1,28 = 0,72 cm. In the apex the distance of line $v_a = 0$ from the axis is 1,4 cm according to the drawings. This warns that around the apex of the cyclone line $v_a = 0$ no more falls on the line connecting the apex with the point at $r'' = \dfrac{r_1\, r_0}{r_a + r_0}$ distance from the axis and at height $h' = 0$. However, it is also possible that line $v_a = 0$ falls into the layer Δr near the apex ; then the inner part of this layer flows upward. If grains recycled into the cyclone by this current do not find free room and passage to their line $d = $ const on the right side of line $v_a = 0$, remaining on the left of line $v_a = 0$, they get into the overflow. In that case grains above d_l may also be discharged in the overflow ; on the other hand, these grains, which do not revolve at a place corresponding to their state of equilibrium, striving after line $d = $ const corresponding to their state of equilibrium, exert pressure on grains hampering them and thereby compact a little the particles originally in "loose" contact, thus the heavy suspension of the hydrocyclone may attain a greater σ and higher specific gravity than would correspond to the state of loose contact ($\sigma \simeq 0{,}52$). The calculation of the radius of the air core and of value Δr of the apex does not go on all fours either, principally because of the uncertainty of values v_a' and v_a. However, the value of σ is not unchanged either along the entire length of the conic wall, but it probably grows toward the apex. The total amount of refuse q_1, on the other hand, does not stick any longer to the wall of the cylindrical section. All these reasons evidence that the approximate method presented can lead only to approximate results.

Table 15

r cm	8	6	4	2
d microns	48	(34)	(21)	(10)
weight %	17	(37)	(72)	(90)
corr. weight	17	33	37	39
m^3/hr	0,51	0,99	1,11	1,17
q cm^3/sec	142	275	308	325
q/σ cm^3/sec	218	423	474	500
q' cm^3/sec	552	757	808	834
$\sim v_a'$ cm/sec	20	25	30	40
$\Delta r'$ cm	0,55	0,80	1,07	1,66
z cm	2,7	2,0	1,3	0,6
$\sim vr$ cm/sec	18	20	18	27
Δr cm	0,61	1,00	1,78	2,46

Discharge of part of the grains above d_l size due to the afore-mentioned cause can be prevented by enlarging the aperture of the apex or by decreasing the density of the suspension fed to the cyclone (for instance employing a suspension of 1,15 sp. gr. instead of 1,2).

A similar calculation executed on a cyclone of $\alpha = 30°$, $h_1 = 10$ cm leads to results presented in Table 15. At $r = 6$, 4 and 2 cm the conic wall is intersected by equilibrium curves of $d < d_l$ ($= 36\mu$). From this size range however, very little gets into the underflow, most of it discharged in the overflow. In the cylindrical section in the range $v_a \simeq 0$ (falling between 5—8 cm) the size fraction of $\sim$ 27—46 μ (about 34% weight) is revolving in equilibrium, along line $v_a = 0$ of the conical section (in the upper 2/3-ds) grains of 16—36 μ (about 45%) accomodate theselves. From these grain fractions, for instance, let 10% be discharged continuously in the underflow (corr. weight). Because of greater distance of line $d = \infty$, $\sigma = 0{,}65$, $v_{a1} = v_{r1} \text{cotg}\, \alpha = 11 \cdot 1{,}73 = 19{,}1$ cm/sec. The

Table 16

		Throughput	$\alpha = 10°$ under flow	$\alpha = 10°$ over flow	$\alpha = 30°$ under flow	$\alpha = 30°$ over flow
Coal	weight %	100	30	70	30	70
	t/hr	8,0	2,4	5,6	2,4	5,6
	m^3/hr	5,0	1,2	3,8	1,2	3,8
average	sp. gr.	1,6	2,0	1,47	2,0	1,47
Quartz	weight %	100	53	47	39	61
	t/hr	8,0	4,2	3,8	3,1	4,9
	m^3/hr	3,0	1,6	1,4	1,17	1,83
Water	weight %	100	5,9	94,1	2,8	97,2
	t/hr (= m^3/hr)	22	1,3	20,7	0,6	21,4
Suspension	weight %	100	18,3	71,7	12,4	87,6
	volume %	100	11,5	88,5	7,2	92,8
	t/hr	30	5,5	24,5	3,7	26,3
	m^3/hr	25	2,9	22,1	1,8	23,2
	sp. gr.	1,2	1,90	1,11	2,07	1,13
Solids	σ	0,121	0,55	0,064	0,65	0,08
	weight %	26,7	76,4	15,5	83,1	18,8
Coal+medium	weight %	100	20,8	79,2	16,0	84,0
	t/hr	38	7,9	30,1	6,1	31,9
	m^3/hr	30	4,1	25,9	3,0	27,0
average slurry	sp. gr.	1,27	1,93	1,16	2,03	1,18
	Solids %	42,1	83,5	31,2	90,0	12,5

calculation gave at $r_a = 2$ cm, $\Delta r \cong 2{,}46$ cm, which has no sense. Either a thinner suspension has to be worked with, or the apex aperture r_a has to be increased. For example, by interpolation at $r_a = 2{,}5$ cm, $\Delta r \cong 2{,}2$ cm; at $r_a = 3$ cm, $\Delta r \cong 2{,}1$ cm layer width is obtained. On the other hand at $\Delta r > r_a$ the air core vanishes, coarser grains not getting through the apex are discharged in the overflow, the underflow is discharged in a straight jet and not in the form of a spreading cone from the cyclone, maybe instead of a fluid compact sausages are pressed through the apex. The moisture content of cyclone underflow then already matches that of filtered products. However, this mode of operation has not spread in practice because of frequent troubles caused by clogging.

The material balance obtained in two cyclones ($\alpha = 10°$ and $30°$) is exhibited in Table 16.

Calculation by formula d valid for the conical section of the cyclone is rather cumbersome. Dispensing with this an approximate information on the trend of lines $d =$ const of the cyclone is obtained if by the formula holding for the cylindrical section

$$d = \frac{80\, e^2}{\sqrt{(\delta - \gamma)\, Q}} \left(\frac{r}{r_1}\right)^{0,8} \frac{1}{\sqrt{h_1 + r_1 \left(1 - \frac{r}{r_1}\right) \operatorname{cotg} \alpha}}$$

some values of d are computed (for instance for values of $r/r_1 = 1/4, 1/2, 3/4, 1$, where $(r/r_1)^{0,8}$ will be in the same order 0,33 ; 0,57 ; 0,79 ; 1,0 ; lines $d =$ const of the cylindrical part can be plotted now already ; on the diagram of the cyclone line $d = \infty$ is drawn, and lines $d =$ const in the conical section of the cyclone according to the position of line $d = \infty$ are drawn "by the touch" after the "first rule" observable in diagrams of Fig. 9. In case of $d = \infty$ near by, lines $d =$ const cling to this, that is, to the conic wall, in case of $d = \infty$ more distant, departing from the axis line they intersect the conic wall at a greater angle. With knowledge of value $r'' = \dfrac{r_1 r_0}{r_a + r_0}$ line $v_a = 0$ can also be drawn and grain size d_l becomes calculable too.

Finally some tests on domestic materials executed in hydrocyclones partly of semi-industrial partly of laboratory scale by the Research Institute for Mining, Budapest, will be described. Literature on results of former domestic hydrocyclone tests is cited under References [4, 5, 6]. Fig. 13 shows flowsheets of semi-industrial tests.

China clay-bound *Sárisáp* sands was washed in the Excelsior drum, the overflow clay pulp of about 300 l/min was first de-sanded in a hydrocyclone of 15 cm diam. afterwards treated in six 7 cm cyclones ; the underflow of these cyclones was fed to a 7 cm cyclone the overflow of which was recycled into the Excelsior washer. The overflow of the multicyclone plant was, after clarification in a settling tank during 24 hours, dewatered by filter presses. From raw material containing 15 % weight of kaolin, 15 percent weight of fine material of 87% kaolin content (93%—20 μ, 100%—30μ) was obtained. Kaolin recovery was 84%. The Sárisáp raw material of 24,4% kaolin content, treated in the routine de-gritting sluices of kaolin purification at a Czechoslovak Research Institute gave the following recoveries : 9,9 percent weight of I. Class China clay of 82,5% kaolin content, 11,6% weight of II. Class China clay of 69,6% kaolin content. (Recovery was here 36,6 + 36,2% only!)

From *Bánk-Petény* fireclay 105 tons were processed in an experimental plant of 1 t/hr throughput. Raw material pre-crushed on toothed rolls was pulped in a washing drum of 0,8 m diam. and 2 m length of special design, and fed at 1,8 at pressure to a hydrocyclone of 7 cm diameter. The cyclone separated

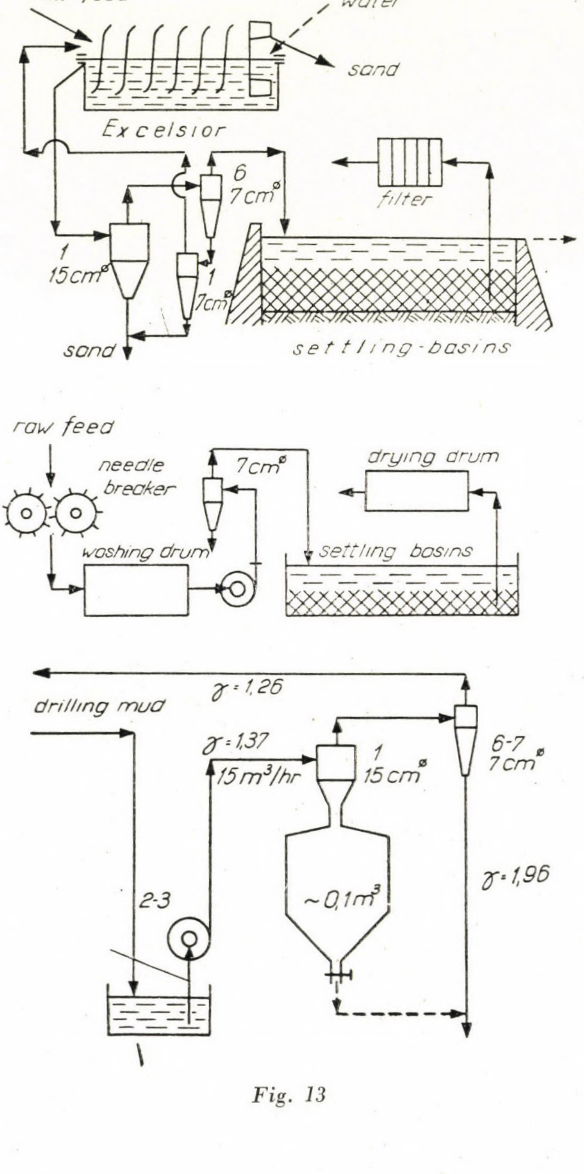

raw feed
water
sand
Excelsior
6
7cm
filter
1
15cm
1
7cm
sand
settling-basins
raw feed
needle
breaker
7cm
drying drum
washing drum
settling basins
γ=1,26
drilling mud
γ=1,37
15 m³/hr
1
15 cm
6-7
7cm
γ=1,96
2-3
~0,1m³

Fig. 13

the material at 20 μ, the fine product was thickened in settling boxes for long periods of time (slurry density was after one day 37%, after 50 days 51%, after 80 days 56%) and dried to 10% water content at 80°C in heat driers. Kaolinite content of the raw material was 76%, of the fine product of 80 percent weight it was 87% (92% kaolinite recovery). The raw material contained before treatment in the hydrocyclone 76% of fines under 20 μ ; after processing in the percentage of fines under 20 μ (recalculated from the products) was 81%. Refractoriness of the raw material was 26—28°S (∼1600°C), that of fine material was 33°S (= 1730°C).

Around some coal mines (Ajka, Dorog, Ebszőny, Komló, Tatabánya, etc.) there are *loess* deposits which are in the natural state unfit to be used as backfill in hydraulic stowage of mine workings. If the quantity of fines under 20 μ is

Table 17

Product	Slurry sp. gr.	Weight %	Volume %	Cumulative weigth %			
				+ 100 μ	+ 80 μ	+ 35 μ	+ 10 μ
Overflow	1,26	69	89	0,2	2,3	10,0	40,0
Underflow	1,96	31	11	56,6	?	78,4	93,7

reduced below 6—8% a good backfill material is obtained. For instance from Ebszőny loess a product containing 5% fines of —25 μ obtained by desliming in the hydrocyclone at 61,4% recovery was found a good backfill material. At Tatabánya the underflow product can be used as backfill, while the overflow product can be utilized as raw material in the fabrication of Portland cement without further grinding. The deposited backfill was after $^1/_2$—1 day still pulpy and had no carrying capacity, but by mechanical treatment (blasting $^1/_2$—1 cartridge of safety explosive at 80—100 cm under the floor of the chamber working) it could be compacted in all cases so that after one day it could be walked upon and a mine prop of 15 cm diam. under 700 kg load was pressed only 20—25 cm into it. After one week it yielded to the pick with difficulty and carried the load on the props without substantial compression [7].

A low pressure ($<$ 0,1 at) hydrocyclone of 7 cm diam. of 6—11 l/min throughput used in a closed cycle with a laboratory ball mill classified fines of 40—60 μ efficiently. The slurry fed at σ = 37—42% volume density was classified to an overflow of 15—16% density and to an underflow of 44—52% density [8].

Regeneration of drilling mud : because of its high structural viscosity drilling mud cannot be freed from rock cuttings coarser than 0,1 mm in the clarification basin, but it can be de-gritted in the hydrocyclone. From the circulating mud the coarse rock particles are deposited in the suction pit. Mud of 15 m^3/hr, of 1,37 sp. gr. was fed at 2—3 at pressure into a pre-treatment cyclone of 15 cm diam., the apex of which was joined to a closed tank of about 0,1 m^3 capacity the spigot of which was opened only at intervals to discharge the grit deposited. The overflow of the pre-treatment cyclone was directly fed to a multicyclone group of 6—7 units of 7 cm diameter, the overflow of which was conditioned mud returned into circulation. Data of over- and underflow are listed in Table 17.

REFERENCES

1. D. F. KELSALL: A study of the motion of solid particles in a hydraulic cyclone. Trans. Inst. Chem. Eng., Vol. 30, 1952, 87—104. (or: Recent developments in mineral dressing. Inst. of Min. and Met., London, 1953. 209—227).
2. M. G. DRIESSEN: Theory of flow in a cyclone. Influence of turbulence and its mathematical interpretation. International Conference on Coal Preparation. Paris — June 1950. E. 4. (Revue de l'Industrie Minérale. 1951. March)
3. H. TRAWISKI: Der Hydrozyklon als Hilfsgerät zur Grundstoff-Veredlung. Chemie-Ing. Techn. 25 (1953) No. 6, 331—341.
4. G. TARJÁN: Hydrocyclone concentration of manganese ore tailings at Úrkút, Hungary. Acta Technica Ac. Sc. Hung., Tom. IV. Fasc. 1—4., 1952.
5. G. TARJÁN: Washing Komló bituminous coal in laboratory hydrocyclone. Acta Technica Ac. Sc. Hung., Tom. V. Fasc. 1. 1952.
6. G. TARJÁN: On the theory and use of the hydrocyclone. Acta Technica Acad. Sc. Hung., Tom. VII. Fasc. 3—4. 1953.
7. F. MARTOS: Backfilling Experiments with Loess. Publications of the Mining Research Institute, Nr. 39., 1956, or Hung. Journal of Mining, No. 3., 1956. (Hungarian).
8. A. HALÁSZ—L. DEMETER: New Type of Hydraulic Classifier. Publications of the Mining Research Institute, Nr. 31., or Hung. Journal of Mining, Nr. 10—11, 1954. (Hungarian).

SUMMARY

Tangential (v_t), radial (v_r) and axial (v_a) velocity components of fluid flow in the hydrocyclone, having been chosen on the basis of KELSALL's experiments, a formula suitable for the calculation of the grain size of particles revolving in equilibrium at different places of the hydrocyclone is arrived at. Values of $v_t r^n = C$ and $v_r \cong \frac{Q}{2\pi r\left[h_1 + (r_1 - r)\operatorname{cotg}\alpha\right]}$ calculated with, if v_r is valid for the cylindrical section of the cyclons — on the conical section values of v_r of the cylindrical section appear broken toward the axis according to the direction tangent

$$\beta = \operatorname{arc}\operatorname{tg}\frac{r_1}{H},$$

on the cylindrical section the formula

$$d = \frac{80\,e^2}{\sqrt{(\delta-\gamma)Q}}\left(\frac{r}{r_1}\right)^n \frac{1}{\sqrt{h_1 + (r_1 - r)\operatorname{cotg}\alpha}},$$

on the conical section the formula

$$d = \frac{80\,e^2}{\sqrt{(\delta-\gamma)Q}}\left(\frac{r'}{r_1}\right)^n \frac{\sqrt{r'\operatorname{tg}\alpha}}{\sqrt{(r' + h'\operatorname{tg}\beta)\left[h_1\operatorname{tg}\alpha + r_1 - (r' + h'\operatorname{tg}\beta)\right]}}$$

is obtained where d is in μ-s, e cm is the diameter of the orifice of entry, r_1 cm is the radius of the cyclone, r cm is the distance from the axis in the cylindrical section, r' is this distance in the conical section, h_1 cm is the height of the cylindrical section of the cyclone, H cm is the height of the conical section, h' cm is the axial distance in the conical section from the common boundary of the cylindrical and of the conical sections, α is the half apex-angle of the cyclone, Q m^3/hr is the quantity of slurry fed, δ is the sp. gr. of solid particles, γ is the sp. gr. of the fluid (water), $n = 0{,}8$. In case of $h' = 0$ the equation of the conical section passes into that of the cylindrical section.

Line $v_a = 0$ may be chosen as the line connecting the apex of the cyclone with a point on the boundary of the cylindrical and of the conical sections, at distance $r'' = r_1 \frac{r_0}{r_a + r_0}$ from the axis, where r_a is the radius of the apex, r_0 that of the vortex finder. This line separates grains discharged through the vortex finder and through the apex. Computed with $r = r''$ the formula valid for the cylindrical section gives limit grain size d_l, the maximum grain size discharged in the overflow.

Formula $\Delta H = \frac{v_{t1}^2}{2gn} \left[\left(\frac{r_1}{r_0} \right)^{2n} - 1 \right]$ gives the pressure drop taking place in the cyclone in m of slurry column, if v_{t1} is expressed in m/sec.

The position of equilibrium of grain size $d = \infty$ is in the cylindrical section of the cyclone at h_1 tg α from the wall of the cyclone, in its conical section it is a straight line tending toward the axis, broken at direction tangent β. On the distance of this line depends the spreading of the grain sizes accomodating themselves on line $v_a = 0$ and the wear on the cyclone. At a distant line $d = \infty$ the spreading is great and the wear is heavy. In the cylindrical section too, a certain size fraction is spread in a broader zone, if line $d = \infty$ comes to lie far from the wall of the cyclone. "Slender" cyclones with line $d = \infty$ near are fit for classification, "stubby" cyclones with line $d = \infty$ distant, are more suited for heavy media concentration.

Numerical examples of heavy media concentration. Results of recent hydrocyclone tests on domestic raw materials.

BEITRAG ZUR KINEMATIK DES HYDROZYKLONS

G. TARJÁN

Korr. Mitglied der Ungar. Akad. der Wissenschaften

ZUSAMMENFASSUNG

Nachdem die tangentialen (v_t), radialen (v_r) und axialen (v_a) Geschwindigkeitskomponenten der im Hydrozyklon stattfindenden Flüssigkeitsströmung auf Grund der Versuche von KELSALL gewählt worden sind, wird eine zur beiläufigen Berechnung der Korngrösse der an verschiedenen Stellen des Hydrozyklons in Gleichgewicht kreiselnden Teilchen geeignete Formel ermittelt. Mit den Werten von $v_t r^n = C$ und $v_r \cong \frac{Q}{2 \pi r \left[h_1 + (r_1 - r) \operatorname{cotg} \alpha\right]}$ gerechnet, wobei v_r für den zylindrischen Teil des Zyklons gilt — am konischen Teil erscheinen die Werte von v_r gegen die Achse gemäss Richtungstangente $\beta = \operatorname{arc\,tg} \frac{r_1}{H}$ gebrochen — wird für den zylindrischen Teil die Formel

$$d = \frac{80\ e^2}{\sqrt{(\delta - \gamma) Q}} \left(\frac{r}{r_1} \right)^n \frac{1}{\sqrt{h_1 + (r_1 - r) \operatorname{cotg} \alpha}}$$

für den konischen Teil die Formel

$$d = \frac{80\ e^2}{\sqrt{(\delta - \gamma) Q}} \left(\frac{r'}{r_1} \right)^n \frac{\sqrt{r' \operatorname{tg} \alpha}}{\sqrt{(r' + h' \operatorname{tg} \beta)\left[h_1 \operatorname{tg} \alpha + r_1 - (r' + h' \operatorname{tg} \beta)\right]}}$$

erhalten, wo d in μ ausgedrückt ist, e cm der Durchmesser der Eintrittsöffnung, r_1 cm der Halbmesser des Zyklons, r cm der Abstand von der Achse im zylindrischen Teil, r' cm derselbe im konischen Teil, h_1 cm die Höhe des zylindrischen Teiles, H cm die Höhe des konischen Teiles, h' cm der axiale Abstand im konischen Teil von der Grenze des zylindrischen und des konischen Teiles, α der halbe Kegelwinkel, Q m³/St die Menge der aufgegebenen Trübe, δ die Wichte der Körner des Feststoffes, γ diejenige der Flüssigkeit (des Wassers), $n = 0{,}8$ ist. Im Falle von $h' = 0$ geht die Gleichung des konischen Teiles in diejenige des zylindrischen Teiles über.

Linie $v_a = 0$ kann als eine Gerade gewählt werden, welche die Spitze des Zyklons mit einem an der Grenze des zylindrischen und des konischen Teiles im Abstande von $r'' = r_1 \frac{r_0}{r_a + r_0}$ von der Achse befindlichen Punkte verbindet, wo r_a der Halbmesser der unteren, r_0 derjenige der oberen Austritsöffnung ist. Diese Linie trennt von einander die durch die untere und die durch die obere Austrittsöffnung ausgetragenen Teilchen. Mit dem Werte von $r = r''$ gerechnet gibt die für den zylindrischen Teil gültige Formel die Grenzkorngrösse d_l, die im oberen Überlauf ausgetragene grösste Korngrösse an.

Die Formel $\Delta H = \frac{v_{t1}^2}{2\,gn}\left[\left(\frac{r_1}{r_0}\right)^{2n} - 1\right]$ gibt das im Zyklon eingetretene Druckgefälle in m Trübensäule an, wenn v_{t1} in m/sec eingesetzt wird.

Die Gleichgewichtslage der Korngrösse $d = \infty$ ist eine im zylindrischen Teile des Zyklons in Abstand h_1 tg α von der Wand befindliche Gerade, im konischen Teile eine nach Richtungstangente β gegen die Achse gebrochene Gerade. Von der Entfernung dieser Linie hängt die Streuung der an Linie $v_a = 0$ sich befindlichen Teilchen, sowie der Verschleiss des Zyklons ab. Liegt Linie $d = \infty$ entfernt, so ist die Streuung und der Verschleiss gross. Auch im zylindrischen Teile verteilt sich eine gewisse Korngrösse in einem breiteren Abschnitt, wenn Linie $d = \infty$ weit von der Zyklonenwand liegt. »Schlanke« Zyklone mit nahe liegender Linie $d = \infty$ eignen sich mehr zur Sortierung nach Korngrösse, gedrungene Zyklone mit weit liegender Linie $d = \infty$ eignen sich mehr für Schwerflüssigkeitswäschen.

Zahlenbeispiele über das Schwerflüssigkeitsverfahren. Ergebnisse neuer Zyklonversuche mit ungarischen Rohstoffen.

CONTRIBUTION À LA CINÉMATIQUE DE L'HYDROCYCLONE

G. TARJÁN

Membre correspondant de l'Académie des Sciences de Hongrie

RÉSUMÉ

En choisissant les composantes de vitesse tangentielle (v_t), radiale (v_r) et axiale (v_a) de l'écoulement du fluide dans l'hydrocyclone, selon les observations expérimentales de KELSALL, on arrive à une formule se prêtant au calcul approximatif de la grosseur du grain en giration équilibrée à des endroits différents du cyclone. En calculant avec $v_t r^n = C$ et

$$v_r \cong \frac{Q}{2\,\pi\,r\left[h_1 + (r_1 - r)\operatorname{cotg}\alpha\right]}$$

si v = vaut pour la partie cylindrique du cyclone et dans la partie conique les valeurs de v apparaissent sur une ligne brisée selon la tangente de direction de $\beta = \operatorname{arc\,tg}\frac{r_1}{H}$ — on arrive pour la partie cylindrique à la formule

$$d = \frac{80\,e^2}{\sqrt{(\delta - \gamma)\,Q}}\left(\frac{r}{r_1}\right)^n \frac{1}{\sqrt{h_1 + (r_1 - r)\operatorname{cotg}\alpha}}$$

et pour la partie conique à la formule

$$d = \frac{80\,e^2}{\sqrt{(\delta - \gamma)\,Q}}\left(\frac{r'}{r_1}\right)^n \frac{\sqrt{r'\operatorname{tg}\alpha}}{\sqrt{(r' + h'\operatorname{tg}\beta)\left[h_1\operatorname{tg}\alpha + r_1 - (r' + h'\operatorname{tg}\beta)\right]}}$$

où d est en μ, e cm le diamètre de l'orifice d'entrée, r_1 cm le rayon du cyclone, r cm la distance de l'axe dans la partie cylindrique, r' cm la même distance dans la partie conique, h_1 cm la hauteur de la partie cylindrique, H cm la hauteur de la partie conique, h' cm la distance axiale de la borne des parties cylindrique et conique, dans la partie conique, α le demi-angle conique du cyclone, Q m³ le débit horaire en boue, δ la gravité spécifique des grains solides, γ la gravité spécifique du fluide (de l'eau), n = 0,8. En cas de $h' = 0$,1'équation de la partie conique passe dans celle de la partie cylindrique.

La ligne $v_a = 0$ peut être choisie comme la ligne droite reliant la pointe du cyclone avec un point sur la borne commune des parties cylindrique et conique à une distance $r'' = r_1\frac{r_0}{r_a + r_0}$ de l'axe où r_a est le rayon de l'orifice d'évacuation inférieur, r_0 est celui du tuyau de décharge supérieur. Cette ligne sépare les grains déchargés par les orifices d'évacuation supérieur et inférieur. Compte tenu de la valeur $r = r''$ la formule valable pour la partie cylindrique donne le calibre limite d_l, le grain le plus gros évacué par l'orifice de décharge supérieur. La formule

$\Delta H = \frac{v_{tl}^2}{2\,gn}\left[\left(\frac{r_1}{r_0}\right)^{2n} - 1\right]$ donne la chute de pression dans le cyclone, en m de la colonne de boue, si v_{tl} est en m/sec.

Le lieu d'équilibre du grain $d = \infty$ dans la partie cylindrique du cyclone est à une distance de h_1 tg α de la paroi du cyclone, dans la partie conique c'est une ligne droite brisée vers l'axe selon la tangente de direction β. De la distance de cette ligne dépend la dispersion des particules prenant place sur la ligne $v_a = 0$, et l'usure du cyclone. Si la distance de la ligne $d = \infty$ est grande, la dispersion et l'usure sont grandes. Même dans la partie cylindrique du cyclone, une certaine grosseur de grains se répandra sur une bande plus large, si la ligne $d = \infty$ est loin de la paroi du cyclone. Les cyclones «minces», à la ligne $d = \infty$ proche de la paroi, se prêtent mieux au classement, les cyclones «trapus», à la ligne $d = \infty$ plus distante, sont plus aptes à la séparation dans un agent ayant un poids spécifique supérieur à celui de l'eau (heavy media separation).

Exemples numériques sur la concentration dans un agent à poids spécifique élevé. Résultats d'essais nouveaux de lavage de matières premières hongroises dans l'hydrocyclone.

К КИНЕМАТИКЕ ГИДРОЦИКЛОНА

Член-корр. АН Венгрии Г. ТАРЬЯН

РЕЗЮМЕ

При использовании выбранных на основе опытных наблюдений Келсаля тангенциальных (v_t), радиальных (v_r) и осевых (v_a) компонентов скорости движения среды в гидроциклоне получается формула, пригодная для приближенного расчета крупности зерен, циркулирующих в равновесии в различных местах гидроциклона. Исходя из

$$v_t\, r^n = C \text{ и } v_r = \frac{Q}{2\,\pi\, r\,[h_1 + (r_1 - r)\operatorname{cotg}\alpha]}\,,$$

если v_r действителен для цилиндрической части циклона и в конической части значения v_r цилиндрической части действуют в сторону оси с учетом тангенса угла $\beta = \operatorname{arc\,tg}\frac{r_1}{H}$ тогда для цилиндрической части получаем,

$$d = \frac{80\,e^2}{\sqrt{(\delta-\gamma)\,Q}}\left(\frac{r}{r_1}\right)^n \frac{1}{\sqrt{h_1 + (r_1 - r)\operatorname{cotg}\alpha}}\,,$$

а для конической части

$$d = \frac{80\,e^2}{\sqrt{(\delta-\gamma)\,Q}}\left(\frac{r'}{r_1}\right)^n \frac{\sqrt{r'\operatorname{tg}\alpha}}{\sqrt{(r' + h'\operatorname{tg}\beta)\,[h_1\operatorname{tg}\alpha + r_1 - (r' + h'\operatorname{tg}\beta)]}}\,,$$

где d — в микронах;
e — диаметр входного отверстия, *см;*
r_1 — радиус циклона, *см;*
r — расстояние от оси в цилиндрической части, *см;*
r' — тоже самое в конической части, *см;* —
h_1 — высота цилиндрической части циклона, *см;*
H — высота конической части, *см;*
h' — расстояние вдоль оси от границы цилиндрической и конической части в конической части, *см;*
α — угол полуконуса циклона;
Q — количество поступающей пульпы, *м³/час;*
δ — удельный вес твердых частиц;
γ — удельный вес среды (воды);
n — 0,8.

В случае $h' = 0$ уравнение конической части переходит в уравнение цилиндрической части.

Линия $v_a = 0$ может быть выбрана в качестве прямой, соединяющей вершину циклона и точку, находящуюся на границе между цилиндрической и конической частиями на расстоянии $r' = r_1\frac{r_0}{r_a + r_0}$ от оси, где r_a — радиус нижнего выходного отверстия, *см;* r_0 — радиус верхнего выходного отвестия, *см.* Эта линия отделяет друг от друга уходящие через нижнюю и верхнюю отверстия циклона зерна. Исходя из значения $r = r''$, действительная в цилиндрической части формула дает предельную крупность d_l, т. е. максимальную крупность зерен, уходящих через верхние отверстия.

Формула

$$\Delta H = \frac{v_{t1}^2}{2gn}\left[\left(\frac{r_1}{r_0}\right)^{2n} - 1\right]$$

дает падение давления в циклоне для столба пульпы m, если v_{tk} *м/сек*.

Прямая, идущая в цилиндрической части циклона на расстоянии h_k tgα от стенки циклона и в конической части преломляющаяся в сторону оси под тангенсом угла β, представляет собою место равновесного положения крупности зерен $d = \infty$. От расстояния этой линии зависит рассев крупностизерен, размещающихся по линии $v_a = 0$, а также износ циклона. При большом расстоянии до линии $d = \infty$ получается большой рассев и большой износ. И в цилиндрической части циклона распределяется более широкой полосой некоторая определенная фракция крупности, если линия $d = \infty$ будет находиться на значительном расстоянии от стенки циклона. Циклоны с небольшим расстоянием до линии $d = \infty$ предназначены для классификации, а циклоны с большим расстоянием до линии $d = \infty$ наилучше всего пригодны для обогащения в тяжелых суспензиях.

Далее приводятся числовые примеры обогащения в тяжелых суспензиях. Наконец, сообщаются опытные данные гидроциклонирования отечественных материалов.

APPLICATION DE LA FORMULE DE GREEN À L'EXAMEN NUMÉRIQUE DES PLAQUES ÉLASTIQUES

K. SZMODITS
CAND. DES SCIENCES TECHN.,
INSTITUT DE LA RECHERCHE SCIENTIFIQUE ET TECHNIQUE DU BÂTIMENT, BUDAPEST

[Manuscrit présenté le 10. juillet, 1956]

Dans l'examen des plaques élastiques, on remplace généralement l'équation bipotentielle de la plaque $\Delta\Delta\, w = \frac{p}{K}$ par des équations de différences, écrites pour les noeuds du réseau régulier adopté dans le plan de la plaque, et l'on procède ensuite à la solution des équations ainsi obtenues. L'inconvénient de ce procédé réside en ce que l'expression des conditions au contour du bord de la plaque en valeurs w des noeuds, devient compliquée si le contour est de forme irrégulière et ne coïncide pas avec les lignes du réseau. Un autre inconvénient de ce procédé apparaît quand il s'agit de plaques de forme compliquée ou à bord encastré. Dans ce cas, une solution suffisamment exacte ne peut être obtenue que par l'adoption d'un réseau dense, c'est-à-dire par la solution onéreuse d'un système d'équations constitué par un grand nombre d'équations.

Le procédé ci-dessous décrit, basé sur des considérations qui relèvent de la théorie du potentiel, ne connaît pas ces inconvénients. Il ne devient, en effet, ni plus compliqué, ni plus long quand il s'agit de plaques encastrées ou de forme irrégulière. Son autre avantage est que les flèches w des différents points de la plaque peuvent être déterminées indépendamment l'une de l'autre, sans qu'il y ait besoin d'adopter des points de réseau et déterminer ensemble leurs valeurs w. Il en résulte que, pour trouver les moments exprimés par les dérivées des valeurs w, il suffira de déterminer les valeurs w dans le voisinage du lieu des moments cherchés. L'exactitude des moments ainsi obtenus peut être augmentée à volonté par la diminution de la distance des points examinés.

Le principe mathématique servant de base à ce procédé peut s'appliquer, outre l'étude des plaques élastiques, à la solution du problème de la valeur au contour d'équations potentielles ou bipotentielles relatives à d'autres problèmes physiques. Parmi les problèmes relevant de la théorie de l'élasticité, rappelons l'étude de la membrane plane, ainsi que les problèmes de la statique des voiles conduisant à une équation potentielle.

Selon la formule simplifiée de Green permettant de résoudre l'équation différentielle bipotentielle homogène $\Delta\Delta\, w = 0$, la valeur de la fonction harmonique $w\ (x, y)$, satisfaisant à l'équation potentielle homogène $\Delta w\ (x, y) = 0$, considérée dans un domaine plan limité par une courbe S close et continue dans ses dérivées seconde et plus hautes, sera

$$w(\xi, \eta) = \frac{1}{2\pi} \int_S \left[w \frac{\partial \left(\ln \frac{1}{r} \right)}{\partial n} - \ln \frac{1}{r} \frac{\partial w}{\partial n} \right] ds \tag{1}$$

dans un point intérieur ξ, η du domaine, et

$$w(\sigma) = \frac{1}{\pi} \int_S \left[w \frac{\partial \left(\ln \frac{1}{r} \right)}{\partial n} - \ln \frac{1}{r} \frac{\partial w}{\partial n} \right] ds \tag{1a}$$

dans le point au contour σ du domaine.

Dans les équations 1. et (1a) η est la normale positive de la courbe au contour S dans la direction du domaine, tandis que r est le rayon partant du point intérieur ξ, η, respectivement du point au contour σ, et aboutissant au contour. Au cours de l'intégration le point final du rayon contourne la courbe au contour fermé S dans le sens inverse des aiguilles de la montre, considéré comme positif (fig. 1.). Les formules 1. et (1a) ne sont pas directement utilisables pour la solution du premier problème de la valeur au contour. Leur application suppose non seulement la connaissance des valeurs $w(s)$ déterminant sans ambiguité le premier problème de la valeur au contour, mais encore celle des valeurs au contour $\frac{\partial w(s)}{\partial n}$ inconnues au début et ne pouvant être obtenues que par la solution du problème.

Selon la formule 1. connue, qui est obtenue par le développement des formules 1., (1a,) la valeur d'une fonction harmonique $w(x, y)$ satisfaisant à une équation bipotentielle homogène $\Delta\Delta\, w(x, y) = 0$ considérée dans un domaine plan limité par une courbe S close et continue et dans ses dérivées seconde et plus hautes est

$$w(\xi,\eta) = \frac{1}{8\pi} \int_S \left[w \frac{\partial \Delta (r^2 \ln r)}{\partial n} - \Delta (r^2 \ln r) \frac{\partial w}{\partial n} + \Delta w \cdot \frac{\partial (r^2 \ln r)}{\partial n} - r^2 \ln r \frac{\partial \Delta w}{\partial n} \right] ds\,, \tag{2}$$

dans un point intérieur ξ, η du domaine, et

$$w(\sigma) = \frac{1}{4\pi} \int_S \left[w \frac{\partial \Delta (r^2 \ln r)}{\partial n} - \Delta (r^2 \ln r) \frac{\partial w}{\partial n} + \Delta w \frac{\partial (r^2 \ln r)}{\partial n} - r^2 \ln r \frac{\partial \Delta w}{\partial n} \right] ds \tag{2a}$$

dans le point au contour σ du domaine.

Le sens des notations des équation 2. et 2a est identique à celui des équations 1. (1a) Les équations 2. et 2a ne sont pas non plus utilisables à la solution directe du problème de la valeur au contour. Pour pouvoir les appliquer en cas de $w(s)$ et $\frac{\partial w(s)}{\partial n}$ donnés, déterminant sans ambiguité le problème de la valeur au contour nous devons également connaître les valeurs au contour $\Delta w(s)$ et $\frac{\partial \Delta w(s)}{\partial n}$.

À cause des coefficients différents des intégrales identiques à leur côté droit, les formules 1. (1a) resp. 2. 2a ne donnent en apparence pas de valeurs w d'une différence infiniment petite pour un point au contour σ et un point intérieur ξ, η infiniment proche du précédent. Néanmoins la continuité subsiste entre les valeurs w des points au contour et des points intérieurs, parce que les rayons r décrivent au cours de l'intégration indiquée das les formules 1. resp. (1a) ou 2. resp. 2a, un angle 2π resp. π et la discontinuité de la fonction $w(x, y)$ se produisant de la sorte le long du contour est égalisée par les coefficients différents.

Pour appliquer les formules 2. et 2a, on a besoin des valeurs connues $w(s)$, $\frac{\partial w(s)}{\partial n}$ déterminant sans ambiguité le problème de la valeur au contour, ainsi que des valeurs au contour inconnues Δw et $\frac{\partial \Delta w}{\partial n}$. La valeur $w(\sigma)$ au côté droit de la formule 2a est identique à une valeur $w(s)$, de sorte que les valeurs $w(s)$ fournissent également la valeur $w(\sigma)$ du côté droit.

Après avoir effectué les différentiations indiquées sous les signes d'intégrale des formules 1., resp. 1a et 2. resp. 2a, on obtient les relations suivantes :

$$\frac{\partial \ln \frac{1}{r}}{\partial n} = \frac{\cos(r, n)}{r}; \qquad \frac{\partial (r^2 \ln r)}{\partial n} = (2r \ln r + r) \cos(n, r)$$

$$\frac{\partial \Delta (r^2 \ln r)}{\partial n} = \frac{\Delta \cos(r, n)}{r}; \qquad \Delta (r^2 \ln r) = 4(\ln r + 1) \tag{3}$$

Par la suite, on procède à l'examen numérique. On divise la courbe au contour S en éléments d'arc Δs de longueur égale, et au côté droit de la formule 2a on remplace $d\,s$ par $\Delta\,s$ et les valeurs au contour par une somme finie formée avec les valeurs au contour $w(s_1)$, $w(s_2) \ldots w(s_1)$ appartenant au centre des éléments d'arc Δs_1, $\Delta s_2 \ldots \Delta s_n$ (fig. 1.).

En tenant compte du groupe d'équations 3. et en introduisant les notations

$$\frac{\partial w}{\partial n} = w' ; \qquad \Delta w = X ; \qquad \frac{\partial \Delta w}{\partial n} = X' ,$$

la formule 2a exprimée par la somme finie devient

$$w(\sigma_l) = \frac{1}{4\pi} \sum_{k=1}^{k=n} \Big[r_k (2 \ln r_k + 1) \cos (r_k, n_k) X_k - r_k^2 \ln r_k X_k' +$$

$$+ \frac{4 \cos (r_k, n_k)}{r_k} w_k - 4 (\ln r_k + 1) w_k' \Big] \Delta s \tag{4}$$

En vue du calcul numérique, et pour des raisons pratiques, on transforme

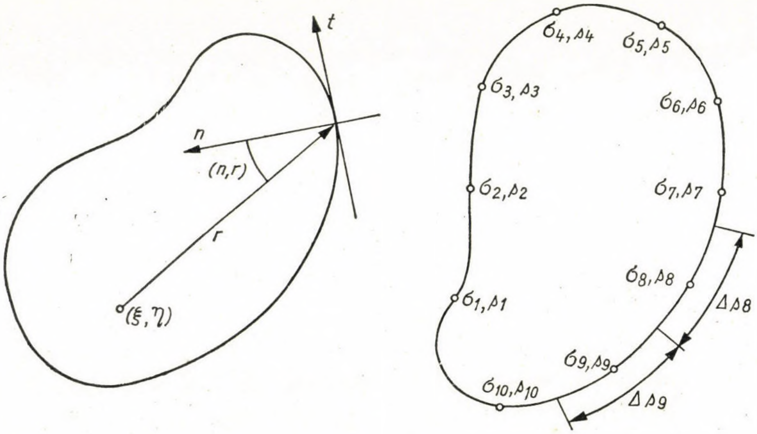


Fig. 1

la formule 4., moyennant l'introduction de la longueur unitaire r_0 de façon à la rendre convenable au point de vue des dimensions :

$$w(\sigma_l) = \frac{1}{4\omega} \sum_{k=1}^{k=n} \Big[r_k \Big(2 \ln \frac{r_k}{r_0} + 1\Big) \cos (r_k, n_k) X_k - r_k^2 \ln \frac{r_k}{r_0} X_k' +$$

$$+ \frac{4 \cos (r_k, n_k)}{r_k} w_k - 4 \Big(\ln \frac{r_k}{r_0} + 1\Big) w_k' \Big] \Delta s \tag{4a}$$

En dehors de cette équation, on peut écrire pour toutes les valeurs au contour $\Delta w = X$ la formule 1a laquelle, en tenant compte de 3. et en introduisant la longueur unitaire r_0 donnera, sous sa forme convenable au point de vue des dimensions

$$X(\sigma_l) = \frac{1}{\pi} \sum_{k=1}^{k=n} \Big[X_k \frac{\cos (r_k, n_k)}{r_k} - X_k' \ln \frac{r_k}{r_0} \Big] \Delta s \tag{5}$$

La substitution de la somme finie aux intégrales des formules 4a et 5., effectuée de la manière indiquée, conduit à une inexactitude considérable sur l'élément d'arc Δs_k contenant le point σ_k examiné. En effet, en avançant du point extrême de l'élément d'arc Δs_k vers le point σ_k, l'expression $\ln \frac{r}{r_0}$ figurant dans la somme finie, diminue rapidement jusqu'à avoir une valeur $-\infty$ dans le point σ_k, si bien que son intégrale ne peut pas être remplacée par l'expression $2\,\frac{s_k}{2} \ln \frac{r_k}{4\,r_0}$ pouvant être écrite à la base de l'approximation ci-dessus.

Dans le voisinage du point σ_k le rayon r pouvant être considéré comme coïncidant avec le contour, l'intégrale le long de Δs_k devient

$$I = \int_0^{\frac{\Delta s_k}{2}} \ln \frac{r}{r_0}\, dr = \frac{\Delta s_k}{2} \left(\ln \frac{\Delta s_k}{2\, r_0} - 1 \right).$$

Si l'on adopte un rayon $\bar{r}_k$ qui satisfait à la relation

$$I = \frac{\Delta s_k}{2} \ln \frac{\bar{r}_k}{r_0}$$

et ainsi

$$\bar{r}_k = r_0 \exp. \left(\ln \frac{\Delta s_k}{2\, r_0} - 1 \right)$$

et si, au lieu du centre de l'élément d'arc $\frac{\Delta s_k}{2}$, on compte avec les valeurs au contour du point indiqué par $\bar{r}_k$, l'inexactitude du calcul dans le voisinage du point σ_k n'augmente pas.

Vu que le nombre des points examinés est n et le nombre des inconnues x_k, x_k est $2\,n$, et que, pour chaque point, on peut écrire deux équations, notamment 4a et 5., le nombre des équations sera également $2\,n$, et les valeurs au contour inconnues x_k et x'_k pourront être déterminées par la solution du système d'équations posé.

En utilisant les valeurs au contour inconnues x et x' obtenues à l'aide du procédé numérique décrit, l'équation 2. nous permet de déterminer directement les valeurs w des points intérieurs.

On a résolu par là le problème de la valeur au contour de l'équation bipotentielle homogène, défini par les valeurs au contour $w(s)$ et $w'(s)$ données.

Grâce à cette solution, on produit la surface élastique d'une plaque chargée donnée de la façon habituelle, en écrivant une solution particulière facile à trouver, qui ne satisfait pas aux conditions au contour de l'équation bipotentielle inhomogène de la surface élastique. On l'additionne à une solution homogène résultant de notre procédé, de façon à ce que la somme des deux solutions satisfasse aux conditions au contour données.

Les conditions au contour de la plaque élastique peuvent être exprimées en fonction du mode d'appui par les relations connues suivantes :

le long du contour d'une plaque *parfaitement encastrée*

$$w = 0 ; \qquad w' = 0 .$$

le long du contour d'une plaque *reposant librement sur appuis*

$$w = 0 ; \qquad \frac{\partial^2 w}{\partial n^2} = 0 .$$

Cette dernière condition peut être exprimée également par le rayon de courbure R de la courbe de contour S ; si en effet t est la tangente du point au contour le long du contour, on a

$$\Delta w = \frac{\partial^2 w}{\partial n^2} + \frac{\partial^2 w}{\partial t^2} = \frac{\partial^2 w}{\partial n^2} + \frac{\partial^2 w}{\partial s^2} + \frac{1}{R}\frac{\partial w}{\partial n} .$$

Comme d'après les conditions au contour, les deux premiers termes du côté droit disparaissent, $\Delta w = \frac{1}{R}\frac{\partial w}{\partial n}$ ou $w' = R X$, c'est-à-dire on a le long du contour de la plaque libre

$$w = 0 ; \qquad w' = R X$$

Le long d'une plaque *à bord libre*

$$\frac{\partial^2 w}{\partial n^2} = 0 ; \qquad \frac{\partial^3 w}{\partial n^3} + (2 - \mu) \frac{\partial^3 w}{\partial n \, \partial t^2} = 0 .$$

La première condition, si l'on tient compte du cas précédent et si le taux de la déformation transversale est $\mu = 0$, est équivalente à la condition $w' = RX$. La deuxième condition ne peut être satisfaite par la formule 4a, que si $\mu = 1$, et dans ce cas elle est équivalente à la condition $X' = 0$.

Le fait que ces deux conditions ne peuvent être satisfaites que par deux valeurs différentes de μ est contradictoire, mais les conséquences pratiques en sont peu importantes, vu que l'effet des valeurs au contour adoptées de façon incorrecte diminue à mesure que l'on s'éloigne du contour, et on peut admettre que dans les points les plus éloignés du contour il devient négligeable.

Le long du contour d'une plaque à bord libre on trouvera donc approximativement :

$$w' = R X ; \qquad X' = 0 .$$

Exemple numérique. Déterminons à l'aide du procédé décrit les valeurs X et X' constantes le long du contour à cause de la symétrie circulaire, en partant des valeurs au contour données w' d'une plaque circulaire de rayon $R = 5$ m (fig. 2.) reposant librement sur appuis et chargée d'un moment constant.

En vue de l'examen numérique, on divise la moitié de la circonference du cercle en 6 parties égales. On relie les centres des parties 2, 3 . . . . . 6 par les rayons $r_2, r_3 \ldots r_6$ au point σ examiné et on calcule la longueur du rayon $\bar{r}_1$ à partir de la formule 6. Soit $r_0 = 10$ m, en ce cas

$$\bar{r}_1 = 10{,}0 \exp. (\ln 0{,}2618 - 1) = 0{,}9632 \text{ m}.$$

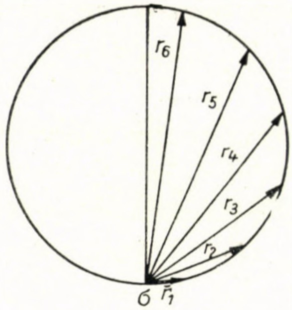


Fig. 2

En écrivant la formule 5. pour le point σ et en exprimant le premier terme de la somme finie sous forme d'intégrale — vue que $\dfrac{\cos(m, r)}{r} = \dfrac{d\varphi}{\Delta s}$ —, on obtient après intégration :

$$X(\sigma) = X - \frac{1}{\pi} \sum_k \left(\ln \frac{r_k}{r_0} X'\right) \Delta s .$$

Il en ressort que sur le contour $X' = 0$.

Le long du contour on a donc $w = 0$, $X' = 0$.

En posant pour le point de contour σ la formule 4a, on oblient l'équation suivante :

$$\frac{1}{4\pi} \sum_1^{\sigma} \left[r_k \left(2 \ln \frac{r_k}{r_0} + 1\right) \cos(r_k, n_k) X - 4 \left(\ln \frac{r_k}{r_0} + 1\right) w' \right] \Delta s = 0 .$$

En introduisant l'une après l'autre dans cette équation les valeurs $\bar{r}_1, r_2 \ldots r_6$ et $\cos(\bar{r}_1 n_1) \ldots \cos(r_6 n_6)$ et en faisant leur somme, on obtient :

$$18{,}5737\, \Delta w - 7{,}2212\, w' = 0$$

d'où

$$\frac{w'}{\Delta w} = 2{,}5721 \text{ m} .$$

La valeur exacte par contre est :

$$\frac{w'}{\Delta w} = \frac{R}{2} = 2{,}50 \text{ m}$$

c'est-à-dire l'erreur commise est de 3% environ.

LITTÉRATURE

1. v. MISES R.: Die Differential u. Integralgleichungen der Mechanik u. Physik I. p. 473 f. Braunschweig 1925.
2. W. STERNBERG: Potentialtheorie. I. II. Samml. Göschen Bd. 901, 944.

RÉSUMÉ

L'auteur utilise la formule de GREEN pour fournir la solution numérique des problèmes de la valeur au contour des équations potentielle et bipotentielle, et applique le procédé mathématique proposé à l' examen des plaques élastiques.

Le procédé substitue à la fonction continue des valeurs au contour, les valeurs discrètes de points équidistants sur le contour, et à l'aide des formules de GREEN écrites pour ces valeurs et remplacées par une somme finie il détermine les valeurs des fonctions cherchées dans les points intérieurs. Les valeurs au contour inconnues, nécessaires pour l'application de la formule de GREEN en dehors des valeurs au contour déterminant le problème sont obtenues par la solution du système d'équations de différences formé par les formules de Green écrites pour les valeurs au contour connues.

L'application du procédé est illustrée par un exemple numérique simple.

DIE ANWENDUNG DER GREENSCHEN FORMEL ZUR NUMERISCHEN UNTERSUCHUNG VON ELASTISCHEN PLATTEN

K. SZMODITS
Kandidat der techn. Wissenschaften

ZUSAMMENFASSUNG

In der vorliegenden Abhandlung wird die GREENsche Formel zur numerischen Lösung der Randwertaufgaben der Potentialgleichung und Bipotentialgleichung benutzt und die vorgeschlagene Methode zur Untersuchung der elastischen Platten angewandt.

Die vorgeschlagene Rechenmethode ersetzt die stetige Funktion der Randwerte durch die diskreten Werte von Randpunkten mit gleichem Abstand, wobei mit Hilfe der mit diesen Werten angeschriebenen — durch eine endliche Summe substituierten — GREENschen Formeln die Werte der gesuchten Funktion in den inneren Punkten bestimmt werden. Die ausser den 2 bekannten Randwerten zur Anwendung der GREENschen Formel notwendigen, die Aufgabe bestimmenden 2 unbekannten Randwerte werden von der Methode durch Auflösung des Differenzengleichungssystems geliefert, das durch die für die bekannten Randwerte angeschriebenen GREENschen Formeln gebildet wird.

Die Anwendung der Rechenmethode wird an Hand eines einfachen Zahlenbeispiels vorgeführt.

APPLICATION OF THE GREEN FORMULA TO THE NUMERICAL ANALYSIS OF ELASTIC SLABS

K. SZMODITS
Cand. of Eng. Sc.

SUMMARY

The paper uses the GREEN formula for the numerical solution of problems of boundary values of the potential and of the bipotential equations and applies the suggested mathematical procedure to the analysis of elastic slabs.

The method substitutes discrete values of boundary points at equal distance to the continuous function of boundary values and determines at the inner points the values of the function sought for, by the GREEN formulas written with those values of boundary points and substituted with finite values. The method produces the unknown boundary values, in addition to the boundary values determining the problem and necessary for the application of the GREEN formula, by the solution of the system of difference equations formed by the GREEN formulas written for the known boundary values.

A simple numerical example presents the application of the method.

ПРИМЕНЕНИЕ ФОРМУЛЫ ГРИНА ДЛЯ ЧИСЛОВОГО ИССЛЕДОВАНИЯ УПРУГИХ ПЛАСТИН

Канд. техн. наук К. СМОДИЧ

РЕЗЮМЕ

В работе формула Грина используется для числового решения задач периметрических значений потенциального и бипотенциального уравнений, и предложенный математический метод применяется для исследования упругих пластин.

Предлагаемый метод заменяет непрерывную функцию периметрических значений дискретными значениями равнопромежуточных периметрических точек, и при помощи формул Грина, составленных на основе этих значений, определяется для внутренних точек значение искомых функций. Определение же неизвестных периметрических значений сверх тех, которые определяют задачу и необходимых для применения формулы Грина, получается предлагаемым методом решения системы дифференциальных уравнений, получаемых из формул Грина, выведенных для известных окружных значений.

Применение предлагаемого метода демонстрируется простым числовым примером.

DIE ERMITTLUNG DES KERNS EINER BELIEBIGEN VIERECKSFLÄCHE

J. BARTA
DOKTOR DER TECHNISCHEN WISSENSCHAFTEN,
INSTITUT FÜR DIE BAUWISSENSCHAFTEN, BUDAPEST

[Eingegangen am 24. Juli 1956]

In der Festigkeitslehre kommt oft die Aufgabe vor, den Kern eines Querschnittes von Stäben, Balken oder Säulen zu ermitteln. Zu diesem Zweck pflegt man das bekannte Verfahren [1] anzuwenden, bei dem man die Hauptträgheitsmomente bestimmen und jene Antipolarität benutzen muss, die zwischen der Querschnittsumhüllung und Kerngrenze besteht. Dieses Verfahren ist etwas verwickelt, so dass der Gedanke naheliegt, für einfache Querschnittsformen einfache Verfahren zu suchen.

Die vorliegende Abhandlung beschreibt ein Verfahren zur Bestimmung des Kerns einer beliebigen Vierecksfläche, das ohne die Benutzung der Trägheitsmomente und der Antipolarität auskommt.

Die Beschreibung des Verfahrens

Man sucht die zu den Seiten a, b, c, d gehörigen Kernpunkte A, B, C, D. Zunächst konstruiere man den Punkt A wie folgt. Man ziehe die Diagonalen EG und FH (Bild 1). Ihr Schnittpunkt ist I. Man zeichne die Punkte I' und I'' auf die Diagonalen so auf, dass $EI' = IG$ und $FI'' = IH$ seien. Man verbinde die Punkte I' und I''. Der Halbierungspunkt ist der Punkt Z, d. h. $I'Z = ZI''$. Dann halbiere man die Seiten a, b, c, d, womit $EK = KF$, $FL = LG$, $GM = MH$, $HN = NE$ sind (Bild 2). Man verbinde jeden Halbierungspunkt mit dem Punkte Z. Diese Verbindungslinien enthalten die Kernpunkte A, B, C, D. Man kann

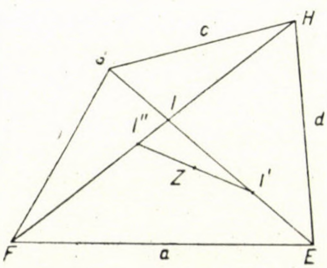


Bild 1

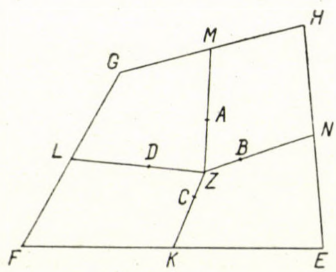


Bild 2

z. B. den Kernpunkt A wie folgt finden. Man messe im Bild 1 die Strecken IG, IH, EG, FH, im Bild 2 die Strecke ZM ab. Dann berechne man

$$ZA = \left(1 - \frac{\frac{1}{2}}{1 - \frac{IG \cdot IH}{EG \cdot FH}}\right) ZM \tag{1}$$

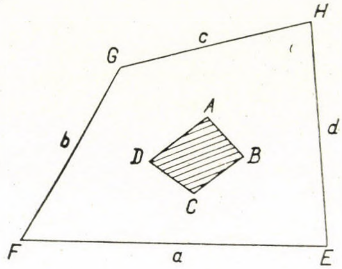


Bild 3

und trage die Strecke ZA auf (Bild 2). Damit ist der Kernpunkt A ermittelt. Analog geschieht die Ermittlung der Kernpunkte B, C, D. Hiermit ist also der Kern $ABCD$ bestimmt (Bild 3).

Die Bilder 1, 2, 3 sind hier nur der leichteren Verständlichkeithalber gesondert aufgezeichnet. In der praktischen Ausführung können sie eine einzige Figur bilden.

Der Beweis des Verfahrens

Das durch die Bilder 1, 2, 3 und durch die Formel (1) angegebene Verfahren lässt sich wie folgt beweisen. Stellen wir uns eine linear verteilte Kraft (Normalspannung) vor, die auf die Vierecksfläche wirkt. Ihre Intensität in einem Punkte sei proportional dem Abstande des Punktes von der Seite a. Die Intensität in der Seite a ist Null. Nun ist der Kernpunkt A identisch mit dem Angriffspunkt der Resultante R der verteilten Kraft. Suchen wir also diesen Angriffspunkt.

Die Vierecksfläche wird durch die Diagonalen in vier Dreiecksflächen geteilt, deren Flächeninhalte mit α, β, γ, δ (Bild 4) bezeichnet seien. Das Bild 4 zeigt auch die Vektoren $\mathbf{e}$, $\mathbf{f}$, $\mathbf{g}$, $\mathbf{h}$. Die Streckenlängen $IE = e$, $IF = f$, $IG = g$, $IH = h$ sind positive Werte. Daher gelten die Formeln

$$\alpha = \frac{1}{2} gh \sin\varphi, \quad \beta = \frac{1}{2} eh \sin\varphi, \quad \gamma = \frac{1}{2} ef \sin\varphi, \quad \delta = \frac{1}{2} fg \sin\varphi \tag{2}$$

und die Gleichungen

$$\boldsymbol{g} = -\frac{g}{e}\boldsymbol{e}, \qquad \boldsymbol{h} = -\frac{h}{f}\boldsymbol{f}. \tag{3}$$

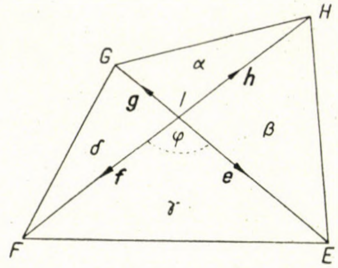


Bild 4

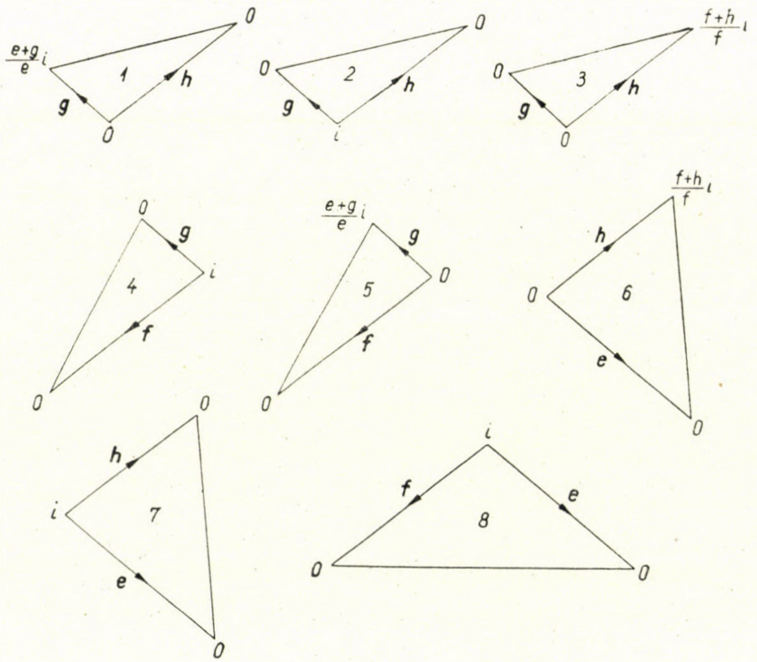


Bild 5

In den Punkten E und F ist die Intensität Null. Die Intensität im Punkte I sei mit i bezeichnet. Mithin folgt aus der Linearität, dass die Intensität im Punkte G bzw. im Punkte H

$$\frac{e+g}{e}i \qquad \text{bzw.} \qquad \frac{f+h}{f}i$$

ist. Die auf die Vierecksfläche wirkende verteilte Kraft lässt sich aus acht Teilkräften zusammensetzen, deren jede auf eine Dreiecksfläche (im Bild 5 von 1 bis 8 numeriert) wirkt und linear verteilt ist. Man kann die Resultante jeder Teilkraft leicht angeben, da sich die Verteilung einer jeden Teilkraft räumlich durch ein Tetraeder darstellen lässt. Die Teilresultanten seien mit $R_1, R_2, \ldots, R_8$, ihre Angriffspunkte mit $Q_1, Q_2, \ldots, Q_8$, der Vektor IQ_1 mit $\boldsymbol{r}_1$, der Vektor IQ_2 mit $\boldsymbol{r}_2$ usw. bezeichnet. So sind

$$R_1 = \frac{1}{3} a \frac{e+g}{e} i, \qquad R_2 = \frac{1}{3} a i, \qquad \ldots, \qquad R_8 = \frac{1}{3} \gamma i$$

und

$$\boldsymbol{r}_1 = \frac{1}{2}\left(\boldsymbol{g} + \frac{\boldsymbol{h}}{2}\right), \qquad \boldsymbol{r}_2 = \frac{1}{4}(\boldsymbol{g}+\boldsymbol{h}), \qquad \ldots, \qquad \boldsymbol{r}_8 = \frac{1}{4}(\boldsymbol{e}+\boldsymbol{f}).$$

Wenn wir diese Werte in die bekannte Formel [2]

$$\boldsymbol{r}_A = \frac{R_1 \boldsymbol{r}_1 + R_2 \boldsymbol{r}_2 + \ldots + R_8 \boldsymbol{r}_8}{R_1 + R_2 + \ldots + R_8} \tag{4}$$

einsetzen und dabei auch von den Formeln (2), (3) Gebrauch machen, ergibt sich

$$\begin{aligned} \boldsymbol{r}_A = \frac{1}{4(ef+eh+fg)} \Big\{ & (e^2 f + e^2 h - efg - egh - 2fg^2) \frac{\boldsymbol{e}}{e} + \\ & + (ef^2 + efh - 2eh^2 + f^2 g - fgh) \frac{\boldsymbol{f}}{f} \Big\}. \end{aligned} \tag{5}$$

$\boldsymbol{r}_A$ bezeichnet den Vektor IA, d. h. den Ortsvektor des Angriffspunktes der Resultante R.

Bezeichnen wir den Vektor IZ mit $\boldsymbol{r}_Z$. Dann ist, wie aus Bild 1 folgt,

$$\boldsymbol{r}_z = \frac{\boldsymbol{e}+\boldsymbol{f}+\boldsymbol{g}+\boldsymbol{h}}{2}.$$

Führen wir hier die Formel (3) ein, so ist

$$\boldsymbol{r}_Z = \frac{e-g}{2e}\boldsymbol{e} + \frac{f-h}{2f}\boldsymbol{f}. \tag{6}$$

Der Vektor ZA sei mit $\boldsymbol{v}$ bezeichnet. Nun ist

$$\boldsymbol{v} = \boldsymbol{r}_A - \boldsymbol{r}_Z.$$

Setzen wir hier die Formeln (5), (6) ein, so ergibt sich

$$\boldsymbol{v} = -\left(1 - \frac{\frac{1}{2}}{1 - \frac{gh}{(e+g)(f+h)}}\right)\frac{\boldsymbol{e}+\boldsymbol{f}}{2}. \tag{7}$$

Wird der Vektor ZM mit $\boldsymbol{m}$ bezeichnet, so ist, wie aus den Bildern 1 und 2 folgt,

$$\boldsymbol{m} = -\frac{\boldsymbol{e}+\boldsymbol{f}}{2}.$$

Wir dürfen also statt (7)

$$\boldsymbol{v} = \left(1 - \frac{\frac{1}{2}}{1 - \frac{gh}{(e+g)(f+h)}}\right)\boldsymbol{m}$$

schreiben. Diese vektorielle Gleichung beweist, unter Benutzung der Bezeichnungen $|\boldsymbol{v}| = ZA$, $g = IG$, $h = IH$, $e + g = EG$, $f + h = FH$, $|\boldsymbol{m}| = ZM$, die Richtigkeit der in den Bildern 1, 2, 3 durchgeführten Konstruktion und die Richtigkeit der skalaren Gleichung (1).

Bemerkung I

Das beschriebene Verfahren lässt sich mit der Schwerpunktermittlung verbinden. Dies geschieht wie folgt : Man verbinde die Punkte I und Z. Man teile die Strecke IZ in drei gleiche Teile (Bild 6). Der zu Z nächstliegende Teilungspunkt ist der Schwerpunkt S der Vierecksfläche.

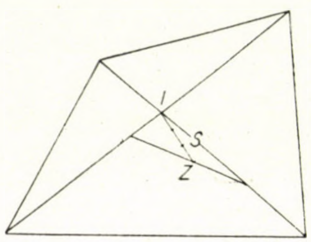


Bild 6

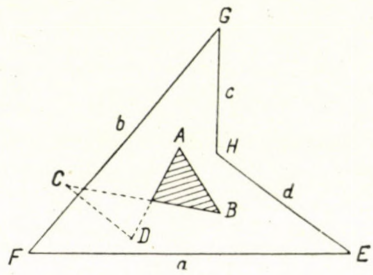


Bild 7

Bemerkung II

Alle obigen Erörterungen beziehen sich auf Vierecksflächen ohne einspringende Ecken (z. B. Bild 3). Ein ähnlicher Gedankengang lässt sich auch dann verfolgen, wenn die Vierecksfläche eine einspringende Ecke besitzt ; in diesem Falle gestaltet sich die Konstruktion nach Bild 7.

SCHRIFTTUM

1. Siehe z. B.: *Hütte*, des Ingenieurs Taschenbuch, Bd. I, Aufl. 27, S. 694, oder A. FÖPPL, Vorlesungen über technische Mechanik, Bd. 3, Aufl. 2, S. 112—118.
2. Siehe z. B.: *Hütte*, des Ingenieurs Taschenbuch, Bd. 1, Aufl. 27, S. 341.

ZUSAMMENFASSUNG

In dieser Abhandlung wird gezeigt, wie man den Kern einer Vierecksfläche leicht ermitteln kann, ohne die Trägheitsmomente und die Antipolarität zu benutzen. Das Verfahren ist aus den Bilden 1, 2, 3 und aus der Formel (1) ersichtlich.

DETERMINATION OF THE KERN OF A TRAPEZOID

J. BARTA
D. of Eng. Sc.

SUMMARY

This paper shows that the kern of a trapezoid can be obtained by a simple way, without using the moments of inertia and the antipolarity. Figures 1, 2, 3 and formula (1) show the method.

DÉTERMINATION DU NOYAU CENTRAL D'UN QUADRILATÈRE

J. BARTA
Docteur des Sc. Techn.

RÉSUMÉ

Ce travail démontre la possibilité de trouver simplement le noyau central d'un quadrilatère sans faire usage des moments d'inertie et du système antipolaire. Les figures 1, 2, 3 et la formule (1) montrent le procédé.

ОПРЕДЕЛЕНИЕ ЯДРА ПРОИЗВОЛЬНОГО ТРАПЕЗОИДА

Й. БАРТА
д-р техн. наук

РЕЗЮМЕ

В статье показан простейший метод определения ядра трапезоида без использования момента инерции и антиполярности. Предлагаемый метод демонстрируется на рис. 1, 2, 3 и приведенной формулой (1).

MÉTHODE DE CALCUL NUMÉRIQUE DES CONTRAINTES CAUSÉES PAR LA TORSION

Prof. P. CSONKA
DOCTEUR DES SCIENCES TECHNIQUES
UNIVERSITÉ TECHNIQUE DU BATIMENT ET DES TRANSPORTS, BUDAPEST,
CHAIRE DE RÉSISTANCE DES MATÉRIAUX

[Reçu le 19 septembre 1956]

1. Introduction

On connaît plusieurs méthodes numériques du calcul des contraintes des barres prismatiques à section pleine soumises à une torsion pure [1, 2, 3]. Toutes ces méthodes nécessitent la détermination de la fonction de forces, ou du potentiel des tensions, avant le calcul des contraintes. Par contre, dans ce qui va suivre nous allons décrire une méthode qui permet de calculer les contraintes engendrées au contour de la section sans la détermination préalable de la fonction de forces ou du potentiel de tension.

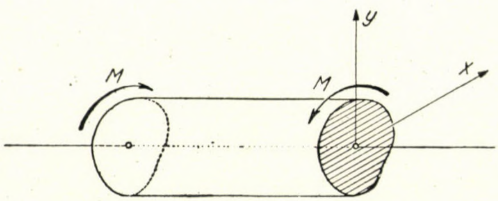


Fig. 1. Barre soumise à la torsion

La méthode en question est basée sur les formules de Green, de la même façon que l'est la méthode de K. Szmodits pour la solution numérique du problème des plaques [4]. Cette méthode se montre avantageuse aussi au cours du calcul des contraintes.

2. Données fondamentales

Soit (Fig. 1) M le moment du couple des forces agissant sur les extrémités de la barre, ϑ la torsion par unité de longueur, G le module d'élasticité transversale, F la surface de la section et finalement S son contour. Désignons la tangente au contour de la section par t, sa normale par n, la contrainte de cisaillement engendrée au contour par τ. Considérons comme sens positif du moment de torsion et de l'angle de torsion de la barre celui de la Figure 1, pendant que les quantités t, n et τ seront positives dans le sens marqué à la Figure 2.

Il est bien connu, que la fonction de forces [5] est une fonction $f(x, y)$ satisfaisant à l'équation differentielle

$$\Delta f = -2 G \vartheta . \tag{1}$$

La valeur de cette fonction est zéro au contour de la section :

$$f(S) = 0 . \tag{2}$$

Connaissant la fonction de forces, la contrainte de cisaillement engendrée au contour est

$$\tau = -\frac{\partial f}{\partial n} . \tag{3}$$

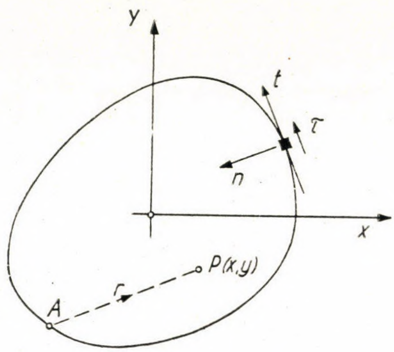


Fig. 2. Section de la barre

Par cette méthode, nous obtenons τ comme fonction de ϑ. Si cet angle est inconnu, on peut le déterminer par la relation de PRANDTL :

$$2 \int_{(F)} f \, dF = M . \tag{4}$$

3. Solution du problème

Choisissons un point A quelconque du plan x, y, nommons le point fondamental et désignons la distance des points du plan x, y de ce point par r. Quand le point fondamental est situé sur le contour de la section, on a suivant une variante connue de la formule de GREEN [6]

$$\int_{(S)} u \frac{\partial (\ln r)}{\partial n} dS - \int_{(S)} \frac{\partial u}{\partial n} \ln r \, dS + \int_{(F)} \Delta u \ln r \, dF = \pi u (A) . \tag{5a}$$

Par contre, si le point fondamental se trouve à l'intérieur de la section, on a

$$\int_{(S)} u \frac{\partial (\ln r)}{\partial n} d S - \int_{(S)} \frac{\partial u}{\partial n} \ln r \, dS + \int_{(F)} \Delta u \ln r \, dF = 2 \pi u (A) . \tag{5b}$$

En appliquant la formule (5a) ou (5b) à la fonction de forces de la torsion et en considérant aussi (1), (2) et (3), on trouve les relations

$$\int_{(S)} \tau \ln r \, dS - 2 G \vartheta \int_{(F)} \ln r \, dF = 0 , \tag{6a}$$

ainsi que

$$\int_{(S)} \tau \ln r \, dS - 2 G \vartheta \int_{(F)} \ln r \, dF = 2 \pi f(A) . \tag{6b}$$

De ces deux formules, nous pouvons utiliser (6a) pour le calcul des contraintes engendrées au contour et la formule (6b) — si nécessaire — pour le calcul des valeurs f appartenant aux points à l'intérieur de la section.

En cas de calculs numériques il est indiqué de passer des intégrales de surface des premières deux formules à des intégrales linéaires. Pour cela, désignons provisoirement par R les rayons tracés du point A aux points du contour et par r les rayons tracés aux points intérieurs de la surface (Fig. 3).

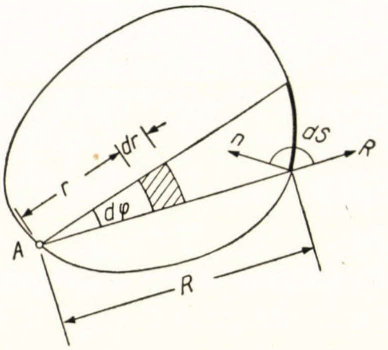


Fig. 3. Données pour le calcul

Avec ces notations,

$$\int_{(F)} \ln r \, dF = \int_0^{\pi} \int_0^{R} r \ln r \, dr \, d\varphi = \int_0^{\pi} \left[\frac{r^2}{2} \ln r - \frac{r^2}{4} \right]_0^R d\varphi .$$

Partant de là, nous arrivons par intégration suivant φ à la formule

$$\int_{(F)} \ln r \, dF = \frac{1}{2} \int_0^{\pi} R^2 \ln R \, d\varphi - \frac{F}{2} .$$

Mais

$$d\varphi = - \frac{1}{R} \cos (Rn) \, dS ,$$

et en conséquence

$$\int_{(F)} \ln r \, dF = - \frac{1}{2} \int_{(S)} R \cos (Rn) \ln R \, dS - \frac{F}{2} .$$

Finalement, si nous désignons de nouveau les rayons tracés aux points du contour par r, nous arrivons à la relation

$$\int_{(F)} \ln r \, dF = -\frac{1}{2} \int_{(S)} r \cos(rn) \ln r \, dS - \frac{F}{2} . \tag{7}$$

En utilisant cette dernière équation, nous pouvons aussi écrire la formule (6a) de la façon suivante

$$\int_{(S)} \tau \ln r \, dS + G\vartheta \int_{(S)} r \cos(rn) \ln r \, dS + G\vartheta F = 0 \tag{8}$$

et nous pouvons transformer de façon semblable aussi la formule (6b).

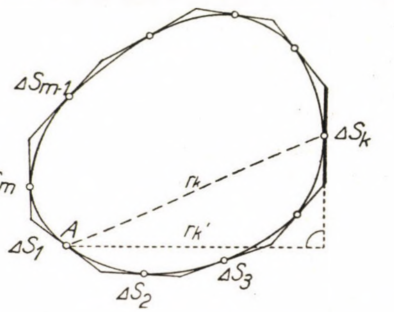


Fig. 4. La section de la barre et le polygone de substitution

Pour rendre possible le calcul numérique, nous allons remplacer, dans ce qui va suivre, la section de la barre par un polygone. Nous accomplisons cette substitution de façon à ce que les côtés du polygone $\Delta S_1, \Delta S_2, \ldots \Delta S_k, \ldots \Delta S_m$ soient égaux ou approximativement égaux (Fig. 4). Comme point fondamental A nous choisissons le milieu du premier côté du polygone. Le long de chaque côté du polygone nous considérons la contrainte de cisaillement τ, comme constante, c'est-à-dire nous remplaçons chacune par la valeur moyenne respective $\tau_1, \tau_2, \ldots \tau_k, \ldots \tau_m$. Cette simplification est permise en général pour des section sans angles rentrants. Si nous considérons encore que le long des côtés du polygone les valeurs $r \cos(r\,n)$ sont constantes, par exemple dans le cas du k-ième côté

$$r \cos(r\,n) = -r_k' ,$$

la formule (8) peut être remplacés par la formule approchée suivante :

$$\sum_1^m \tau_k I_k + G\vartheta \left(F - \sum_1^m r_k' I_k\right) = 0 . \tag{9}$$

La signification du symbole I_k figurant dans cette expression est :

$$I_k \equiv \int_{(\Delta S_k)} \ln r \, dS . \tag{10}$$

Nous pouvons calculer de façon simple les quantités I_k appartenant aux côtés ΔS_k du polygone. Pour le premier côté

$$I_1 = 2 \int_0^{\frac{\Delta S_1}{2}} \ln x \, dx = 2 \left[x (\ln x - 1) \right]_0^{\frac{\Delta S_1}{2}} ,$$

ou bien

$$I_1 = (\ln \Delta S_1 - \ln 2 - 1) \Delta S_1 . \tag{11a}$$

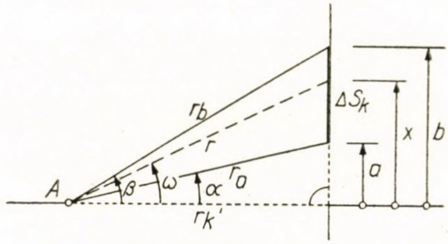


Fig. 5. Données pour le calcul

Pour les autres côtés du polygone (voir Fig. 5) :

$$I_k = [x \ln r - x + r_k' \omega]_a^b ; \quad k \neq 1 .$$

De cette dernière formule nous obtenons, en y introduisant les limites, la formule

$$I_k = b \ln r_b - a \ln r_a - \Delta S_k + r_k' (\beta - \alpha) ; \quad k \neq 1 . \tag{11b}$$

Si le long d'un côté ΔS_k du polygone, ln r ne change pas de façon considérable, nous pouvons remplacer les valeurs ln r appartenant aux différents points du côté par la valeur ln r_k appartenant à son milieu. En ce cas, nous utilisons au lieu de la formule (11b) la formule suivante :

$$I_k \cong \ln r_k \Delta S_k ; \quad k \neq 1 . \tag{11c}$$

Écrivant la formule (9) séparément pour les milieux de chaque côté, nous obtenons un système d'équations ou il n'y a que les valeurs τ_k qui soient inconnues. De ce système de m équations linéaires inhomogènes, nous pouvons calculer sans équivoque les valeurs τ_k cherchées.

4. Remarques

Les formules précédentes ont l'imperfection, de contenir au lieu des logarithmes de nombres purs des logarithmes de longueurs. Nous pouvons éliminer facilement ce défaut en écrivant à la place des nombres des logarithmes le rapport de ces longueurs et de l'unité de longueur [4].

Il faut considérer aussi la question de ce que deviennent nos formules si nous exprimons les longueurs en d'autres unités, par exemple en mm au-lieu de cm. Soient, par exemple, les valeurs numériques des longueurs dans le système nouveau c-fois les valeurs originales. Dans ce cas, après les simplifications possibles, nous pouvons écrire au lieu de la formule (8) la formule

$$\int_{(S)} \tau \ln (cr)\, dS + G\vartheta \int_{(S)} r \cos (rn) \ln (cr) \;\; dS + G\vartheta F = 0 \,, \tag{12}$$

qui ne diffère de la formule (8) qu'en ce que $\ln r$ y est partout remplacé par $\ln (cr)$. Il faut donc démontrer que la formule (12) exprime la même chose que la formule (8). Pour cela, il faut partir de la relation

$$\ln (c\, r) = \ln c + \ln r \,.$$

En l'utilisant, nous pouvons transformer la formule (12) de la façon suivante :

$$\ln c \int_{(S)} \tau\, dS + \int_{(S)} \tau \ln r\, dS + G\vartheta \ln c \int_{(S)} r \cos (rn)\, dS +$$
$$+ G\vartheta \int_{(S)} r \cos (rn) \ln r\, dS + G\vartheta F = 0 \,. \tag{13}$$

Étant donné que

$$\int_{(S)} r \cos (rn)\, dS = -\, 2\, F \,, \tag{14}$$

et que suivant la formule de Stokes

$$\int_{(S)} \tau\, dS = 2\, G\vartheta F \,, \tag{15}$$

nous retrouvons la formule originale (8) en introduisant (14) et (15) dans la formule (13). Il s'ensuit que le changement du système des unités ne change pas le contenu de l'équation (8).

En tenant compte de ceci, il est utile de choisir les unités de longueur dans les équations de façon à ce que tous les logarithmes soient du même signe.

5. Exemple numérique

Nous allons appliquer la méthode que nous venons de décrire à une section circulaire de rayon $a = 0{,}5$ (Fig. 6).

En remplaçant la circonférence du cercle par un polygone circonscrit régulier de 12 côtés, la longueur de chaque côté est

$$\Delta\, S_k = 0{,}268$$

et la surface du polygone est

$$F = 0{,}804 \,.$$

Chosissions comme point fondamental le milieu du premier côté du polygone, et déterminons la longueur des rayons $r_1, r_2, \ldots, r_{12}$ appartenant aux milieux de côtés, ainsi que les distances $r_1', r_2', \ldots, r_{12}'$ entre les milieux des côtés et le point fondamental. Ensuite, calculons les valeurs $I_1, I_2, \ldots, I_{12}$ et $r_1' I_1, r_2' I_2, \ldots, r_{12}' I_{12}$ appartenant aux côtés du polygone. En calculant les valeurs I_1 par la formule (11a), les valeurs I_2, I_3, ..., I_{12} par la formule approximative (11c) nous trouvons les résultats suivants :

k	r_k	r'_k	I_k	$r'_k\, I_k$
1	0,000	0,000	—0,807	0,000
2	0,259	0,067	—0,362	—0,024
3	0,500	0,250	—0,186	—0,046
4	1,414	0,500	—0,093	—0,046
5	0,866	0,750	—0,039	—0,029
6	0,966	0,933	—0,009	—0,009
7	1,000	1,000	0,000	0,000
8	0,966	0,933	—0,009	—0,009
9	0,866	0,750	—0,039	—0,029
10	1,414	0,500	—0,093	—0,046
11	0,500	0,250	—0,186	—0,046
12	0,259	0,067	—0,362	—0,024
			—2,185	—0,308

Écrivons ensuite l'équation (9) pour le point fondamental A :

$$\tau \sum_1^m I_k + G\,\vartheta\,(F - \sum_1^m r'_k\, I_k) = 0\,.$$

De là, en substituant les valeurs numériques précédentes nous obtenons l'équation

$$-\,2{,}185\,\tau + G\,\vartheta\,(0{,}804 + 0{,}308) = 0\,.$$

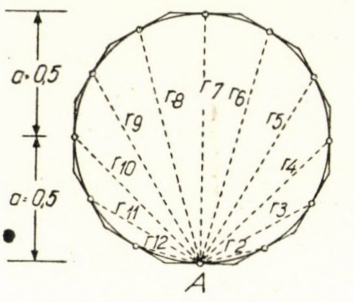


Fig. 6. Section circulaire

Dans cette équation il n'y a qu'une seule inconnue, dont la valeur est

$$\tau = 0{,}509\, G\,\vartheta\,.$$

Par contre, la valeur exacte en est

$$\tau = a\,G\,\vartheta = 0{,}5\,G\,\vartheta\,,$$

donc l'erreur commise au cours du calcul approximatif n'est que 1,8%. L'erreur provient surtout du fait que nous avons choisi comme polygone de remplacement le polygone circonscrit au lieu du polygone de surface égale. Si nous avions utilisé ce dernier, l'erreur ne serait que 0,6%.

LITTÉRATURE

1. Runge, C.: Über eine Methode, die partielle Differentialgleichung $\Delta u =$ constans numerisch zu intergrieren. *Zeitschrift für Mathematik und Physik* 56 (1908), pp. 225—232.
2. Richardson, L. F.: The Approximate Arithmetical Solution by Finite Differences of Physical Problems Involving Differential Equations, with an Application to the Stresses in a Masonry Dam. *Philosophical Transactions of the Royal Society of London.* A. 210 (1911), pp. 307—357.
3. Liebmann, H.: Die angenäherte Ermittlung harmonischer Funktionen und konformer Abbildungen. *Sitzungsberichte der mathematisch-physikalischen Klasse der K. B. Akademie der Wissenschaften zu München* (1918), pp. 385—416.
4. Szmodits, K.: L'utilisation de la formule de Green à l'examen numérique des plaques élastiques. *Acta Technica. 18* (1957) 383/392.
5. Timoshenko, S.: Theory of Elasticity. I. Ed. p. 230. McGraw-Hill Book Company, Inc. New York and London, 1934.
6. v. Mises, R.: Die Differential- u. Integralgleichungen der Mechanik u. Physik I, pp. 473—474. Friedr. Vieweg und Sohn A. G., Braunschweig, 1925.

RÉSUMÉ

La méthode de calcul numérique décrite ci-dessus permet de calculer d'une façon simple les tensions engendrées dans les sections d'une barre prismatique pleine soumise à la torsion simple, à condition que l'angle spécifique de torsion soit connu. La section de la barre est remplacée par une section polygonale et le long des côtés du polygone, les tensions de cisaillement sont remplacées par leur moyennes. La formule de Green est utilisée pour le calcul de ces moyennes inconnues. Si on écrit cette formule pour chaque côté du polygone, on obtient un système un constitué de tant d'équations linéaires qu'il y a de côtés de polygone. De ce système d'équations, on peut déterminer sans équivoque les tensions de cisaillement le long de chaque côté du polygone. Le travail s'achève par un exemple numérique, dont les résultats ne dévient que de peu des résultats du calcul exact.

EIN NUMERISCHES VERFAHREN FÜR DIE BERECHNUNG DER TORSIONSSPANNUNGEN

P. CSONKA
Doktor der technischen Wissenschaften

ZUSAMMENFASSUNG

In der Arbeit wird ein numerisches Verfahren bekanntgegeben, mit dessen Hilfe die in den Querschnitten eines auf reine Verdrehung beanspruchten Stabes entstehenden Spannungen einfach berechnet werden können, vorausgesetzt dass der spezifische Verdrehungswinkel bekannt ist. Der Querschnitt des Stabes wird durch einen Polygonquerschnitt ersetzt und entlang den einzelnen Polygonseiten werden die Schubspannungen durch deren Durchschnittswerte ersetzt. Zur Bestimmung dieser unbekannten Durchschnittswerte wird die Green'sche Formel verwendet. Wenn diese für jede Polygonseite gesondert aufgeschrieben wird, erhält man ein System von so vielen linearen Gleichungen, wie die Anzahl der Polygonseiten beträgt. Aus diesem Gleichungssystem können die Näherungswerte der entlang den einzelnen Polygonseiten wirkenden Schubspannungen eindeutig bestimmt werden. Die Arbeit wird durch ein Zahlenbeispiel abgeschlossen, wobei die Ergebnisse nur wenig von den Ergebnissen der genauen Rechnung abweichen.

A METHOD FOR THE ARITHMETICAL DETERMINATION OF TORSIONAL STRESSES

P. CSONKA
D. of Eng. Sc.

SUMMARY

In the paper a numerical method is described by which the shear stresses arising in a solid prismatic bar, submitted to pure torsion, are easily calculated, provided the angle of twist per unit length is known.

According to the paper, the cross section of the bar is replaced by a polygonal one and along the sides of the polygone, the shear stresses are replaced by their average values. GREEN's formula is used for computing these unknown average values. Establishing these equations separately for the middle of each side of the polygone, the author obtains a system of linear equations. The number of equations is equal to the number of polygon sides. From this system of equations the approximate value of the shear stresses along the individual polygone sides can be entirely determinated.

The paper is terminated by a numerical example. The result differs only slightly from the result of the precise calculations.

ЧИСЛОВОЙ МЕТОД РАСЧЕТА НАПРЯЖЕНИЙ КРУЧЕНИЯ

Д-р техн. наук П. ЧОНКА

РЕЗЮМЕ

Сообщается числовой метод, позволяющий простыми расчетами определить напряжение среза при чистом кручении в сечении сплошного призматического стержня при условии — что известен угол удельного скручивания.

Профиль поперечного сечения аппроксимируется многоугольником, а напряжение среза вдоль отдельных сторон многоугольника замещается их средним значением. Для определения этих неизвестных средних значений используется формула Грина. Формула составляется для срезной точки каждой стороны многоугольника отдельно и, таким образом, получается система линейных уравнений, состоящая из такого же числа уравнений, какое число сторон имеет многоугольник. Приближенные значения напряжения среза вдоль отдельных сторон многоугольника можно определить однозначно, используя эту систему уравнений.

В конце статьи дается числовой пример. Полученный результат мало отличается от результата точных расчетов.

UNTERSUCHUNGEN ÜBER DIE KORNGRÖSSE DES MITTELS LUFTAUSRÜHRENS HERGESTELLTEN TONERDEHYDRATES

S. DUNAY und M. KALMÁR
FORSCHUNGSINSTITUT DER METALLINDUSTRIE, BUDAPEST

[Eingegangen am 5. Oktober 1956]

Bei Untersuchung der Wirksamkeit von Impfhydraten prüften WRIGGE und GINSBERG [1] vor allem den Einfluss der physikalischen Eigenschaften im Zusammenhang mit der Ausbildung der Kristalloberflächen. Nach ihrer Meinung wird die Erhöhung der Hydratausscheidungsgeschwindigkeit durch solche Stoffe hervorgerufen, die kristallisiertes Aluminiumtrihydrat in Hydrargillitform enthalten. Die auf Aluminatlaugen ausgeübte Impfwirkung hängt von der Menge des kristallisierten Hydrargillits ab.

Daneben stellten die oben genannten Autoren fest, dass eine langsamere Impfwirkung auch bei Verwendung von Tonerde zu beobachten ist.

Der Korngrösse des Impfhydrats kommt — ihrer Meinung nach — keine besondere Bedeutung zu, demgegenüber spielen die Oberflächen eine entscheidende Rolle.

Das Ergebnis wird durch Erhöhung der Menge des Impfstoffes — wahrscheinlich infolge des häufigeren Vorkommens der sog. Leerstellen — verbessert. Es muss auch daran erinnert werden, dass die Ausscheidung neuer Kristallschichten an Aktiv- oder Leerstellen weniger Energie erfordert als die Bildung eines neuen Kristallkeimes.

Wird ein solcher Aktivstellen enthaltende Kristall in eine übersättigte Lösung eingesetzt, dann beginnt das Kristallwachstum an diesen Aktivstellen. Die zur Bildung der neuen Kristallkeime notwendige gesamte Energiemenge wird erst nach Anlagerung einer neuen Schicht benötigt, demgemäss wird das Weiterwachsen des Kristalls auch langsamer vor sich gehen.

Im Laufe der Versuche der Autoren war eine vollkommene Impfwirkung auch bei Verwendung von Grobhydrat, sogar von mehrere Monate lang getrocknetem Hydrat zu beobachten.

Die Autoren setzten voraus, dass mehrere oder wenigere Leerstellen wegen des raschen Ausscheidens an allen Seiten des Kristalls übrigbleiben. Die Impfwirkung bestand auch dann weiter, wenn die Kristalle in die gesättigte Lösung mehrmals zurückgesetzt wurden, da an den neugebildeten Kristallen wieder Leerstellen vorhanden sind. An diesen Kristallen verringert sich die Zahl der Aktivstellen. Darauf weist die Veränderung der Alkaliadsorptionsfähigkeit hin, die gegenüber der Ursprünglichen um 70—75% geringer wurde.

Durch solches wiederholtes Rückführen war es möglich, Kristalle von geringer Impfwirkung herzustellen, die aber ihre Aktivität nach Behandlung mit verdünnter Salzsäure wieder zurückgewannen.

Durch entsprechendes Auswählen der Kristallisationsbedingungen kann die Aktivität des Impfhydrats bis zu einem gewissen Grade erhöht werden, z. B. wenn die Ausbildung der Kristalle gestört wird. (Intensive Rührung!) Die Häufung der Leerstellen an den kleinen Kristallen kann nicht nach Belieben erhöht werden, da hierbei ein schleimiger, unfiltrierbarer Stoff entsteht.

Die Autoren schreiben der bei verschiedenen Temperaturen durchgeführten Vorbehandlung keine besondere Bedeutung zu, nur ist die Intensität des Rührens entscheidend.

In einer weiteren Mitteilung [2] beschrieb GINSBERG jene Untersuchungen, bei denen galliumhaltige Aluminatlaugen zersetzt wurden. Durch die Isomorphie von Al_2O_3 und Ga_2O_3 konnte die Annahme unterstützt werden, dass die Wirkung des Impfstoffes von den an der Oberfläche des Hydrargillits befindlichen Aktivstellen abhängt.

Von japanischen Forschern [3] wurden 9 Hydrargillite und 7 Bayerite — als Versuchsmuster — bei Temperaturen von 30—75° C aus verschiedene Menge von NaOH und Al_2O_3 enthaltenden Aluminatlaugen zum Ausscheiden gebracht.

Verschiedene $Al_2O_3 \cdot H_2O$-Präparate als Impfstoffe anwendend haben diese Autoren eine, 140 g/Liter NaOH und 105 g/Liter Al_2O_2 enthaltende Aluminatlauge hydrolisieren lassen.

Die Aktivität der verschiedenen Präparate war verschieden, wodurch die Wichtigkeit des Impfstoffoberflächezustandes erwiesen wurde.

Die sich als aktiv erweisenden Impfkristalle zeigten unter dem Elektronenmikroskop eine unregelmässige Form.

Aus obigen Erfahrungen ist ersichtlich, dass als Ursache der Impfkristall-Aktivität die durch unvollkommene Kristallisation entstandenen komplizierten Kristalloberflächen anzusehen sind.

Aus den oben beschriebenen Literaturangaben kann gefolgert werden, dass die Dimension der Aktivstellen bei Qualifizierung der Impfhydrate von grösster Wichtigkeit ist.

Es kann auch festgestellt werden, dass die kleineren Teilchen — auf gleiches Hydratgewicht bezogen — mit Hinsicht auf die Aktivstellen günstiger sind, jedoch dass ein äusserst feinkörniges Hydrat kein entsprechender Impfstoff ist, da es ein schleimiges Produkt ergibt. Die beschriebenen Untersuchungen weisen auch darauf hin, dass der Kristallisationsverlauf durch die Umstände des Ausrührens ebenso, wie durch die Zusammensetzung der zur Verarbeitung gelangenden Aluminatlauge, beeinflusst wird, weshalb wir Untersuchungen unter Betriebsumständen einer Tonerdefabrik fortgesetzt haben. Hierdurch war es möglich, der Praxis besser angenäherte Ergebnisse zu sammeln, als wenn die Untersuchungen nur im Laboratorium durchgeführt worden wären.

Durch Untersuchungen wollten wir die Veränderungen an Impfstoffkörnchen verschiedener Korngrössen bei betriebsmässigem Luftausrühren prüfen.

Wir haben darum zum Luftausrühren gegriffen, da eine den richtigen Zustand widerspiegelnde Probenahme wegen der bei dem mechanischen Ausrühren eintretenden Sedimentation unmöglich war.

Wir wollten die Veränderung der Impfhydrate auf die Weise verfolgen, dass, nachdem die Kornverteilung des Impfstoffes bestimmt wurde, dieselbe an während des Ausrührens genommenen Hydratproben ermittelt wird. Die Vorbedingung solch einer Bestimmung bildet eine zuverlässige, genügend empfindliche Messmethode. Um eine solche auszuwählen, wurden die möglichen Methoden praktisch überprüft.

Die Bestimmung der Kornverteilung

Zur Bestimmung der Kornverteilung dient als einfachste Methode die Siebanalyse. Eine gewogene Stoffmenge wird durch Siebe verschiedener Maschenweiten gesiebt und die Menge der einzelnen Siebfraktionen gewogen. Da die in der Praxis benutzten Siebfeinheiten eine Trennung der Fraktionen nur in ziemlich groben Stufen ermöglichen, war diese Methode für uns nicht brauchbar.

Bedeutend empfindlichere Korngrössenbestimmungen können durch Beobachtung der Teilchensedimentation in einer Flüssigkeit ausgeführt werden.

Die Sedimentationsverfahren beruhen auf der Beobachtung, dass die kleinen Teilchen in einer Flüssigkeit mit konstanter Geschwindigkeit absinken. Nach Feststellung von STOKES besteht zwischen der Fallgeschwindigkeit und dem Radius eines kugelförmigen Körpers folgender Zusammenhang :

$$v = \frac{2g(d_1 - d_2)}{9\eta} r^2$$

v = Geschwindigkeit des absinkenden Körpers
g = Fallbeschleunigung
d_1 = spezifisches Gewicht des absinkenden Körpers
d_2 = spezifisches Gewicht der Flüssigkeit
η = Viskosität der Flüssigkeit
r = Radius des absinkenden Körpers

Aus der obigen Gleichung kann der Radius berechnet werden :

$$r^2 = \frac{9 v \eta}{2g(d_1 - d_2)}.$$

Mittels der Methode von APPIANI—ATTERBERG [4] können die Teilchen in Fraktionen beliebiger Korngrössen getrennt werden.

Der hierzu nötige Apparat besteht aus einem etwa 45 cm hohen, mit Kork verschliessbaren Glaszylinder. Am unteren Teil ist an diesem zum Ablassen der Flüssigkeit ein Glasrohr angebracht. Die Aufschlämmung der kleineren Teilchen wird in niedrigerer Flüssigkeitssäule durchgeführt, um eine zu lang dauernde Absetzzeit zu vermeiden. Aus der Stockesschen Formel kann die bei einer bestimmten Korngrösse nötige Absetzdauer bei einer gewissen Absetzhöhe berechnet werden. Die durch das Seitenrohr während der berechneten Zeit abgelassene Flüssigkeit enthält die Teilchen, die kleiner sind als die, die der Absetzdauer entsprechen. Durch die richtige Auswahl der Absetzdauer können beliebige Korngrössefraktionen getrennt werden.

Auch das *Pipettenverfahren* ist allgemein gebräuchlich. Aus der durchgeschüttelten Trübe wird nach Ablauf der zur Sedimentation einer bestimmten Korngrösse r nötigen Zeitdauer t, aus einer Höhe a mittels einer Pipette eine Flüssigkeitsmenge von bekanntem Volumen herausgenommen. Während der Zeitdauer t sinken die Teilchen, die grösser als die gewählte Korngrösse r sind, unter die Höhe a. Aus der, in einer Höhe a liegenden Schicht herausgenommenen Probe sind am Ende der Zeitdauer t nur Teilchen, deren Korngrösse kleiner als r ist, zugegen. Der feste Teil der Probe wird nach dem Trocknen gewogen, und die Menge der Teilchen, deren Korngrösse kleiner als r ist — auf die ganze Flüssigkeitsmenge bezogen — berechnet.

Es sind auch Methoden bekannt, bei welchen die einzelnen Fraktionen nicht voneinander getrennt werden, sondern nur Angaben über die Korngrösse-verteilung liefern. Das Prinzip dieser Methoden ist gleich. Das spezifische Gewicht der wässerigen Suspension ist grösser als die des Wassers. Wie nun die schwebenden Teilchen sich absetzen, so vermindert sich das spezifische Gewicht der Trübe. Zwischen dem spezifischen Gewicht der Suspension, der Tiefe der untersuchten Schicht und der Zeitdauer des Absetzens besteht ein fester Zusammenhang. Wird das sp. Gewicht der Trübe gemessen, kann durch diesen Wert auf die Menge der schwebenden oder schon abgesetzten Teilchen gefolgert werden.

Unter den auf der Bestimmung des sp. Gewichtes fussenden Methoden ist die *Areometermethode* die bekannteste.

Das fest-flüssige Gemisch wird gut durchgeschüttelt, das Areometer vorsichtig eingesetzt, und dessen Einteilung von Zeit zu Zeit abgelesen.

Die Berechnung kann mittels der folgenden zwei Gleichungen ausgeführt werden :

$$2r = \frac{1800\,\eta\, h}{(d_1 - d_2)\, t}$$

r, d_2, d_2, η sind die gleichen Werte wie in der Stokesschen Formel,
h = Tiefe des Areometerschwerpunktes,
t = verstrichene Zeit.

$$p = \frac{100\, d_1}{\frac{s}{d_1} - L}\,(L + j)$$

p = Gewichtsprozente der abgesetzten Teilchen,
s = Gewicht des geprüften Stoffes,
L = Ablesewerte des Areometers,
j = Temperaturkorrektion.

Auch nach Methode von F. Evva [5] werden die verschiedenen Fraktionen voneinander nicht getrennt. Das Absetzen wird in einem 1 m langen Glasrohr ausgeführt. Der Anfangspunkt der Messung ist die Oberfläche der schon abgesetzten Teilchen. Im Laufe unserer Untersuchungen zeigte diese Oberfläche nicht immer eine scharfe Grenzlinie, sondern manchmal nur einen verschwommenen Übergang.

Unabhängig von der verwendeten Methode können bei der Korngrössemessung genaue Resultate — abgesehen von den sonst auftretenden Fehlern — nur bei kugelförmigen Teilchen und nur in einem Korngrössenintervall von ca. 0,1—200 Mikron erreicht werden. Das lässt sich dadurch erklären, dass das Stokessche Gesetz streng nur für kugelförmige Teilchen und auch bei diesen nur innerhalb des obigen Korngrössenintervalls gültig ist. Bei Teilchen unter ca. 0,1 Mikron Korngrösse tritt schon Brownsche Bewegung auf und dadurch wird deren Absetzen verhindert. Die durch das Absetzen von Teilchen über

200 Mikron hervorgerufene Strömung ist schon unlaminar. Der aus den Resultaten der auf dem Stokesschen Gesetz beruhenden Korngrössebestimmungsmethoden erhaltene Radius zeigt bloss die Abmessungen jenes kugelförmigen Teilchens, das die gleichen hydrodynamischen Eigenschaften hat, wie die Teilchen unseres untersuchten Stoffes. Die Abweichung zwischen beiden Abmessungen wird in der Praxis ausser acht gelassen und man rechnet, als ob die Probe nur aus kugelförmigen Teilchen bestünde.

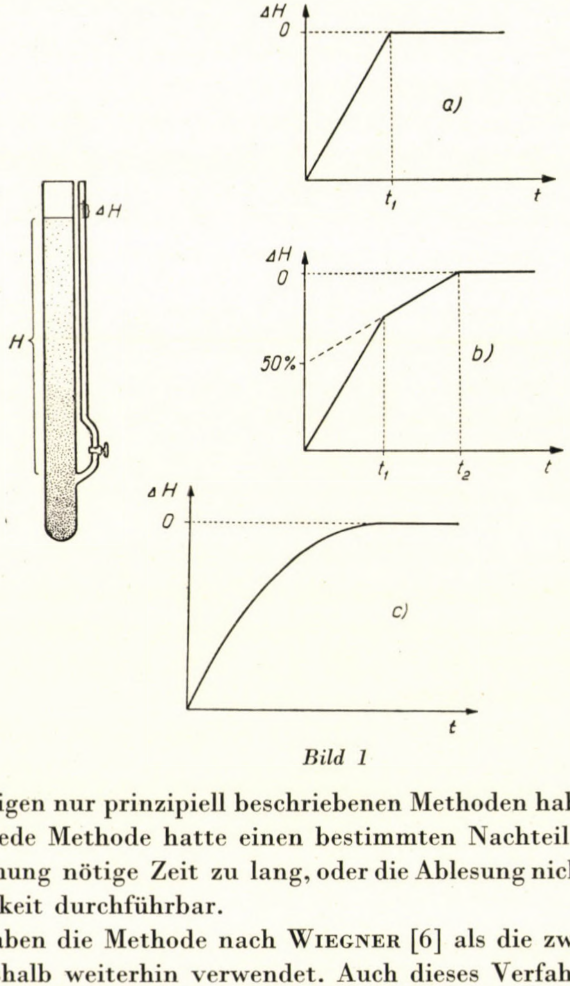


Bild 1

Die obigen nur prinzipiell beschriebenen Methoden haben wir in der Praxis überprüft. Jede Methode hatte einen bestimmten Nachteil : entweder war die zur Bestimmung nötige Zeit zu lang, oder die Ablesung nicht mit der gewünschten Genauigkeit durchführbar.

Wir haben die Methode nach WIEGNER [6] als die zweckmässigste gefunden und deshalb weiterhin verwendet. Auch dieses Verfahren beruht auf dem Stokesschen Gesetz und auf der Bestimmung des sp. Gewichtes.

Beschreibung des Apparates: Die ganze Länge des Rohres beträgt ca. 1 m, der Durchmesser ca. 30 mm. An den unteren Teil schliesst sich ein mit einem Hahn versehenes dünnes Röhrchen an, das eigentlich als Manometerrohr dient (siehe Bild 1).

Das Seitenrohr soll vor der Messung mit reinem Wasser bzw. mit jener Flüssigkeit, in welcher das Absetzen eintritt, blasenfrei angefüllt werden. Zu diesem Zweck wird soviel Flüssigkeit in das breitere Rohr hineingegossen, dass die Abzweigstelle bedeckt werde. Dann wird die Flüssigkeit in das Seitenrohr aufgesaugt und der Hahn an letzterem wird geschlossen.

Das mit Flüssigkeit innig vermischte Versuchsmaterial wird in das breite Rohr eingegossen und wird, wenn es nötig ist, noch mit Flüssigkeit aufgefüllt. Beide Rohre werden mit Korkstoppeln verschlossen und durch mehrmaliges Umkippen gut durchgeschüttelt. Nach gründlichem Durchmischen stellt man den Apparat senkrecht auf, nimmt die Korke ab, öffnet den Hahn an Manometerrohr und lässt die zur Zeitmessung dienende Stopperuhr anlaufen.

Die Höhe H wird von der Abzweigung des Seitenrohrs bis zur Oberfläche des Flüssigkeitsspiegels gemessen. Die Zeit wird in Minuten — zuerst jede Minute, später nur in längeren Zeiträumen — gemessen, gleichzeitig wird die Niveaudifferenz h auch festgestellt.

Wegen der Abweichung der Röhrendurchmesser zeigt sich sogar schon bei reiner Flüssigkeit eine ständige Niveaudifferenz in dem dünneren Rohre ; diese Kapillarkorrektion wird von dem gemessenen Wert h abgezogen. Die so gewonnenen Werte werden mit ΔH bezeichnet.

Stellt man die Werte ΔH in Abhängigkeit von der Zeit dar, so bekommt man die Absitzkurve. Die zu einem beliebigen Punkte der Kurve gezogene Tangente zeigt an, wie die Teilchenabmessungen über bzw. unter der, der gewählten Zeitdauer entsprechenden Korngrösse des untersuchten Probematerials prozentuell verteilt sind.

Es soll z. B. ein Stoff geprüft werden, dessen Teilchen gleicher Abmessung sind, d. h. der Stoff ist homodispers. Es ist leicht einzusehen, dass gleiche Stoffmengen sich innerhalb gleicher Zeitabstände absetzen, d. h. die Veränderung des sp. Gewichtes der Suspension, oder, was gleichwertig ist, die Veränderung von ΔH ist linear (Bild 1/a).

Wenn die ganze Stoffmenge sich schon abgesetzt hat, wird der Wert von ΔH gleich 0, die Kurve wird also horizontal.

In einem anderen Falle besteht der zu prüfende Stoff aus einer Mischung von zwei homodispersen Fraktionen. Die eine wird sich aus der Höhe H in 10 Minuten absetzen, die andere in 20 Minuten. In diesem Falle hat sich der gröbere Stoff innerhalb 10 Minuten völlig abgesetzt, während der feinere Stoff nur die Teilstrecke $H/2$ zurückgelegt hat, also die Hälfte des Letzteren noch im Absetzen ist. Nach 10 Minuten haben sich also 75% der ganzen Stoffmenge abgesetzt, erst nach weiteren 10 Minuten 100%. Die dargestellte Kurve wird aus Geraden bestehen, die scharfe Knicke aufweisen (siehe Bild 1/b).

Die prozentuelle Korngrössenverteilung kann man aus der dargestellten Kurve durch Ziehen der geeigneten Tangenten bzw. in obigem Falle durch die Verlängerung der Geraden bekommen. Wird die bei 10 Minuten beginnende schräge Linie verlängert, so zeigt deren Schnittpunkt mit der Ordinatenachse an, wieviel Prozente solcher Teilchen in der Mischung vorhanden sind, deren Korngrösse kleiner ist, als die der 10 Minuten währenden Absetzdauer entspechende Korngrösse.

In den meisten Fällen werden verschiedene Mischungen *von Teilchen verschiedener Korngrössen* untersucht, bei diesen bekommt man hierbei keine Geraden, sondern Kurven (siehe Bild 1/c).

Die Mengenverteilung der den verschiedenen Absetzdauern entsprechenden Fraktionen kann man durch Konstruktion der geeigneten Tangenten erhalten. Durch die zu beliebigen Zeitpunkten (t) gehörigen Tangenten können die Fraktionen nach Belieben begrenzt werden.

Der Radius der Teilchen wird auch hier nach dem Stokesschen Gesetz berechnet:

$$v = \frac{2g(d_1 - d_2)}{9\eta} r^2, \text{ wobei} \tag{1}$$

v = Geschwindigkeit des absinkenden Körpers cm/sec,
g = Fallbeschleunigung 981 cm/sec^2,
d_1 = spezifisches Gewicht des absinkenden Körpers g/cm^3,
d_2 = spezifisches Gewicht der Flüssigkeit g/cm^3,
η = dynamische Viskosität der Flüssigkeit g/cm sec (in Poise),
r = Radius des absinkenden Körpers cm.

Da die Bestimmungen bei ungefähr gleicher Temperatur ausgeführt werden, können die von der Temperatur abhängigen und unveränderlichen Glieder (sp. Gewicht, Viskosität) in eine Konstante (c) einbezogen werden:

$$\frac{2g(d_1 - d_2)}{9\eta} = c. \tag{2}$$

Aus den Gleichungen (1) und (2):

$$v = c r^2 \tag{3}$$

$$r^2 = \frac{v}{c} \tag{4}$$

$$r = \sqrt{\frac{v}{c}}. \tag{5}$$

Die Absetzgeschwindigkeit wird nicht unmittelbar gemessen, sondern bei bekannter Höhe (H) wird die Zeit (t) bestimmt.

$$v = \frac{H}{t}. \tag{6}$$

Nach dem Zusammenziehen der Gleichungen (3) und (6):

$$\frac{H}{t} = c r^2 \tag{7}$$

$$r = \sqrt{\frac{H}{ct}}. \tag{8}$$

Die Absetzdauer eines Teilchens von belibigem Radius beträgt

$$t = \frac{H}{c r^2}. \tag{9}$$

Aus der Gleichung (8) bzw. (9) kann man den zu der bekannten Zeit t gehörenden Radius r, bzw. die zu dem gewünschten Radius gehörende Zeit (t) berechnen.

Praktisches Beispiel:

Ein Tonerdehydrat wird mittels der Wiegners Methode geprüft. Das Klären wird bei einer Temperatur um 20° C Wasser ausgeführt. Berechnung von c, nach der 2. Gleichung :

η	=	Viskosität des Wassers bei 20° C in Poise	0,01
d_1	=	sp. Gewicht des Tonerdehydrats laut der Bestimmung	2,38 g/cm^3
d_2	=	sp. Gewicht des Wassers 0,99823, abgerundet	1,0 g/cm^3

Nach der Substitution :

$$c = \frac{2 \cdot 981}{9 \cdot 0{,}01} \cdot (2{,}38 - 1{,}0)$$

$$c = \frac{1962}{0{,}09} \cdot 1{,}38 = 30{,}084, \text{ abgerundet } 30{,}100$$

Absitzhöhe (siehe Bild 1) H = 64,7 cm
Kapillarkorrektion 6 mm

Messwerte :

Zeit Min.	H mm	ΔH mm
0	23	17
2	15	9
3	13	7
4	11	5
5	10	4
6	10	4
8	8	2
10	7	1
12	7	1
14	6	0

Das Absetzen war nach der 14. Minute beendet. Es haben sich also auch die kleinsten Teilchen aus der Aufschlämmung entfernt. Die Berechnung dieser Korngrösse :

$$t = 14' = 840 \text{ sec.}$$

Nach Substitution in die 8. Gleichung

$$r = \sqrt{\frac{64{,}7}{30{,}100 \cdot 840}} = \sqrt{0{,}00000256} = 0{,}0016 \text{ cm}$$

$$d_{min} = 0{,}0032 \text{ cm, das heisst 32 Mikronen.}$$

Will man z. B. feststellen, wann Teilchen von 50 μ Korngrösse sich aus dem Absetzraum entfernen, dann setzt man die obigen Messwerte in die 9. Gleichung ein :

$$t = \frac{H}{c r^2},$$

worin

$$t_{50 \text{ Mikr. } \varnothing} = \frac{64{,}7}{30{,}100 \cdot 0{,}0025^2} = \frac{64{,}7}{0{,}188125} = 344 \text{ sec} = \underline{5' 44''},$$

Verlängert man die zu einem gewählten Zeitwert zugeordneten Punkt der dargestellten Kurve gezogene Tangente bis zur Ordinatenachse, dann kann hierdurch das prozentuelle Verhältnis zwischen Teilchen über bzw. unter 50 μ bestimmt werden.

Nach Durchführung der gleichen Berechnung z. B. bezogen auf die Korngrösse von 60 μ, kann man aus der Differenz der prozentuellen Werte feststellen, wieviel Prozente der Teilchen des Gemisches Abmessungen von 50—60 μ zeigen.

In dieser Weise ist es möglich, die prozentuelle Verteilung für beliebige Korngrössengrenzen festzustellen.

Beschreibung der Versuche

Vorerst wurde die Verlässlichkeit der Methode durch Vorversuchsreihen überprüft. Hierbei erwies sie sich als befriedigend. Bei demselben Stoff waren die Ergebnisse reproduzierbar.

Weiterhin wurde geprüft, wie sich die Korngrösse der Hydratteilchen im Laufe des betriebsmässigen Luftausrührens prozentuell verändert.

Aus den während des Ausrührens zeitweise genommenen Proben wurde das Tonerdehydrat durch Filtration abgetrennt, ausgewaschen und die Verteilung der Teilchenkorngrössen durch Sedimentation in Wasser bestimmt.

Aus den durch die Auswertung von zwei Betriebsuntersuchungen erhaltenen Ergebnissen kann man — auch bei nötiger Vorsicht — Folgerungen ziehen, die bezüglich der beim Ausrühren eintretenden Veränderungen Anthaltspunkte liefern. Es mahnt hierbei zur Vorsicht, dass die bei den Berechnungen benutzte Stokessche Formel genau nur für kugelförmige Körper gültig ist und das Tonerdehydrat dieser Voraussetzung nicht entspricht. Deshalb sind die bei Verwendung der Kurven bestimmten Korngrössen nur annähernde Werte.

Die erste Versuchsreihe wurde mit 20, innerhalb von 60 Stunden genommenen Proben ausgeführt. Hierbei wurde alle 3 Stunden eine Probe genommen. Gleichzeitig wurde auch die Molverhältniszahl im flüssigen Teile geprüft.

Die mittels der WIEGNERS-Methode festgestellten Korngrössenwerte wurden in Diagrammen aufgetragen, in welchen die zu den Korngrössen 0,05, 0,06, 0,07 und 0,08 mm gehörenden Absetzzeiten sowie die prozentuelle Korngrössenverteilung — letztere mittels je einer zu den entschprechenden Zeitpunkten gehörigen Kurvenpunkten gezogenen Tangente — bestimmt werden.

Die Bilder 2 und 3 stellen 7 von obigen Diagrammen dar. Das Diagramm 2/a stellt Messwerte einer während des Impfstoffeinmischens genommenen Probe, deren Tonerdehydrat durch Filtration getrennt wurde, dar. Die Ausrührzeiten, die auch gleichzeitig Zeitpunkte der Hydratprobenahme waren, und die entsprechenden Resultate sind : bei Diagramm 2/b 3 Stunden, bei 2/c 6 Stunden, bei 2/d 9 Stunden, bei 3/e 36 Stunden, bei 3/f 42 Stunden und bei 3/g 57 Stunden.

Es kann festgestellt werden, dass der Impfhydratanteil mit der Korngrösse von 40—50 μ sich innerhalb 3 Stunden von der 25%-igen Anfangsmenge bis auf 8% verringerte. In der 6. Stunde ist er überhaupt nicht mehr zu beobachten. Die kleinste Korngrösse ist auch in den anderen Proben nicht auffindbar. Sie meldet sich erst in der 60. Stunde. Ein diesbezügliches Diagramm fehlt aus den Abbildungen.

Die Teilchen, deren Korngrösse grösser war als 80 μ und deren Menge anfangs 12% betrug, verschwanden nach der 3. Stunde. Sie waren dann nach

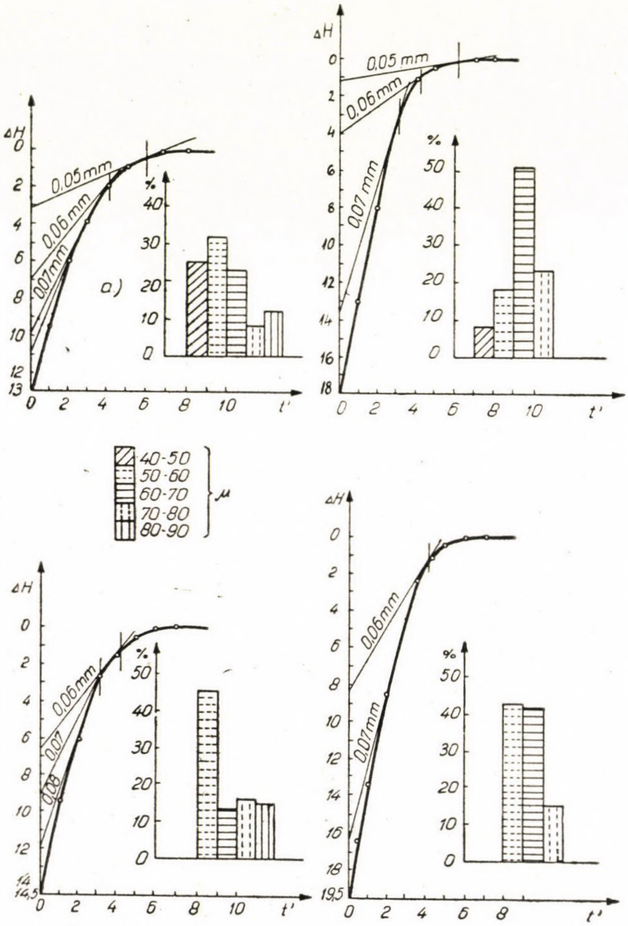


Bild 2

der 6. Stunde in einer Menge von 15% wieder vorhanden. Die grossen Teilchen fehlten im Zeitintervall der 9—36. Stunde, nach der 42. Stunde konnten sie aber in einer Menge von ca. 15% beobachtet werden.

Die Teilchen des Korngrössengebietes von 50—80 μ wurden in 10 μ Stufenunterschieden geprüft. Die konkrete Auswertung der Ergebnisse war hierbei umständlich, so viel lässt sich aber festzustellen, dass die prozentuelle Menge bei einigen Korngrössen zu-, später aber plötzlich abnimmt, offenbar wegen Verwendung des Stokesschen Gesetzes, da das Absitzen der unregelmässig gearteten Teilchen eben unregelmässig ist. Werden längere Zeitdauern miteinander verglichen, z. B. die Ergebnisse der 9., 36., 42., 50. und 60. Stunde, dann lässt sich feststellen, dass die anfangs während 9 Stunden zunehmende Menge der Teilchen von 50—60 μ später abnimmt und in der 60. Stunde gleich dem in der 42. Stunde beobachteten Tiefpunkt war.

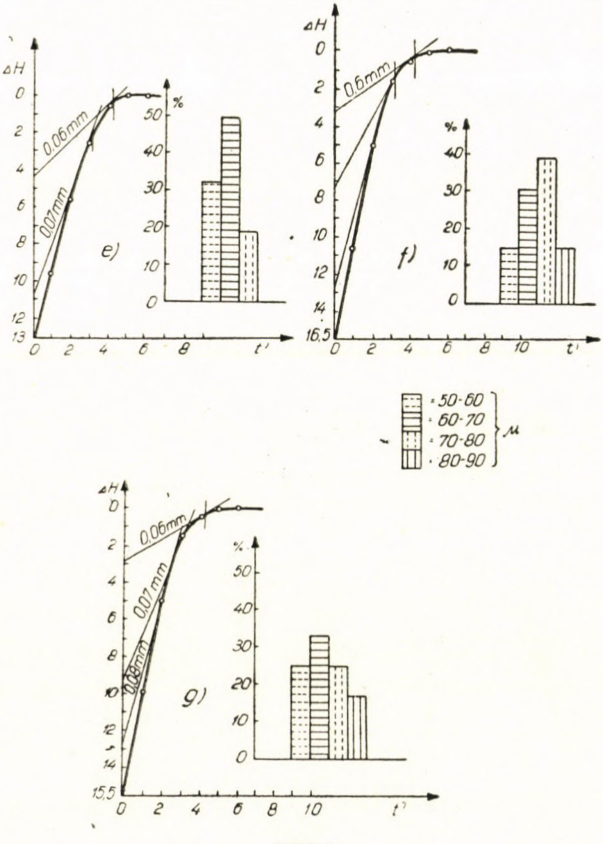


Bild 3

Die Menge der Teilchen von 60—70 μ zeigt bis zur 36. Stunde einen grossen Anstieg. In der 42. Stunde beginnen sie sich — nach einer Verminderung bis zu beinahe 20% — langsam wieder zu vermehren.

Die Teilchen von 70—80 μ zeigen bis zur 42. Stunde einen ständig ansteigenden Wert. Hiernach nimmt dieser wieder stark ab.

Es sei bemerkt, dass nur die Mengenänderungen der grössten sowie der kleinsten Teilchen konkrete Feststellungen erlauben, da der prozentuelle Anteil der anderen Korngrössen auch in jenem Falle zu- oder abnehmen kann, wenn ihre absolute Menge unverändert bleibt, aber irgend eine Fraktion ab- oder zunimmt. Die mengenmässige Bestimmung der während des Ausrührens eintretenden Veränderungen kann eventuell mit Hilfe von Isotopen ausgeführt werden.

Die zweite Versuchsreihe wurde ebenso mit aus einem Betriebsluftausrührer genommenen Proben durchgeführt. Diese wurde bis zur 9. Stunde jede dritte, nachher jede zweite Stunde genommen. Der Absetzprozess wurde bis zur 35. Stunde untersucht. In diesem Falle wurde das Impfhydrat vor der Zumischung gesondert geprüft.

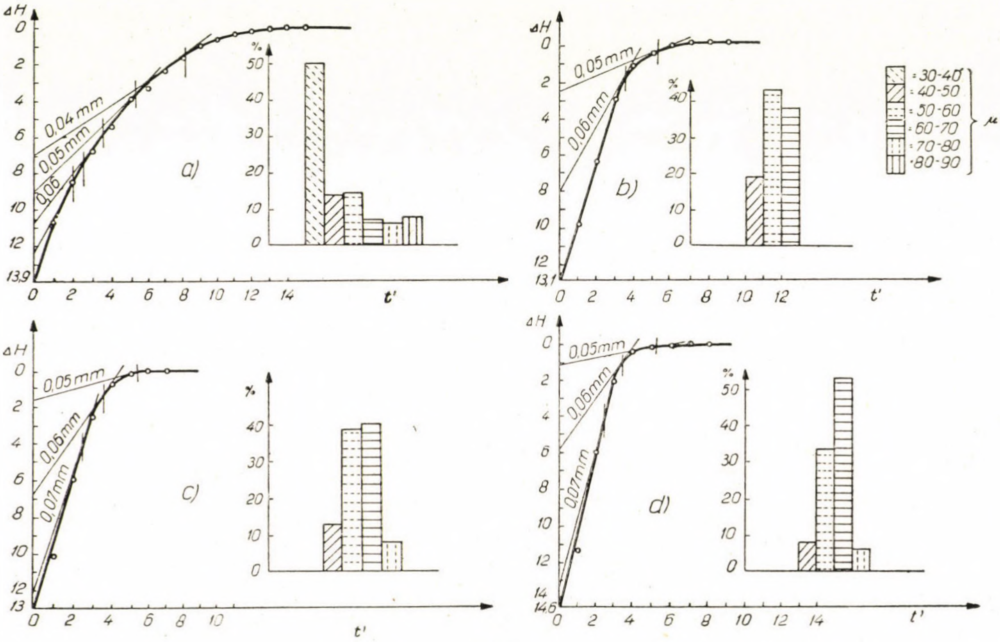


Bild 4

Auf Bild 4/a ist das Absitzdiagramm des Impfstoffes, weiterhin die prozentuelle Korngrössenverteilung seiner Teilchen ersichtlich. Auf Bild 4/b sind die Versuchsresultate des aus der nach der Zumischung unmittelbar genommenen Probe des durch Filtration abgetrennten Impfstoffes dargestellt.

Die Probe 4/c wurde in der 9., 4/d in der 21., 5/e in der 29., 5/f in der 31. Stunde und endlich 5/g in der 34. Stunde genommen.

Ein Vergleich der Diagramme 4/a und 4/b zeigt, dass die Korngrössenzusammensetzung des Impfstoffes schon bei der Zumischung sich verändert. Die kleinsten Teilchen von 30—40 μ Korngrösse sowie jene, die grösser als 70 μ sind, verschwinden. In der 9. Stunde sind die Teilchen von 70—80 μ Korngrösse beobachtbar, wohl in einer relativ geringen (kleiner als 10%) Menge. In der in der 21. Stunde genommenen Probe nimmt die Menge der Teilchen von 60—70 μ Korngrösse zu. In der 29. Stunde fehlen die Teilchen von 40—50 μ Korngrösse, die Mengen der Fraktionen von 50—60 μ und 60—70 μ Korngrössen sind dagegen beinahe gleich. In der 31. Stunde hat die prozentuelle Menge der Teilchen von 70—80 μ Korngrösse zugenommen. In der 34. Stunde vermindern sich die Teilchen von 50—60 μ Korngrösse stark, die von 70—80 μ nehmen aber zu.

Die kleinsten Teilchen (von 30—40 μ Korngrösse) verschwinden bei der Zumischung vollkommen, deshalb waren sie in der ersten Versuchsreihe, wo die

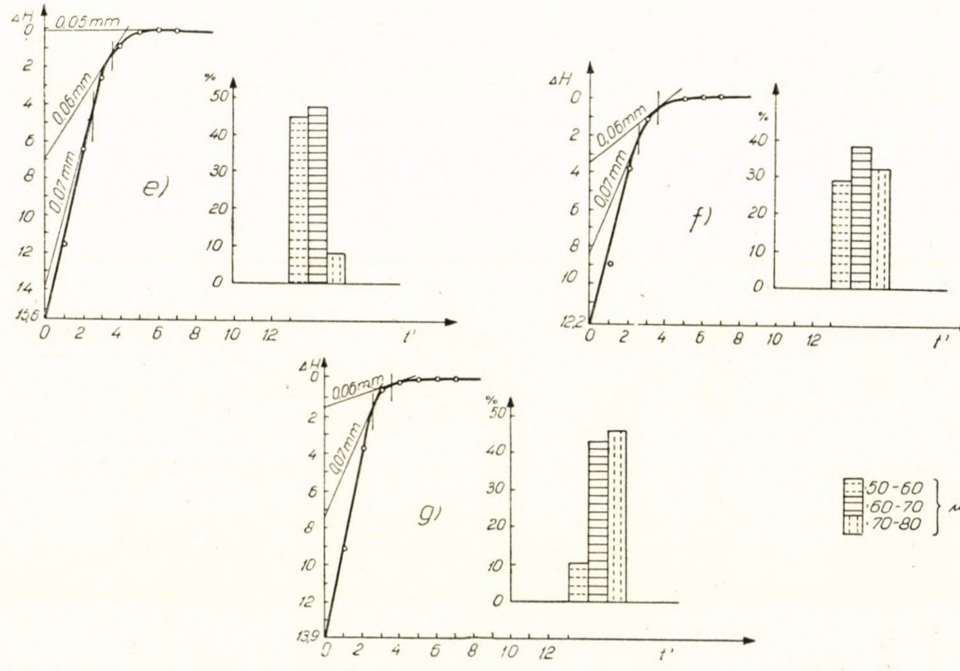


Bild 5

erste Probe nach der Zumischung genommen wurde, nicht beobachtbar. Die Abnahme der grösseren Teilchen wurde im Verlauf der Zeit bei beiden Versuchen festgestellt.

Aus der ständigen Zunahme des Molverhältnisses Na_2O/Al_2O liess sich annehmen, dass das Verschwinden der Korngrössen nicht durch Auflösung, sondern durch Agglomeration bzw. Zerkleinerung verursacht wird.

Diese Annahme wurde durch die Ergebnisse folgenden Versuches bestätigt: Impfhydrat wurde in auf einem Wasserbade warm gehaltenen dest. Wasser mittels eines mechanischen Rührers gerührt. Die Kornverteilung wurde nun in der 9. und nach der 18. Stunde des Rührens geprüft. Die Versuchsergebnisse sind auf Bild 6 ersichtlich.

Es kann festsgestellt werden, dass die Teilchen von 30—40 μ Korngrösse, die in dem Ausgangsmaterial in bedeutender Menge vorhanden waren, nach 9 Stunden vollkommen verschwanden, bei der Korngrösse von 40—50 μ dagegen ist eine grosse Zunahme zu beobachten. Ebenso verschwanden die Korngrössen über 80 μ. Die letzteren sind in der in der 18. Stunde gezogenen Probe schon wieder zu beobachten. Diese Versuche wurden mit der ganzen Stoffmenge ausgeführt, die prozentuelle Verteilung bedeutet also gleichzeitig auch eine mengenmässige Angabe. Da die Zersetzung der Aluminatlauge während des Ausrührens erst nach 20—24 Stunden beginnt, zeigt diese Erscheinung sehr eindrucksvoll die Wirkung der Korngrösse. Hierbei kann angenommen werden, dass die aktiven Oberflächen der kleineren Teilchen trotz ihrer Agglomeration wirksam bleiben.

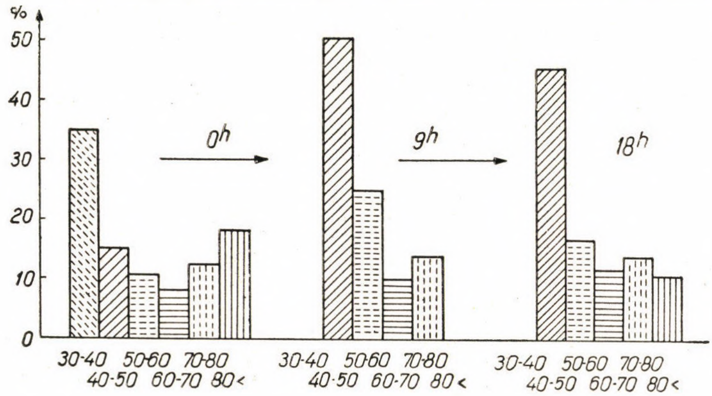


Bild 6

Die agglomerierten Teilchen erwiesen sich als stabil. Trotz des mehrstündigen Kochens mit Dampf konnte an ihnen keine Zerkleinerung beobachtet werden.

Die bisher beschriebenen Untersuchungen wurden mit Betriebsimpfhydrat und mit aus Betriebsausrührern genommenen Proben durchgeführt. Da auch das Luftausrühren die Abnahme von echten Durchschnittsproben nicht vollkommen sichert, haben wir zur Kontrolle der bisherigen Resultate auch Laboratoriumsversuche ausgeführt.

Der Impfstoff wurde in der folgenden Weise vorbereitet: Das Betriebstonerdehydrat wurde in Wasser längere Zeit gekocht, um ein eventuelles Zusammenballen desselben zu verhindern. Hiernach wurden die Teilchen von einer Korngrösse kleiner als 40 μ zur Beseitigung der durch die grösseren Körner hervorgerufenen Unsicherheit, mittels Absetzens entsprechend dem Stokesschen Gesetz getrennt. Nach mehrmaliger Wiederholung dieses Arbeitsganges stand das Tonerdehydrat von der auf Bild 7/a dargestellten Korngrössenzusammensetzung, worin die Teilchen von einer Korngrösse kleiner als 40 μ fehlten, zur Verfügung.

Eine synthetische Aluminatlauge, welche 114,3 g Al_2O_3 und 125 g Na_2O pro Liter enthielt (ihr Molverhältnis war also 1 : 1,8), wurde mit diesem vorbereiteten Tonerdehydrat eingeimpft.

80 g des Impfstoffes wurden zu 500 ml Aluminatlauge zugegeben und das Ausrühren wurde auf dem Wasserbad bei 60° C 21 Stunden lang ausgeführt. Alle drei Stunden wurde das ganze Probematerial filtriert, sein Gewicht gewogen und die Korngrössenverteilung nach dem Auswaschen bestimmt.

Das Gewicht des zugegebenen Hydrats hat sich während der einund-

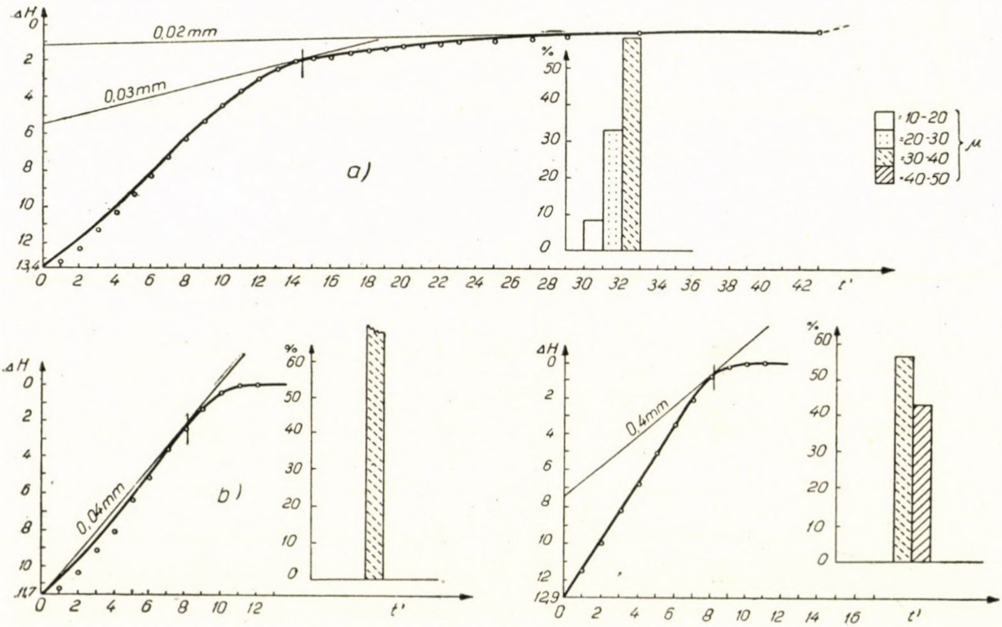


Bild 7

zwanzigstündigen Versuchsdauer nicht verändert, ein Zeichen, dass die Tonerdeausscheidung aus der Aluminatlauge noch nicht begonnen hat.

Die Feststellung der Korngrössenveränderungen wurde mittels der schon beschriebenen Diagramme ausgeführt. Das auf Bild 7/b dargestellte Diagramm wurde nach dreistündigem Ausrühren aufgenommen. Es ist daraus ersichtlich, dass nur Teilchen von 30—40 μ zurückgeblieben sind. Nach sechsstündigem Ausrühren liessen sich Teilchen von 40—50 μ Korngrösse, wie es aus Bild 7/c ersichtlich ist, in einer Menge von über 40% nachweisen. Hiernach blieb die Korngrössenverteilung beinahe unverändert.

Während des 21 Stunden langen Versuches wurden die beobachtete minimale und die aus der prozentuellen Zusammensetzung berechnete durchschnittliche Korngrössenveränderung graphisch dargestellt (siehe Bild 8).

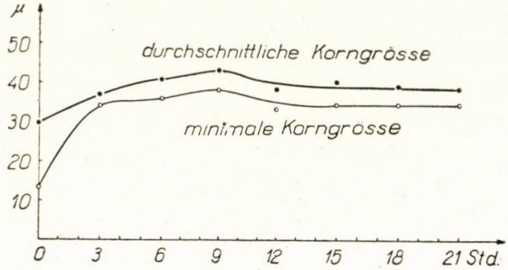


Bild 8

Ein ähnlicher Versuch wurde auch mit einem grobkörnigen Impfhydrat ausgeführt. In diesem Falle haben sich die Korngrössen nicht verändert.

Durch die oben beschriebenen Versuchsergebnisse konnten die Feststellungen weiter unten in der Zusammenfassung unter 1—6 bestätigt werden.

SCHRIFTTUM

1. WRIGGE—GINSBERG: Ztschr. f. anorg. und allg. Chemie, 264. 1951. 285.
2. GINSBERG: Ztschr. f. anorg. und allg. Chemie, 269. 1952. 179.
3. TAICHI SATO: Chem. Abstr. 48. Jahrg. 11237.
4. J. JÁKY: Bodenmechanik. Budapest. 1944.
5. F. EVVA: Aluminium II. 1950. 276.
6. A. BUZÁGH: Kolloidik. Leipzig. 1936.

ZUSAMMENFASSUNG

1. Das Messverfahren nach Wiegner ist zur Bestimmung der Korngrösse sowie ihrer prozentuellen Verteilung an Tonerdehydrat geeignet.

2. Die während des Ausrührens eintretenden Korngrössenveränderungen können mittels der Wiegners Methode gut beobachtet werden.

3. Bei den untersuchten Impf- und Ausrührverhältnissen im Betrieb verschwinden die Teilchen unter 50 μ des Impfhydrats zu Beginn des Ausrührens und erscheinen erst wieder gegen Ende desselben — im untersuchten Falle in der 60. Stunde — wieder. Das Verschwinden der kleinsten Teilchen verursacht keine Molverhältnisabnahme.

4. Dieselbe Feststellung ist auch gültig für Impfhydratteilchen, die grösser als 80 μ sind. Letztere zeigen sich aber während des Ausrührens schon früher als die kleineren Teilchen.

5. Beim Laboratoriumsversuch verschwanden die Teilchen des in destilliertem Wasser gerührten Impfhydrats unter 40 μ und über 80 μ in 9 Stunden. Die Teilchen grösser als 80 μ zeigten sich erst in der 18. Stunde wieder.

6. Bei dem — mittels in Aluminatlauge gerührten Impfhydrat, dessen Korngrösse kleiner als 40 μ war — durchgeführten Laboratoriumsversuch verschwanden die Teilchen kleiner als 30 μ nach 3 Stunden, und nach insgesamt 6 Stunden zeigten sich auch die Teilchen der Korngrösse 40—50 μ. Die Korngrössenveränderungen verursachten weder eine Gewichtsab- noch Zunahme.

INVESTIGATIONS OF THE GRAIN SIZE OF ALUMINA HYDRATE AT MIXING WITH AIR

S. DUNAY and M. KALMÁR

SUMMARY

1. The method of Wiegner for the investigation of grain size is suitable for determining the grain size of alumina hydrate and its percentual distribution.

2. The changes of grain size occurring during mixing can be traced very well by the Wiegner method.

3. Under the plant conditions of inoculation and mixing which have been examined, the grains of the inoculation hydrate smaller than 50 microns disappear at the begin of the mixing and reappear only towards the end of the mixing — in our case in the 60th hour. The disappearance of the small grains is not connected with a reduction of mol ratio.

4. The same effect has been observed for the grains over 80 microns contained in the inoculation hydrate, but these appear in an earlier stage of the mixing process than the fine grains.

5. In our laboratory tests, the grains under 40 microns and over 80 microns of the inoculation hydrate disappear within 9 hours. The grains over 80 microns re-appear in the 18th hour.

6. In our laboratory tests with inoculating hydrate of a grain size under 40 microns, mixed in aluminate solution, the grains under 30 microns disappeared within 3 hours, after 6 hours appeared the grains of 40—50 microns. The changes of grain size were neither connected with weight diminution, nor with weight increase.

RECHERCHES SUR LA GROSSEUR DES GRAINS DE L'ALUMINE HYDRATÉE DURANT LE MÉLANGE AVEC DE L'AIR

S. DUNAY et M. KALMÁR

RÉSUMÉ

1. La méthode de Wiegner pour l'examination de la grosseur des grains peut être appliquée à l'examen de la grosseur des grains de l'alumine hydratée et de leur repartition relative.

2. Les changements de la grosseur des grains durant le mélange peuvent être bien suivis avec la méthode de Wiegner.

3. Sous les conditions d'inoculation et de mélange industriels qui ont été examinées, les grains en-dessous de 50 microns de l'hydrate d'inoculation disparaissent au début du mélange et réapparaissent seulement vers la fin du mélange — dans notre cas à la 60ième heure. La disparation des grains fins ne va pas avec une réduction de la proportion molaire.

4. Le même effet a été observé pour les grains au-dessus de 80 microns de l'hydrate d'inoculation, qui toutefois apparaissent plus tôt, au cours du mélange, que les grains fins.

5. Pendant nos essais de laboratoire, les grains plus petits que 40 μ et plus grands que 80 μ de l'hydrate d'inoculation mélangé dans l'eau distillée ont disparu après 9 heures. Les grains plus grands que 80 μ ont réapparu à la 18ème heure.

6. Pendant nos essais de laboratoire avec de l'hydrate d'inoculation à grains plus petits que 40 μ, mélangé dans de la solution d'alumine, les grains plus petits que 30 μ ont disparu dans les 3 heures, et après 6 heures sont apparu aussi les grains de 40—50 μ. Les changements de la grosseur des grains n'allait ni avec diminution, ni avec augmentation du poids.

ИССЛЕДОВАНИЕ ГРАНУЛОМЕТРИЧЕСКОГО СОСТАВА ГИДРАТА ГЛИНОЗЕМА ПРИ АЭРАЦИИ ВОЗДУХОМ

Ш. ДУНАИ и М. КАЛЬМАР

РЕЗЮМЕ

1. Методика гранулометрического анализа Вигнера подходит для определения гранулометрического состава гидрата глинозема, а также процентного распределения.

2. Изменение гранулометрического состава, происходящее в процессе аэрации, можно хорошо проследить с помощью методики Вигнера.

3. При исследованных производственных условиях затравки и аэрации зерна затравного гидрата с крупностью менее 50 микрон исчезают в начале процесса аэрации и вновь появляются только в конце процесса аэрации — в нашем случае через 60 часов после начала аэрации. Исчезновение мелкозернистых фракций не связано со снижением молярного соотношения.

4. Это же установлено также для зерен затравного гидрата с крупностью более 80 микрон. Однако эти явления в процессе аэрации возникают раньше, чем в случае мелких фракций.

5. При лабораторных опытах зерна затравного гидрата с крупностью менее 40 микрон и более 80 микрон при смешивании в дистиллированной воде через 9 часов исчезают. Зерна с крупностью более 80 микрон вновь появляются через 18 часов.

6. В случае лабораторных опытов, проведенных с затравным гидратом, смешиваемым с алюминатной щелочью и имеющим крупность менее 40 микрон, зерна с крупностью менее 30 микрон исчезают через 3 часа, и через 6 часов появляются также зерна крупностью 40—50 микрон. С изменением гранулометрического состава не происходило ни снижения, ни прибавления веса.

DATA ON THE HISTORY OF METALLURGY IN HUNGARY*

V.

MANUFACTURE OF PIG IRON FROM HIGH-ALUMINA ORES IN THE 18-TH CENTURY**

Prof. A. SCHLEICHER
D. ENG. SC.

[Manuscript received 18th March, 1957]

In Western Hungary, on the Budapest—Czelldömölk railline, 16 miles north of Lake Balaton, in the village of Kislőd, a blast furnace was operated in the second half of the 18-th century, the interesting feature of which was that it produced pig iron not from a definite kind of iron ore, but from a burden that might have been some natural mixture of bauxite and of limonite.

The blast furnace was abandoned definitely in the last years of the 18-th century and on its place only some ruins of masonry and slag heaps are found. 5 slag samples and one sample of pig iron found by chance were analyzed with the following results :

Pig iron***	C 3,70	Si 3,94	Mn 8,40	P 0,672	S 0,027	%			
Slag samples	SiO_2	Al_2O_3	CaO	MgO	FeO	Fe_2O_3	MnO	S	TiO_2	P_2O_5
	%									
No 1.	48,02	13,26	10,62	6,9	0,88		10,4		0,53	
No 2.	40,97	15,59	24,51	7,07	1,66	0,88	9,4	0,03		0,09
No 3.	51,18	20,20	9,50	1,82	6,83		10,2			
Grey slag	37,83	26,57	17,70	4,78	2,09	1,35	9,4	0,07		0,11
Black glassy slag	49,61	21,—	11,—	3,35	4,27		10,1			

In the chemical composition of the slag samples the high content of Al_2O_3 is striking. Iron ores smelted for pig iron are known to contain only decimal

* In this series the following papers of the author have thus far been published : I. History of Non-ferrous Metallurgy in the Mátra Mountains. Acta Technica Acad. Sc. Hung. *2* (1951) 3/42 ; II. Data on the Use of Brass in the Late Middle Ages and on the Beginning of Wire Drawing in Europe. Ibidem 7 (1953) 225/231 ; III. Restoration of a Blast Furnace Built in Hungary in 1813. Ibidem *8* (1954) 425/433. IV. First Industrial Production of Tellurium. Ibidem *9* (1954) 213/222 (all German).

** Condensed from a detailed paper of the author published in Hungarian in the Magy. Tud. Akad. Műsz. Oszt. Közl. (Transactions of the Engineering Section of the Hung. Acad. of Sc.,) *21* (1957) 395/411.

*** Unfortunately it was impossible to make slides for microscopic investigation from the iron sample.

percentages, more rarely 2—3%, and quite exceptionally 5—6% of Al_2O_3, not to speak about low-iron, high-silica iron ores whose Al_2O_3 content may reach 11—13%.

Therefore the above analyses raised the suspicion that our predecessors might have processed for iron some kind of bauxite high in Fe_2O_3, for in that part of Hungary there are large deposits of bauxite. In Hungarian bauxites there are many of 23—28, even of 34%, rarely even of 39% Fe_2O_3 content [1]. Hungarian bauxites were taken 60—70 years ago for iron ores. It was Hungarian Metallurgical Eng. BÉLA MIKÓ who recognized in 1903 a sample of "iron" ore as actual bauxite and fit for the manufacture of aluminium [2].

The supposition, that in this case bauxite was processed for iron appeared acceptable, because there were no data available in the very extensive Hungarian literature that there had ever been known an occurrence of iron ore in that region.

The content of 0,53% of TiO_2 of one slag sample (the others were not analyzed for TiO_2) appeared to be a decisive proof that the pig iron had actually been produced from bauxite. In bauxites of Western Hungary there are TiO_2 contents of at least 2%, often of 3—4%, sometimes even of more than 5%. That Swedish magnetic iron ores also contain TiO_2 does not contradict that, because the use of such ores under the given circumstances 200 years ago was out of question, moreover, the Swedish ores contain only 0,03—0,19% of TiO_2.

The analyses of slag samples were compared with those of such slags as have been obtained in actual planned smelting tests of Hungarian bauxites for pig iron.

Blast furnace slag is known to be a Ca-silicate generally of 30—40% of SiO_2. The third main constituent of blast furnace slag, Al_2O_3 reaches rarely more than 15%. During the last 50 years there have been made experiments in several countries to smelt with a high alumina slag, one of the principal objects of which was to obtain a slag fit for cement manufacture. The latter initiative is still earlier; it is known that already in 1882 a patent was taken out on the production of a blast furnace slag fit for cement manufacture by adding bauxite to the burden [3].

It is perspicuous therefore that the production of pig iron from bauxite called the attention of Hungarian metallurgical engineers too, since this country is one of the richest bauxite areas of the world. Such experiments were first made in 1937—38. From 1948 onward, for about two years the tests were executed at Diósgyőr in a 48 cu. m blast furnace built for this purpose [4].

Experimental results are not detailed here, it is stated only that the comparison does not support the assumption hat the manufacture of pig iron 200 years ago, dealt with here, was based on bauxite high in iron. The composition of these old slags more resembles those of slags obtained by smelting iron with an acid slag, but with the essential exception that the Al_2O_3 and CaO contents of our old slags are much higher than those of the above. This speaks for the origin of these old slags from a high-alumina (bauxitic) burden, if it does not prove that these slags originated from pure bauxite.

Besides the high Al_2O_3 content of the slag, its MnO content varying between 9,4 and 10,4% and the 8,4% Mn-content of the pig iron was also difficult to explain. Though there is no manganese in Hungarian bauxites, there is a manganese deposit, mined at present still, 3,5—4 miles* off at Úrkút. Manganese ores were even won nearer to the blast furnace, which were also taken for iron ores by our predecessors, since manganese was discovered as an independent element only in 1774 by BERGMANN and SCHEELE. However, tempting was the assumption that the manganese content came from Úrkút ores, it had to be disconsidered, short of any evidence whatever.

Another explanation had to be sought therefore for what could have been the raw material of smelting, if it was neither iron ore, nor bauxite or manganese. Such explanation was obtained from Prof. E. VADÁSZ of Budapest University according to whom in that topographically precisely defined area at the surface no bauxite could have any more existed 200 years ago or can exist at present. However, at the base of the once existing bauxite deposit, marked by remnants of bauxite worn off by the Miocenic abrasion of the area, heaped up locally as detritus on the dolomite bedrock, there exists a limonitic ferriferous crust, which may have been the source. This is part of the bauxite deposit, but cannot be taken for bauxite especially from the point of view of iron smelting in question. At the same time its TiO_2 content is explained by its genetic association with bauxite. This ferriferous crust is high in manganese — a sample from Gánt, Hungary, contains 28% MnO_2 —, and it is also high in silica (15%). This assumption explains the data of the analysis of Kislőd blast furnace slag, there is no need to conclude to the addition of manganese ores to the burden, moreover the high silica content of the slag is also explained. Depletion of the places of occurrence of the ferriferous crust may have been the cause of the abandonment of the blast furnace.

This assumption of Prof. VADÁSZ is all the more acceptable, as no burden can be composed of a mixture of Hungarian bauxites high in iron and of manganese ores mined at Úrkút which would yield the pig iron and slag of the aforegiven composition. Our predecessors could have obtained such pig iron and slag only if they had ores higher in iron and silica and lower in alumina than the ores known in that area. Such might have been the kind of ore supposed by Prof. VADÁSZ. The question cannot be decided definitely, because no such ore sample is available from the area. It is improbable that high-Fe and high-SiO_2 ores from far regions would have been charged to the burden, because data found in archives — presented in the original Hungarian version of this paper in detail — convince the author that there was no shortage of ores mined near the blast furnace.

* Statute or land mile.

As an extreme possibility of the composition of the burden used it may be supposed that gravel was charged to the burden, a practice favoured by iron masters of old.

REFERENCES

1. E. Vadász: Geology of Bauxite. Budapest, 1951, Publishing House of the Acad. of Sc., p. 104 (Hungarian).
2. Kohászati Lapok (Journal of Metallurgy) *89* (1956) p. 388 (Hungarian).
3. J. Ferfer: Die neuere Geschichte der Buderus'schen Eisenwerke. S. 357/358. in "Vom Ursprung und Werden der Buderus'schen Eisenwerke Wetzlar" Bd. I., F. Bruckmann KG. München, 1938.
4. Geleji—Schleicher (editors): Vaskohászati enciklopédia. VI. köt., Nyersvasgyártás, Budapest, 1955, p. 667/682. (Encyclopaedia of Iron Metallurgy, Vol. VI., Production of Pig Iron.) (Hungarian.)
5. Die geologische Entwicklung und das Alter der ungarischen Bauxitvorkommen. Annal. Inst. Publ. Geol. Hung. *37* (1946).

SUMMARY

In Hungary in the second half of the 18-th century a low-output blast furnace was operated, in the case of which, on the basis of the analysis of pig iron produced and of slag obtained, it is difficult to establish from what kind of burden they originated. The blast furnace was not far from known Hungarian bauxite deposits. The plausible supposition that bauxite alone was processed for pig iron, cannot be proved. Similarly there is no evidence that the high Mn-content of the pig iron and the high MnO-content of the slag would be due to charging manganese ores from some manganese ore mine nearby. Gaps in metallurgical interpretation leads to the geological assumption that a limonitic type of ore — genetically associated with bauxite — was processed, which is presumably a unique procedure in the history of metallurgy by the peculiarity of occurrence of that ore.

BEITRÄGE ZUR GESCHICHTE DES HÜTTENWESENS IN UNGARN

V.

ROHEISENHERSTELLUNG AUS TONERDEREICHEN ERZEN IN DEM 18. JAHRHUNDERT

Prof. A. SCHLEICHER
Doktor der technischen Wissenschaften

ZUSAMMENFASSUNG

In Ungarn war in der zweiten Hälfte des 18. Jahrhunderts ein Hochofen kleiner Leistung in Betrieb, worüber auf Grund von Analysen des dort erzeugten Roheisens und der erhaltenen Schlacken es sich schwer feststellen lässt, welcher Art von Möller dieselben entstammen. Die Hütte lag nicht weit von bekannten ungarischen Bauxitvorkommen. Die an der Hand liegende Annahme, dass Bauxit allein zwecks Roheisengewinnung verhüttet worden wäre, lässt sich jedoch nicht beweisen. Ebenfalls ist es nicht beweisbar, dass der hohe Mn-Gehalt des Roheisens und der hohe MnO-Gehalt der Schlacke dem Zuschlag von Manganerzen aus einem nahe liegenden Mangenerzbergwerk zuzuschreiben wäre. Infolge von Lücken in der hüttenmännischen Erklärung liegt die geologische Annahme nahe, dass eine Art Limoniterz — genetisch mit der Bauxitlagerstätte verknüpft — verarbeitet wurde, was in der Geschichte des Hüttenwesens infolge der Eigentümlichkeit des Vorkommens vermutlich einzig darsteht.

SUR L'HISTOIRE DE LA MÉTALLURGIE EN HONGRIE

V.

FABRICATION DE LA FONTE À PARTIR DE MINERAIS ALUMINEUX AU 18ème SIÈCLE

Prof. A. SCHLEICHER
Docteur des sc. techn.

RÉSUMÉ

En Hongrie dans la seconde moitié du 18ème siècle on faisait opérer un haut fourneau de bas rendement, dont il est dificille à constater — à partir de la fonte et des scories obtenues — de quelle charge elles étaies obtenues. L'usine n'était pas loin des gisements des bauxite connus. La supposition probable qu'on eût élaboré la fonte à partir de la bauxite seule, n'a pu être pruvée. Aussi est-il indémontrable que la haute teneur en Mn de la fonte et la haute teneur en MnO des scories soient dues à ce qu'on eût ajouté à la charge des minerais de manganèse d'une mine de tels minerais pas loin de l'usine. Les lacunes de l'interprétation sidérurgique porte en premier plan la supposition géologique qu'on eût utilise minerais génétiquement allié à la bauxite. Cela paraît être un procédé unique dans l'historie de la sidérurgie par la particularité du gisement.

К ИСТОРИИ МЕТАЛЛУРГИИ В ВЕНГРИИ V.
ПРОИЗВОДСТВО ПЕРЕДЕЛЬНОГО ЧУГУНА ИЗ БОКСИТНОЙ СМЕСИ В XVIII ВЕКЕ

Д-р техн. наук, проф. А. ШЛЕЙХЕР

РЕЗЮМЕ

В Венгрии во второй половине XVIII в. работала маломощная железоплавильная печь, для которой на основе анализа изготовленного там передельного чугуна и шлака трудно определить — из какой именно смеси они происходят. Печь была расположена не далеко от известных месторождений боксита в Венгрии. Однако то предположение, что для доменного процесса был использован только боксит не может быть доказано. Также нельзя доказать, что высокое содержание марганца в передельном чугуне и высокое содержание MnO в шлаке происходит от шихтования марганцевой руды, добывавшейся на одном из шахт по добыче марганцевой руды. Вследствие пробела в металлургическом толковании наиболее вероятным является то геологическое предположение, что производилась переработка лимонитной руды, генетически связанной с бокситом, вследствие особенности которой в истории металлургии предположительно является одиноким случаем.

A kiadásért felel az Akadémiai Kiadó igazgatója
Műszaki felelős: Farkas Sándor
A kézirat nyomdába érkezett: 1957. V. 27. — Terjedelem: 19,50 (A/5) ív, 96 ábra
42 599/57 — Akadémiai Nyomda, Budapest, V., Gerlóczy u. 2. — Felelős vezető: Bernát György

INDEX

The Acta Technica publish papers on technical subjects in English, German, French and Russian.

The Acta Technica appear in parts of varying size, making up one volume.

Manuscripts should be addressed to:

Acta Technica
Budapest 62, Postafiók 440.

Correspondence with the editors and publishers should be sent to the same address.

The rate of subscription to the Acta Technica, is 110 forints a volume. Orders may be placed with "Kultura" Foreign Trade Company for Books and Newspapers (Budapest, VI. Népköztársaság útja 21. Account No. 43-790-057-181) or with representatives abroad.

Les Acta Technica paraissent en français, allemand, anglais et russe et publient des travaux du domaine des sciences techniques.

Les Acta Technica sont publiés sous forme de fascicules qui seront réunis en un volume.

On est prié d'envoyer les manuscrits destinés à la rédaction à l'adresse suivante:

Acta Technica
Budapest 62, Postafiók 440.

Toute correspondance doit être envoyée à cette même adresse.

Le prix de l'abonnement est de 110 forints par volume.

On peut s'abonner à l'Entreprise pour le Commerce Extérieur de Livres et Journaux «Kultura» (Budapest, VI. Népköztársaság útja 21. Compte-courant No. 43-790-057-181) ou à l'étranger chez tous les représentants ou dépositaires.

«Acta Technica» публикуют трактаты из области технических наук на русском, немецком, английском и французском языках.

«Acta Technica» выходят отдельными выпусками разного объема. Несколько выпусков составляют один том.

Предназначенные для публикации рукописи следует направлять по адресу:

Acta Technica
Budapest, 62, Postafiók 440.

По этому же адресу направлять всякую корреспонденцию для редакции и администрации.

Подписная цена «Acta Technica» — 110 форинтов за том. Заказы принимает предприятие по внешней торговле книг и газет «Kultura» (Budapest, VI., Népköztársaság útja 21. Текущий счет № 43-790-057-181) или его заграничные представительства и уполномоченные.

56,— Ft