SOME IMPORTANT TECHNICAL—ECONOMIC FACTORS OF THE SEAMLESS TUBE PRODUCTION

By

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The sudden increase in the world's steel tubular product consumption which is brought about by the progressive construction of gas and oil pipelines traversing the continents, and by the development of oil mining, call the attention of competent technical and economic circles more and more to the problems of steel tube production. In the following a concise analysis of some important technical and economic factors concerning the production of seamless tubes made of carbon steel or low-alloy steel, dia. 50—500 mm, should be given.

I. The role of starting materials

1.1 *Steel quality*

The majority of steel sorts used for standard tubes are carbon steel, with a minor part consisting of low-alloy steel. Every process of tube production requires steels free of impurities, inclusions and inhomogeneities. The individual processes, however, show different sensitivities to such undesirable impurities or crystalline enrichments. It is in the automatic Stiefel tube rolling method that impurities and inhomogeneities in steel texture give rise to the greatest troubles. Endeavours are made therefore to fix the maximum sulfur content of starting steel materials in 0.06%, with the phosphorus content reduced to 0.04%. The Pilger process is less sensitive to inhomogeneities, *e.g.* to crystalline enrichments in the steel texture. The different sensitivities of both tube manufacturing processes can be explained with their different hot metalworking methods, since in the automatic tube mill the elongation of the material is finished at abt. 1200° C temperature with continuous rolling, whereas in the Pilger mill the same is done at abt. 900° C, with intermittent forge rolling.

Steel producers are turning more and more to the use of killed steel. As known, the gas solvability increases in steels killed with aluminium or ferrosilicon before casting, and this is manifested in the cast ingots mainly by a clodding of gas cavities and of the concomitant sulfurous or phosphorous enrichments along the longitudinal axis and in the head part of the ingot (Fig. 1. A), whereas in case of rimming steel ingots the gas cavities accompanied by sulfurous and phosphorous enrichments are to be found all over the ingot. In automatic tube mills using blooms as starting material the head part is cut as early as in the blooming mill and gets into

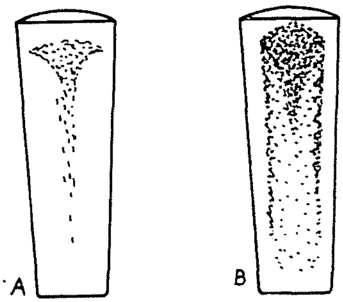


Fig. 1. Distribution of impurities, inclusions, and draws in steel ingots. *A)* Killed steel ingot; *B)* Rimming steel ingot

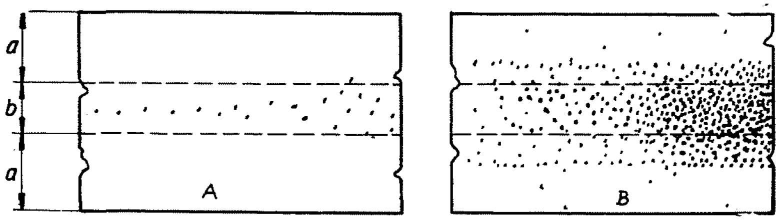


Fig. 2. The most frequent forms of distribution of impurities and inclusions in wide steel band. *A)* Wide band rolled of killed steel; *B)* Wide band rolled of rimming steel

wastage, whereas for Pilger mills special ingots are made, the innermost part of which, containing the bulk of impurities, is gathered by the preliminary piercing at the bottom, and this is not removed until cutting off the ends of the finished Pilger tubes.

For heavy-walled tubes with large diameters (abt. 300—500 mm) there are generally specifications prescribing the use of killed steel; the manufacturers of tube production equipment do not assume quality or output guarantees but for killed steel tubes. In this range of production the most frequent deficiencies in tubes made of rimming steel are cracks and scales scattered over the inner wall of the finished tubes.

Also the process of weld tube manufacture bears great sensitivity to the purity and homogeneity of starting steel band material. It is particularly with skelps split of wide bands that irregularities will occur, owing to which only second-rate commercial tubes of inferior value can be produced. In Fig. 2 the most frequent forms of distribution of impurities in wide bands rolled of killed steel resp. of rimming steel ingots are displayed. It can be clearly observed that by splitting out the middle zone of the wide band, it is also here the skelp of killed steel that supplies the best starting material and herewith weld tubes of superior quality.

Obviously the use of killed steel skelps is much costlier, all the more so as the yield, related to ingots, is lower when processing is done carefully.

1.2 *Sizes and dimensions of steel ingot sections*

Some tube rolling processes (*e. g.* automa-ic tube mills) use cogged circular tube billets as starting material. In this case steel production and tube manufacture are opposed by their conflicting interests. The blooming mills strive to produce ingots of the largest possible size and to convert them into blooms, thus increasing their output. At the same time, however, the tube rolling mills require tube billets made of ingots of the least possible weight and section, since small-section ingots show, owing to a rapid cooling, fewer crystalline enrichments than those having a large mass and section, where primary enrichments nearly always occur (Fig. 3. B). And the automatic tube rolling process is extremely sensitive to detrimental crystalline enrichments.

Fig. 4 shows the derivation of tube billets, starting material of automatic tube mills, from ingots, with the approximative proportions of sections. In case of large sections the danger of primary crystalline enrichments is imminent.

With Pilger tube rolling mills the position is entirely different, as they are less sensitive to the primary crystalline enrichments of the ingots on the one hand, and, on the other, their production starts directly from the ingots. The original Mannesmann—Pilger process, owing to a technical solution represented by the oblique pair of rollers on the piercing stand, cannot use but circular ingots as starting material. In Fig. 5. A the proportions of ingot sections falling into the range of 50—500 mm tube diameter are illustrated.

In the new Elongating-Pilger process the preliminary piercing of the ingots is done on a hydraulic press, thus the starting ingot may have a square section. The mantle of bigger square-sectioned ingots is cast in a corrugated form, to avoid crack hazards,

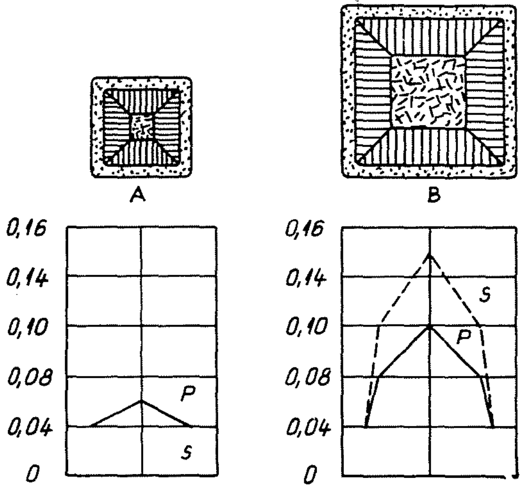


Fig. 3. Texture of ingots with different sections and percentage of sulfuric or phosphorous crystalline enrichments. *A)* Small-sectioned ingot, roughly homogeneous; *B)* Large-sectioned ingot, with crystalline enrichments

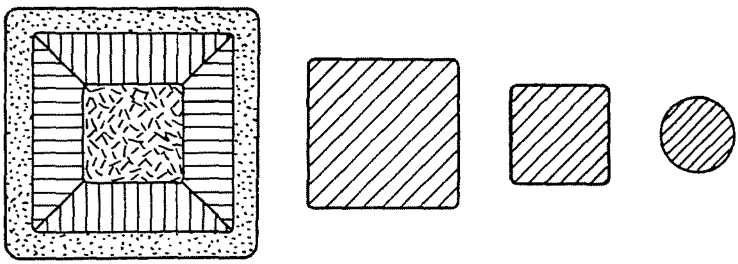


Fig. 4. Circular-sectioned tube billets, starting material for automatic tube rolling mills. Cross-section proportions related to the starting ingots

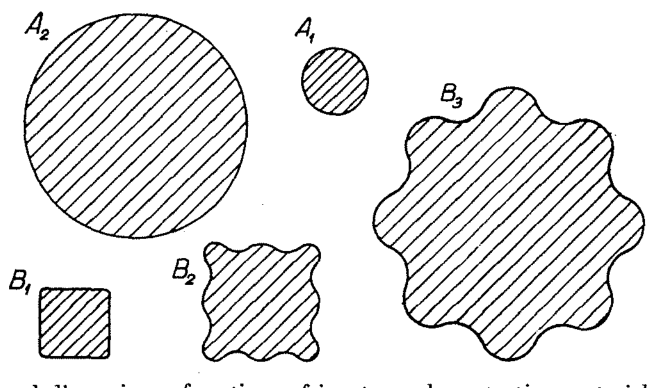


Fig. 5. Shape and dimensions of sections of ingots used as starting material in Pilger tube mills. *A)* Circular-sectioned ingots of the old Mannesmann—Pilger process; *B)* Sections of ingots used in the new Elongating-Pilger process

whereas large-size tubes are made, for reasons of better metalworking, of circular ingots with corrugated mantle (Fig. 5. B). It is a well-known fact that square-sectioned ingots are easier and cheaper to make than circular ones, owing to the reduced waste percentage. Changing over to square-sectioned ingots with corrugated mantle has brought about an average increase of 4 to 6% in the yield of the Pilger process.

In case of tubes with identical geometrical dimensions the tube production practice uses, in general, quadrangular ingots with much bigger section areas than in case of circular sections, owing to which the factors of metalworking will show a favourable trend and a better compaction of the material can be attained.

II. Features of the finished tubes

2.1 *Minimum tube wall thickness*

The processes for manufacturing seamless steel tubes can attain roughly the same minimum wall thicknesses. Table 1 shows minimum standard wall thickness values for a few nominal tube sizes. There are, naturally, seamless tubes with somewhat lighter walls than those indicated below.

The reduction of wall thickness had been a very old endeavour of steel tube manufacturers. A definitive solution to this problem was furnished by the tube weld processes which in the last decades have restricted the continuous and automatic tube rolling mills producing commercial ware to a limited scope; the Pilger process, following the general trend of specialization, is undergoing a further development as a process for producing high-quality tubes on the one hand, and, on the other, as a process of smaller production verticality for industrially backward countries which, besides, is able to ensure a great elasticity in production, *i. e.* to offer a rich choice of tubes with profitable conditions. The reduction of wall thickness is a question of general interest because in some cases (*e. g.* in pipelines) the strength requirements would allow for wall thicknesses by millimetres lower than the minimum values attainable with seamless tubes. This, however, can be achieved satisfactorily in case of tubes welded of steel skelps.

2.2 *Possibilities for dimensional stability*

The concentricity of inner and outer tube mantles and the variations in wall thickness ensuing therefrom show near-by the same values for seamless tubes in all manufacturing processes. Beforehand better results were recorded with automatic tube mills than with the Mannesmann—Pilger process. However, owing to the preliminary piercing on hydraulic presses introduced in the Pilger process and chiefly to the elongation done on the elongator stand, the wall thickness tolerances of Pilger tubes are, as a rule, far within the standard specifications for high-quality tubes.

In Table 2 we have compiled some data for medium tube diameters:

With all manufacturing processes the reduction of wall thickness as well as closer wall thickness tolerances depend largely on a careful manufacture and on the skill of the staff. It is mainly in the production of high-quality tubes (*e. g.* boiler tubes, oil well drill pipes) that the importance of dimensional stability comes into prominence.

Table 1

Nominal tube dia.					
	Inch	6″	8″	10″	12″
	mm	168	219	273	325
Minimum wall thickness, mm		5	6	6.5	7.5

Table 2

	Standard specifications for tubular products and technical optimum applied	Tube wall thickness tolerances in percentage
Standard specifications	For commercial tubes For high-quality tubes	±12.5 ±10.0
Attainable optimum	On automatic tube mills On Mannesmann-Pilger mills On Elongating-Pilger mills	±(5—8) ±(8—10) ±(5—7)

2.3 *Surface quality of finished tubes*

All hot processes of the steel tube production furnish tubes of a smooth exterior surface, with sparse scratches or scale cavities. The quality of the interior surface is, however, not so favourable. The interior surface of tubes rolled over a plug in automatic mills are very often scattered with scale cavities of various depths. This roughness is a consequence of the metalworking process; it is further increased if the raw tubes preliminarily pierced cool down and have to undergo an intermediate re-heating. It is the Pilger process that ensures the smoothest inner tube surfaces, as a result of an elongating process similar to mandrel forging. In Fig. 6 the average surface qualities of inner tube walls are compared (automatic and Pilger process).

The smoothness resp. roughness of inner tube surfaces is a factor of decisive importance for many reasons. Thus *e. g.* experience shows that with tubes of rough surfaces the fatigue limit, with the static tensile strength increasing, drops more rapidly than with tubes of smooth surfaces. Table 3 contains some characteristic data in this respect. The fatigue limit is of primary importance in case of tubes subjected to repeated alternating stresses (boiler tubes, oil well drill pipes, *etc.)*.

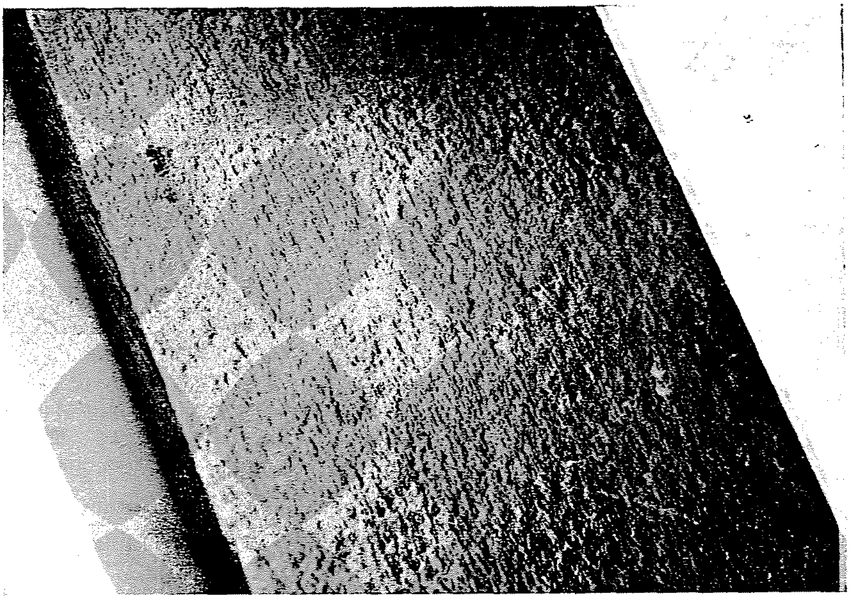
The majority of steel tubes is used for pipelines delivering aeriform or liquid substances. In such cases the roughness of inner tube surfaces is particularly disadvantageous. It is well-known that in tubes with cross sections above 20—30 mm inner dia. and at the usual speeds of delivery there is generally a turbulent flow arising. Tests carried out in the range above the critical value of the Reynolds' number (Ro = 2320) have revealed the well-known phenomenon that at greater speeds of delivery the brake effect of the rough tube surfaces comes into prominence. To illustrate the relations, some of the factors used for computing the flow losses are indicated in Table 4. The technical and economic significance of tube resistance cannot be underrated in extensive pipeline systems.

Besides, experience shows that the surface roughness increases the susceptibility to

Table 3

Comparatively reduced values of the fatigue limit				
If the static tensile strength σ_B kg/mm^2 increases	30	70	110	150
Smooth tube surface %	96	90	88	87
Rough tube surface* %	78	54	40	30

* The relative value of roughness is represented by average rusty surfaces or by inside rough surfaces of tubes made on automatic tube mills.



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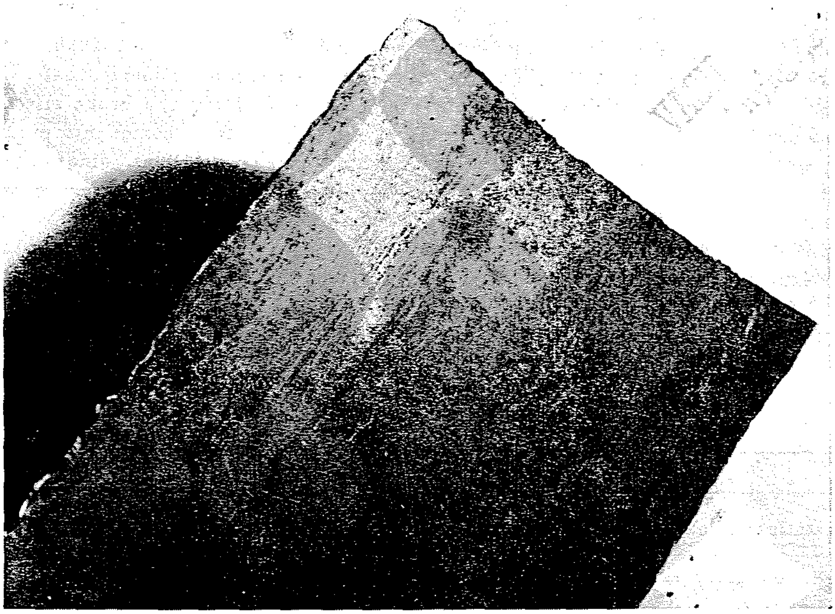

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Fig. 6. Average surface qualities of inner tube walls. *A)* Tubes made on automatic tube mills; *B)* Tubes made on Pilgrim mills

Table 4

Factors proportional to the internal resistance of tubes	Inner tube surface		Resistance surplus of rough tubes, %
	smooth	rough*	
Medium tube resistance factor as indicated by Dupuit	0.02	0.03	abt. 50
Roughness number "k" for the computation of tube resistance factor (after Hütte)	1.5—2.0	2.5—5.0	over 100

* The relative value of roughness is represented by average rusty surfaces or by inside rough surfaces of tubes made on automatic tube mills.

corrosion and furthers the corrosion once started.

It should be added that the inner surfaces of tubes welded of cold-rolled steel skelps are smooth, but from the longitudinal weld a slightly protruding part remains even after the mechanical draw-off.

2.4 *Texture of the steel tube materials*

When analysing the texture of carbon steel tubes at the most frequent C-content of 0.15—0.50, it is found that the grain size resp. the shape of the occurring pearlitic-ferritic texture elements is roughly similar in all tubes made with different manufacturing processes, provided that the tubes made on automatic mills are subjected to a subsequent normalization. However, the arrangement of texture elements ensuing from the primary texture, from inhomogeneities shows deviations in case of tubes made on automatic resp. Pilger tube mills. *E. g.* with automatic tube rolling the primary crystals of the steel stretch, as a result of unidirectional elongating rolling, into lines along the longitudinal axis of the tubes (Fig. 7. A). On account of the "fibrous" texture thus obtained the longitudinal and transverse mechanic properties of the tubes show very disadvantageous differences. The stability against major interior overpressures will deteriorate.

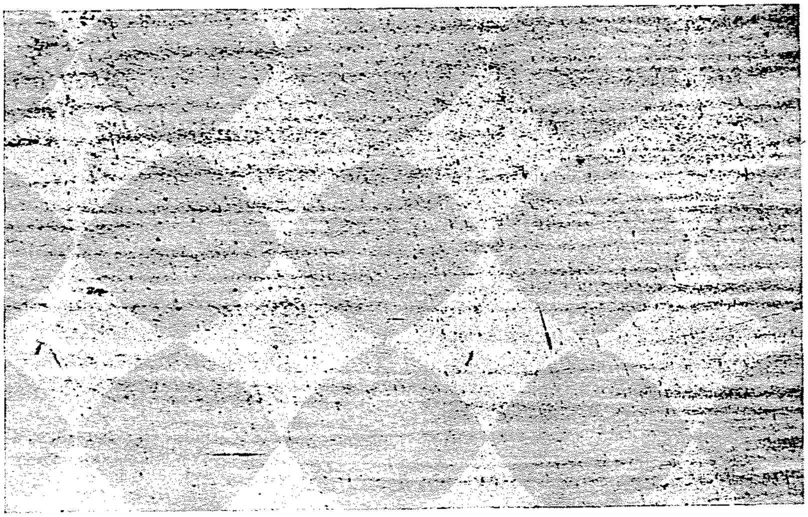
In case of pilgerized tubes the primary crystalline enrichments, owing to the multi-directional, forging-like elongation, form an undulatingly entangled, irregular texture (Fig. 7. B), advantageous as regards the longitudinal and transverse properties of the tubes.

It should be mentioned that whereas tubes rolled in automatic mills at a final temperature of 1200° C need, in general, a subsequent heat treatment for refining the grains, the tubes elongated in Pilger mills at abt. 900° C final temperature can dispense with it, their grain fineness being, as a rule, satisfactory.

2.5 *Strength properties of tubes*

The results of strength tests carried out with tubes of different manufacturing processes are rather difficult to compare as the crosswise and lengthwise strength properties are greatly subject to the relative purity of steel which in turn, depends primarily on the manufacturing and casting process. As set out in the foregoing, with tubes made on automatic and continuous rolling mills the primary crystalline enrichments and inhomogeneities of steel ingots results in a "fibrous" texture, whereby the crosswise and lengthwise strength properties show deviations. The greatest difference can be observed mainly with the so-called ductility values (*e. g.* Charpy impact value, contraction and elongation). Taking for steels of fibrous micro-structure the average strength values in longitudinal direction of the tubes a 100, the order of crosswise strength values will show the ratios to be found in Table 5.

The ratios of Table 5 are based on Mester's and Rössing's data published in the literature.



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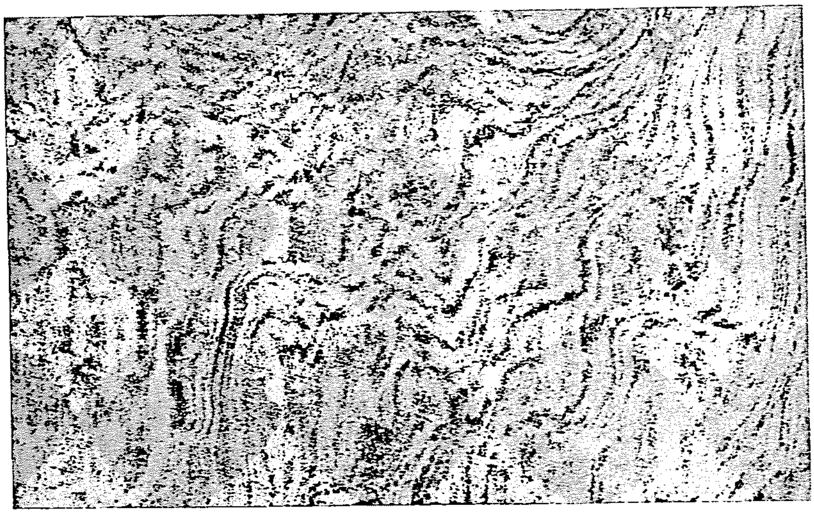

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Fig. 7. Photograph of a tangential section made next to the exterior mantle of finished tubes (magnification: 7×). *A)* Fibrous texture of tube walls made on automatic tube mills; *B)* Entangled texture of tube walls made on Pilger mills

Their tests stress the more favourable mechanic properties of pilgerized tubes, as in this case no fibrous steel texture may arise.

The fibrous texture of tube walls is, in general, reflected also in the results of standardized expanding tests, of the ring method, and chiefly of the flattening tests. In the expanding and the ring tests the fibrous material usually shows burstings with a slight contraction or without contraction. After the flattening test there are cracks mostly visible also to the naked eye, arising along the texture elements.

Table 5

Differences in the strength properties of steels with a "fibrous" texture	Lengthwise index	Crosswise index
Static tensile strength	100	abt. 90
Elongation	100	25
Contraction	100	35
Charpy impact value	100	20
Fatigue limit	100	75

Table 6

Manufacturing process	Upper limit of yield, %	Index of material consumption
Elongating Pilger Mill	abt. 85	1.18
Mannesmann—Pilger Mill	abt. 80	1.25
Automatic (Stiefel) Mill	abt. 65	1.54
Tubes welded of skelps	abt. 60	1.67

III. Economic considerations

3.1 *Material yield*

The Pilger process, starting from steel ingots, ensures the best yield: whereas for the automatic tube mills blooms, quadrangular blooms and circular tube billets have to be cogged from the ingots (cf. Fig. 4), production in the Pilger mills is based on the ingot itself. Owing to this, automatic tube mills show considerably worse yield indices. To illustrate the order of different yields, we have compiled in Table 6 the upper limits of yields attainable in practice, completed with estimated data of tube production starting from steel skelps.

As set out under 1.2, the new Elongating-Pilger process, by changing over from circular ingots to the square-sectioned or corrugated-mantle ingots, has added a further increase of 4—6% to the favourable yield of the Mannesmann—Pilger process. Table 6 shows also the indices of material consumption, *i. e.* the amount of liquid steel or ingots required for obtaining 1 kg of finished tube products.

3.2 *Productivity*

By scrutinizing the optimum possibilities in productivity both for automatic and Pilger tube mills, basing on the literature and our own experiences, the following general notions can be formed: In case of producing light-walled tubes of the same diameter, the output of automatic mills is better, whereas for heavy-walled tubes of the same diameter it is the Pilger process that shows better results. The output of both tube-rolling methods represented by indices is compared in Table 7, with the specific output of automatic tube mills taken a 100.

According to competent circles, in automatic tube rolling mills the level of optimum output has been fairly approached by the practice. At the same time, the optimum attainable output of Pilger mills may surpass, even by 55—85%, the present level. Further speeding up of productivity may be expected in this process from increasing the revolution number of working rolls in the Pilger stand, from a continuous improvement of the feed and brake systems, from rolling

Table 7

Producing tubes of the same diameter but with different wall thickness	Output index	
	Automatic mills	Pilger mills
In case of light-walled tubes	100	abt. 93
In case of heavy-walled tubes	100	abt. 108

longer tubes and, in general, from applying the most up-to-date working methods.

It should be pointed out once more that the high-productivity tube weld processes which work from steel skelp as starting material, compete in first line with the automatic tube rolling, since both processes can offer the best productivity and largest output in mass products of the 50—150 mm outer diameter range. Pilger tube mills, on the other hand, embody a process for the production of special and high-quality tubes with potentialities to increase productivity and shall be, in all probability, indispensable for a long time to come.

3.3 *Assortment of tubes*

It is the Pilger process that offers the largest assortment of tubes, considering that their production covers tubes of 50—620 mm diameter, whereas automatic tube mills work in the 60—400 mm diameter range.

It is well-known in the trade that automatic tube mills acquire themselves advantage in productivity if they produce over a longer period tubes of the same quality and size. The length of tubes made by them is usually 10—12 m, sometimes 15 m. Hence follows that automatic tube mills turn out seamless tube mass products mainly for large inland markets.

Pilger mills can offer a wider range of assortment, as re-tooling from one size to another is quick and simple in such mills. Moreover, they lend themselves also for producing heavy-walled tubes of 24—36 m length, and other specialities *e. g.* tubes with polygonal sections.

It is not without interest to note that the U. S. A., where at first the automatic tube mills had gained ground, and later, in the last decades, abt. 70 per cent of the steel tube production have been supplied by weld processes, are reduced to covering the demand in quality tubes from imports; a sizable part of the tubes needed by the oil mining in the U. S. are imported from the German Federal Republic, wherefrom they obtain high-quality tubes made with the Pilger process.

3.4 *Investment cost ratios for the technological equipment*

It is the Pilger process that shows the comparatively shortest production verticality. For this process no additional rolling mill capacities have to be earmarked, in contradistinction to automatic tube mills of long production verticality, where in the investment capital also the share proportionate to the capacity of the cogging mill, of the blooming mill, and of the billet mill has to be included.

Fig. 8 shows a comparison between the weights and export prices of technological machinery in case of automatic tube mills and Pilgrim mills generally used in European countries: choosing four types of both mills (for the production of max. 100, 200, 300, and 400 mm nominal tube diameters), the values pertaining to Pilger mills are taken as a basis (100), and the weight and price indices of automatic tube mills are related to this basis. The figures show clearly that in case of producing tubes above 150 mm nominal diameter the weights and international market prices of automatic tube mills are considerably higher than those of Pilger mills of similar destination.

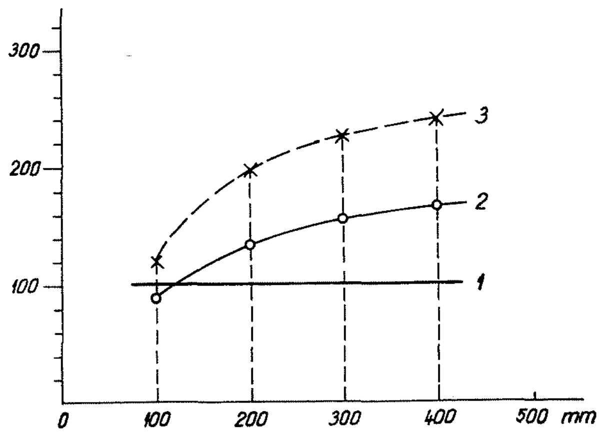

Fig. 8. Comparison of weight and price indices, in case of main technological equipment of automatic and Pilger mills. The weights and prices of the Pilger mill are taken as a basis (100)

As set out in the foregoing, the erection costs of automatic tube mills are further increased by the additional investment outlays in rolling mills.

IV. Conclusions

1. The technological process of Pilger tube mills is less sensitive to the quality of starting materials, it is therefore the most desirable process to be applied in countries entering the initial stage of setting up a metallurgical industry. This is also backed by the fact that the Pilger process offers, in spite of the shortest production verticality, the largest assortment of products, and can be realized at the lowest specific investment costs.

2. The most appropriate process for producing light-walled commercial tubes is the tube weld process, starting from steel skelp; it demands, however, a highly developed siderurgy and facilities for skelp rolling.

3. In countries with a developed siderurgy but lacking an appropriate basis for the tube weld technique (steel skelp rolling), the production of commercial tubular products up to a nominal dia. of 150 mm on automatic tube rolling mills can be considered competitive.

4. For the production of high-quality, large-diameter, and special tubes the up-to-date Elongating-Pilger process is indispensable, even in countries with an advanced industry.

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RECENT DEVELOPMENT IN THE AIR-COOLED CONDENSING EQUIPMENT "SYSTEM HELLER" AND THE SLOTTED-RIB HEAT EXCHANGERS "SYSTEM FORGÓ"

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I. Air-cooled condensing "System Heller"

The steady growth of industrial works and power stations both in size and capacity has given rise lately to serious problems regarding the water supply, almost all over the world. In a number of industrially highly developed countries the scarcity of cooling water has even impeded extensive industrialization. Thus every possibility to expand industry without a simultaneously increased cooling water demand is of extraordinary significance and explains the great interest shown during these last years in the leading industrial countries in the air-cooled condensing equipment "System Heller". Three large equipments are at present under construction and three more in the designing stage.

In the course of design work and during the erection of the equipments a considerable number of new problems and tasks has arisen the elaboration and solution of which has contributed to the further development of the air-cooled condensing system.

As known, in the air-cooled condensing equipment "System Heller" the expanded exhaust steam of power station turbines is condensed in jet condensers. The cooling water entering the jet condenser and mixing therein with steam, warms up. The warmed up cooling water is subsequently passed over a surface-type heat exchanger in which it is exposed to atmospheric air and cooled down to a temperature where it can be once more injected into the condenser. By the application of a pump and a recuperating water turbine the pressure in this closed circulation is so adjusted as to be above the atmospheric at every point of the large surface-type heat exchanger. By this arrangement it is possible to obviate eventual pollution of the cooling water at leakage points on the one hand, and it facilitates the discovery of defects in the system on the other.

A small portion of the circulating cooling water, a quantity corresponding to the steam condensed in the condenser, is passed to the boilers as feed water.

The air-cooled condensing equipments are associated with the slotted-rib heat exchangers "System Forgó". These heat exchangers consist of cold-pressed aluminium elements and are characterized by remarkable heat transfer properties and very small pressure drop on the air side.

During the past years a marked development has taken place with regard to almost each element of the air-cooled condensing equipment.

a) Jet condenser

While evolving the jet condenser type to operate within the air-cooled condensing system many problems, theoretical as well as practical, have arisen claiming thorough investigation and solution. It is known that jet condensers though widely used in conjunction with low-capacity steam turbines some thirty or fourty years ago, have hardly if ever been applied in power stations during the recent decades. This was due to the fact that problems of space requirement, small pressure drop in the spray nozzles and ideal cooling water temperature (*viz.*

its warming up to the temperature of the steam space) had not assumed the overall importance in the low-output power generating machines of that day which they have now in modern power stations.

To find solution to similar problems new methods and means had to be found, fundamentally different from those applied so far. An investigation into the constructional details of jet condensers, as for instance drip trays, spray nozzles, etc., disclosed that these are unsuitable to be used in modern condensers, for the following reasons:

While drip trays, owing to their considerable steam-side resistance, cause substantial drop in the pressure of steam entering the condenser, spray nozzles, due to their conical shape, cannot advantageously utilize the available condenser space. In addition to these drawbacks the fairly high pressure necessary for atomization will increase the power consumption and lead to rather uneconomical operation.

These were the preliminaries of our theoretical investigations. These were followed by hydraulic and heat transfer experiments which aimed at developing an adequate jet condenser and which ultimately led to the type suitable to meet all requirements of large, up-to-date power generating stations.

The most essential feature of the new jet condenser type is the spray nozzle creating thin fluid films, *viz.* dispersing the cooling water in thin vertical sheets. The formation of these thin fluid films takes place in the following manner:

The water ejected by the nozzles hits the baffle plates and disperses on their surface in a thin film. Due to the conditions of their formation the fluid films are extremely turbulent, ensuring by this very turbulence excellent heat transfer and the warming up of the cooling water practically to the temperature of the steam space. Experiments and tests have established that the temperature of the cooling water approximates that of the steam space, to a difference of merely 0.1 to 0.2 centigrade, a most essential precondition of the economical operation of steam turbines equipped with jet condensers.

The very favourable utilization of the condenser space appears as another advantage of the spreading of cooling water in thin films, as compared with the conical spray nozzles. Whereas conical nozzles could fill the available space (generally cylindrical or cubiform) only with voids between them, the thin fluid films can be spaced close to each other and with their plane parallel to the steam flow, ensuring very low steam-side resistance.

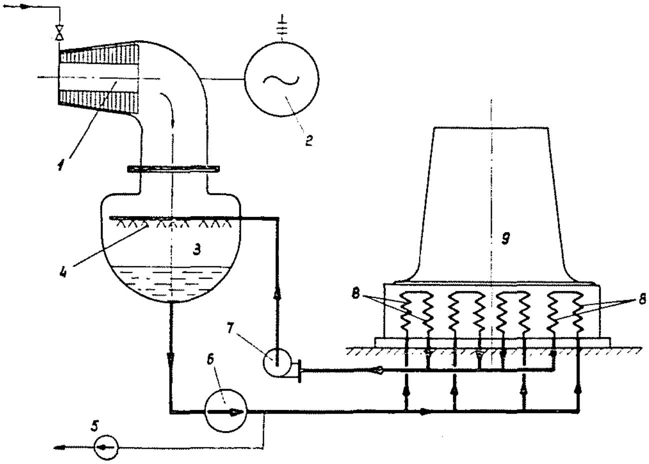

Fig. 1. Air-cooled condensing equipment System Heller. Schematic diagram
1. Steam turbine, 2. Alternator, 3. Jet condenser, 4. Spray nozzles, 5. Condensate pump, 6. Cooling water circulating pump, 7. Water turbine, 8. Heat exchanger cooling columns, 9. Dry cooling tower

The good utilization of the steam space by the closely spaced fluid films helps to a considerable reduction of condenser dimensions and ultimately results in a space requirement for up-to-date power station turbines materially below that needed by surface-type condensers applied so far.

Fig. 2 illustrates a double-exhaust steam turbine of 150 MW capacity with a 75 MW surface condenser on its left-hand side and a jet condenser of the film-spray-nozzle type of identical capacity on its right-hand side. The small dimensions of the jet condenser will be conspicuous and so will be another very important architectural feature, namely the considerably shallower condenser basement.

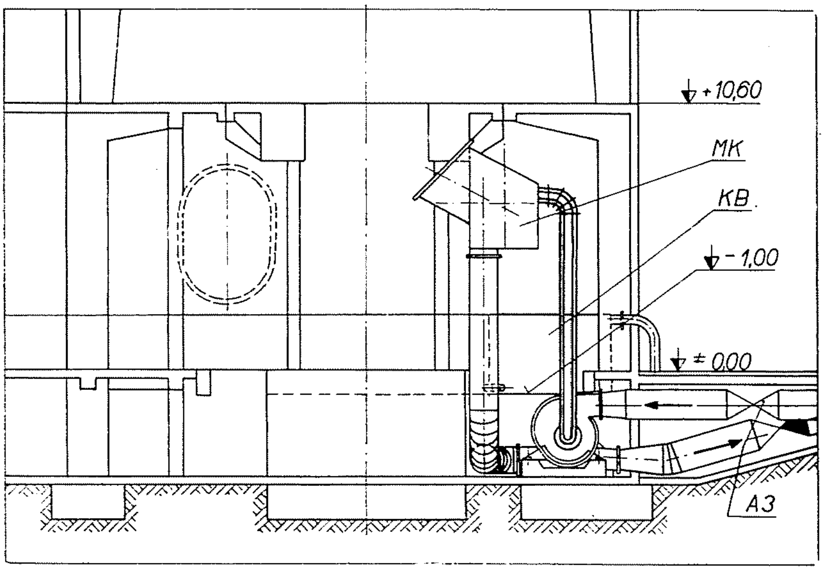

Fig. 2. Comparison of jet and surface condenser of 75 MW capacity

While condenser basements required for the usual steam turbine performances had been in the range of 8 to 12 m, for jet condensers a basement of 5 to 6 m height is sufficient, permitting substantial savings in building costs.

In addition the turbine foundations, too, will be only half their former dimensions whereby a great deal of the vibration associated to steam turbine operation can also be eliminated.

b) *Cooling cell fan*

Atmospheric air can be passed across the air-cooled condensing equipment "System Heller" either by means of a natural-draught heat exchanging equipment or by fans.

While in the first case the slight pressure difference necessary to cause air to circulate is ensured by a tall tower (which creates the requisite depression through warmed-up air), in the latter case large-size, so-called "cooling tower fans" have to be applied. Such cooling tower fans are generally of the vertical-shaft axial-flow type and are supplied with diffusers of 5 to 10 m height.

Air-cooled condensing equipments are coordinated with diffusers, with two aims in view:

In the first place diffusers help to reduce outlet losses and with it fan power demand, in the second place they prevent warm air exhausted by the fans to be sucked back across the cooling elements. Experiments have shown that diffusers of 5 to 10 m height ensure complete protection against such re-entry of warmed up air.

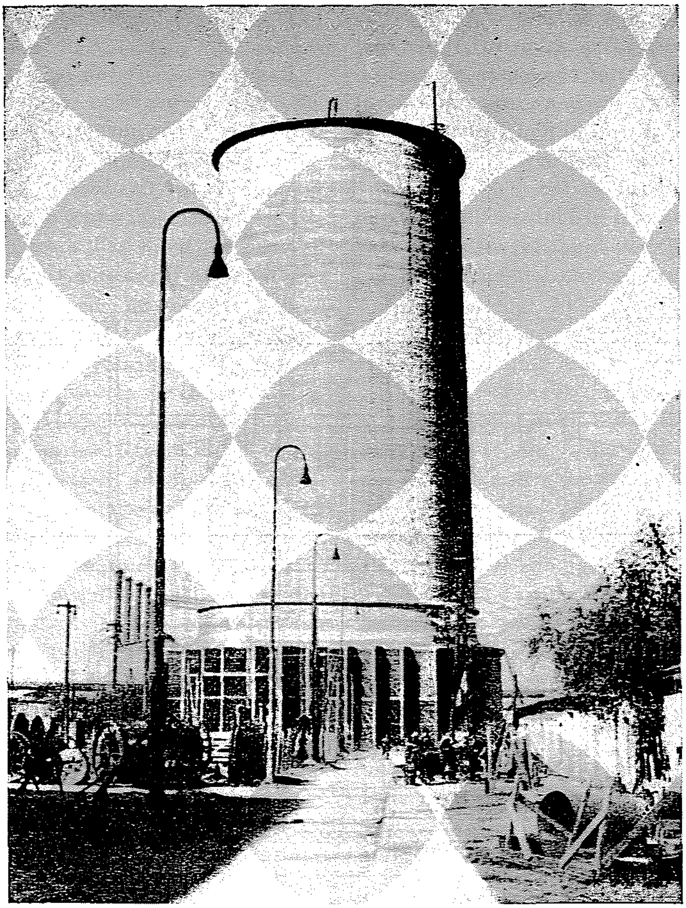

Fig. 3. The natural draught air-cooled condensing equipment of the Danube Steel Works (Hungary)

In the development of fans during the last few years the simplification of blade design and the application of plastics of high tensile strength opened up the way toward the construction of large-diameter fan units at relatively low cost.

Fan outlet losses can naturally be reduced also by applying larger diameters. Although investigations as to the most economical design have disclosed that large-diameter fans offer notable advantages over high diffusers, the still existing risk of the recirculation of warm air through the cooler elements have prevented practical application. To clarify the problem a test equipment was built and in this equipment smoke tests have been conducted to establish the places where suction takes place and that are reached by warm air ejected by the fans. The "neutral zone", *i. e.* the sum of the points where neither suction occurs nor warm air passes through, was found in the lower portion of the diffuser. This finding proves that upwards from the part where this zone is still connected with the equipment, the diffuser may be dispensed with as even altogether without this upper portion no danger of warm air ingress prevails.

Accordingly fan diameters have been increased from the earlier 6 to 8 m, to 10 m

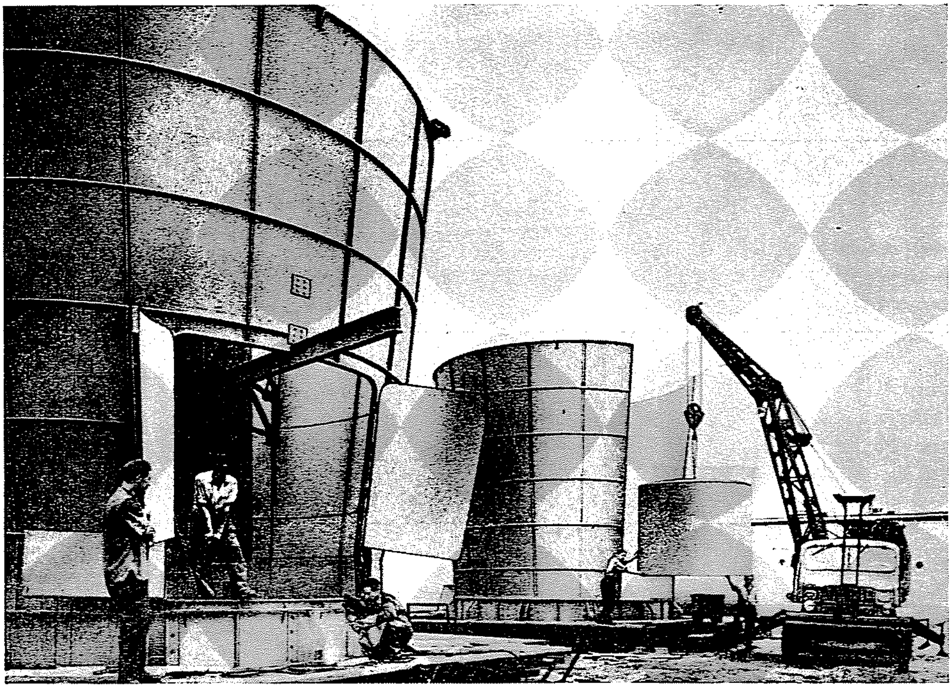

Fig. 4. Diffuser of a cooling tower fan during assembly

and instead of the 10 m high diffusers of the earlier design exhaust orifices of 1 to 1.5 m height have been provided. By this solution alone it was possible to reduce fan costs by about 40 per cent at identical air delivery and identical power consumption. As a natural consequence the costs of the entire air-cooled condensing equipment could be reduced and new fields added to its economical application.

II. New applications of the slotted-rib heat exchanger "System Forgó"

As already mentioned in the preceding chapter air-cooled condensing equipments apply the so-called slotted-rib heat exchangers "System Forgó", a system of very favourable heat transfer properties and small air-side pressure drop.

The heat exchangers System Forgó owe their advantageous properties to the principle of fins (slotted ribs) and to their material, pure aluminium throughout. The equipment consists of abt. 15 mm diameter aluminium tubes to which ribs are attached through a cold process. The surface of the ribs is slotted so as to prevent the formation of a continuous and thick air boundary layer that would deteriorate heat transfer. Namely, on the slotted ribs the air boundary layer is continually cut up and the absence of a thick boundary layer ensures excellent heat transfer coefficients.

Pure aluminium as the material of the heat exchangers has manifold inherent advantages:

absence of corrosion;

outstanding heat conductivity making for better heat transfer;

light weight, rendering assembly simple and erection easy.

The heat exchangers System Forgó, over and above their important role in air-cooled condensing systems, have been utilized in a very wide field and found to be of outstand-

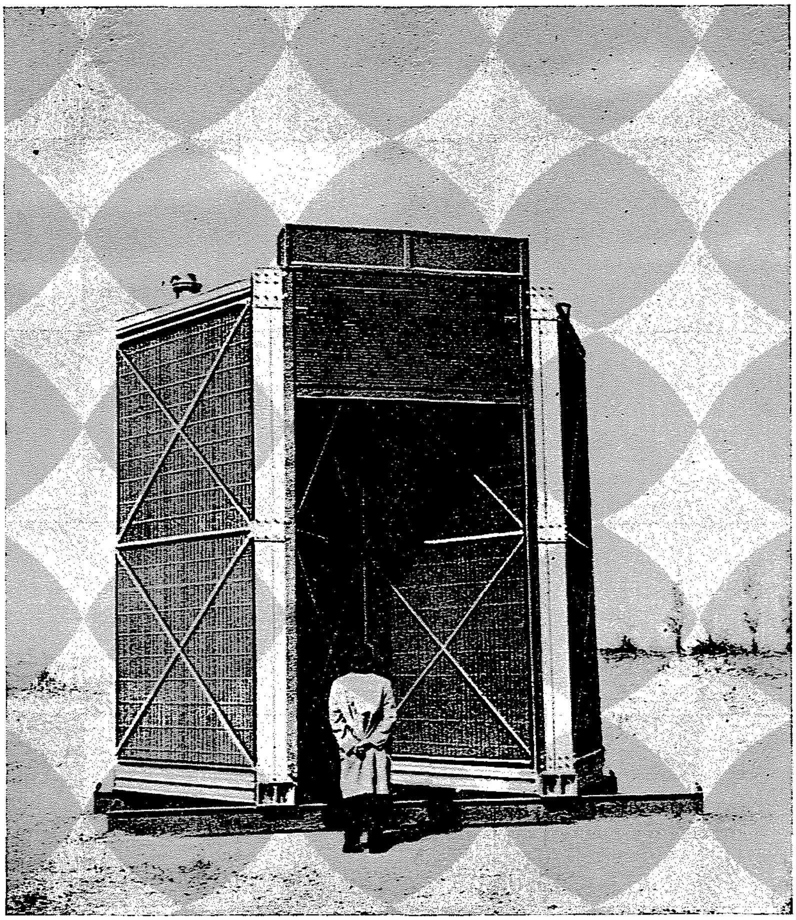

Fig. 5. Assembly of cooling elements "System Forgó" for operation in the desert, with protective shutter against sand storms

ing qualities both as to versatility and economy. Their application in a number of technical fields helped to considerable savings in water, a matter of no small significance in consideration of the present water shortage in almost all industrially developed countries.

a) *Petroleum refineries*

The air cooling is extensively applied in the petroleum refineries and in petrochemistry in general.

As known the chemical processes of petroleum refining require great quantities of water. This fact restricts the location of refineries to the proximity of waterways with ample flow. Even if such were granted, various difficulties will still face the plants because the excessive warming up of cooling water will cause scale deposits on the heat exchanger surfaces and necessitate frequent stoppages for their removal.

To meet this difficulty, cooling by means of air has been introduced in oil refineries, particularly in the United States of America, to substitute water-cooled condensers and oil coolers. Highly favourable experiences have been gained with air-cooled condensers and the air coolers showed considerable economic advantages over the water coolers thanks to their low operation and maintenance costs.

System Forgó heat exchanger elements can be utilized in the petroleum industry according to two schematic arrangements. By the first method the product itself, to be condensed or cooled (kerosene, etc.), is passed into the tubes of the slotted-rib heat exchangers and air is flown across the elements by fans, while according to the second method the oil products, especially the heavier varieties (fuel oil, crude oil, bottom products) are cooled down in the conventional water-cooled tube-bank-type heat exchangers and the cooling water cooled back in the slotted-rib elements, by means of air.

The first method is particularly suitable to cool the lighter varieties having a lesser tendency to form deposits and which, due to their lower viscosity, are easier to be passed through the relatively small-diameter heat exchanger tubes. This method is very advantageous inasmuch as low temperatures of the product can be obtained with remarkably economical cooler dimensions.

It may be stated in general that assuming a maximum ambient temperature of 30 centigrade, petroleum products can be cooled down to approx. 45 centigrade temperature. Lower air temperatures will naturally help to reach proportionately lower temperatures of the product.

The latter indirect cooling process is more suitable for viscous oils liable to form deposits and thus calling for wider flow diameters, easily accessible for cleaning. Indirect cooling has substantial advantages even in such cases because by it not only cooling water make-up can be saved but, having always the same water circulated in the system, scale deposit will be eliminated and working time considerably extended at lower maintenance cost.

The above outlined facilities have not only helped to reduce the cooling water demand of petroleum refineries to half of its former volume but rendered at the same time their siting easier to solve.

b) *Refrigerating industry*

Another important field of application of the System Forgó heat exchangers is the refrigerating industry. With the sole exception of small-capacity equipments working with air cooling, refrigerating condensers have been equipped with water cooling up to now.

The widespread use of air cooling in connection with the major refrigerating plants had been hindered by the lack of a suitable heat exchanger to extract heat efficiently and with good economy.

The System Forgó cooling elements, thanks to their excellent heat transfer characteristics, are eminently suitable to cope with the heat exchange requirements of the refrigerating industry and are at the same time economical in operation.

As to the method of air cooling in the refrigeration industry, it is the same as applied in petrochemistry: ammonia or some other cooling medium is either directly cooled in the heat exchanger tubes, or heat is extracted in an indirect way through the intermediary of water, *viz.* by means of cooling water circulated in a closed circuit within the refrigerating condenser and re-cooled in slotted-rib heat exchangers.

This system, too, has the advantage over the conventional water-cooled system that it operates without make-up, is free from the risk of pollution on the water side and incurs low maintenance costs.

The economy of a given air-cooled equipment is decisively determined by the temperature difference between ambient air and condensation. Heat exchangers capable of ensuring very slight difference between these two temperatures, although generally rather expensive, can achieve the possible lowest condensing temperatures and the corresponding condenser pressures at any given ambient air temperature and reduce thereby the power demand of the cooling cycle. On the other hand, heat exchangers built at lower first cost will operate at higher condensing temperatures and at higher compression power requirement.

The optimum area of the cooling surface shall at all times be determined on the basis of thorough economy calculations, taking into consideration all relevant factors.

Air-cooled condensers should be so dimensioned that condensing pressure should never, even at full thermal load and highest summer temperatures, exceed a certain predetermined maximum (generally set by the cooling compressor). This condition, in certain cases, may preclude the application of the cooling surface proved most economical in the economy calculations, because at extremely hot summer temperatures an excessive pressure might set in.

To prevent excessive pressure a system has been devised which helps to keep the cooling surface (condenser) within economical limits even in extreme summer heat. The system consists of the insertion of a "booster" compressor, to be operated in very hot ambient temperatures to compress the cooling medium to a higher pressure than that of the normal condenser (*viz.* the pressure setting in hot summer weather).

As to its size this booster compressor is rather small, being just enough to compress the cooling medium already compressed previously by the conventional compressor. In view of the fact that compressor dimensions and costs are determined by the volume of inlet, such units will be small and consequently inexpensive. Their power consumption, too, will be low due to the slight compression work performed, and to the short duration of the operation. Booster compressions operate namely hardly more than a few hundred hours per annum, only when temperatures above the average prevail.

We have in our economy calculations considered both investment and operation costs of booster compressors and found that, assuming European climatic conditions and average first costs, their insertion is definitely economical with direct as well as with indirect condensation method.

c) *Transformer cooling*

The heat exchangers System Forgó have been investigated also as to their suitability for the cooling of electric transformers. The investigations have brought favourable results inasmuch as it has been found that their small air pressure drop renders them suitable to operate with natural-draught coolers. This feature simplifies construction and helps to reduce power consumption.

The System Forgó heat exchangers are, however, economical not only with natural-draught cooling but with fan cooling as well. In the course of comparative examinations the conventional heat exchanger equipment of a transformer has been substituted by a slotted-rib exchanger System Forgó. Subsequent tests have proved that while with identical fan and pump power and identical space requirement the weight of the Forgó heat exchanger is only about half of that of the conventional equipment, its thermal capacity is higher by 20 to 25 per cent. These figures eloquently speak for the System Forgó heat exchangers as a means of transformer cooling.

In the foregoing we have briefly outlined the fields in which the development in the past years has gained popularity for the air-cooled condensing equipment "System Heller" and the heat exchanger elements "System Forgó".

Over and above the new applications here mentioned, almost each part and element has been thoroughly examined with a view to further development and essential improvements have been carried out to render both systems capable of keeping pace with progress and meeting demands.

MODERN HUNGARIAN REFRIGERATING COMPRESSORS

By

L. Takáts

The manufacture of refrigerating machines in Hungary can look back upon a past of nearly a century. To cope with the economic requirements of the country industrialization made great strides already as early as the latter half of the past century. In the Hungary of those days, overwhelmingly agrarian in character, the production of diverse foodstuffs and later their steadily increasing export, called for the application of refrigeration as an up-to-date means of food preservation. This trend brought forward the problem of supplying the refrigerating industry with mechanical equipment and Hungarian industry, thanks to its excellent technical qualification, has undertaken to solve this problem and to solve it to full satisfaction.

In the first stage of development Hungarian industry followed in the footsteps of foreign manufacturing firms. Horizontal compressors of slow speed were constructed which, by their conscientious design and suitability to cope with the then existing demands, gained ground on the domestic market and soon became much sought-for and competitive export articles.

Horizontal compressors have in the course of technical progress been superseded by vertically arranged multiple-cylinder units, using ammonia as coolant. These compressors had a considerably smaller space requirement than their predecessors.

The development of the refrigerating machine manufacture, which skyrocketed in the past few years and was manifested particularly by the production of great series of medium- and hig-capacity refrigerating plants (10 000 to 600 000 kcal per hour), has opened up the way towards the evolution of so-called "machine families". The machine families have been designed along the most up-to-date constructional principles, in a large range of graded capacities, with the aim of coping with the existing demands.

As known, machine families are units of identical main dimensions but of different performances, with a view to a possibly versatile utilization of the constructional parts. Their operational, maintenance and production advantages are obvious.

Taking advantage of the recent technical achievements Hungarian industry has evolved two machine families, both highly modern and advanced and working on the principle of direct flow. As to their technical-economic characteristics as well as regarding their construction and pleasing outer design, the members of either family are well capable of keeping pace with the similar products of the leading manufacturers of refrigerating equipment.

One of the families comprises so-called "medium-output" machines in the range of 10 000 to 50 000 kcal per hour (at $-10°$ C evaporation, $+25°$ C condensing and $+15°$ C aftercooling temperature), the second includes high-capacity units (100 000 normal kcal per hour and above). While the units of the former group are delivered as cooling aggregates (complete with electric motor for the direct drive of the compressor through shaft coupling, with oil separator and with condenser),

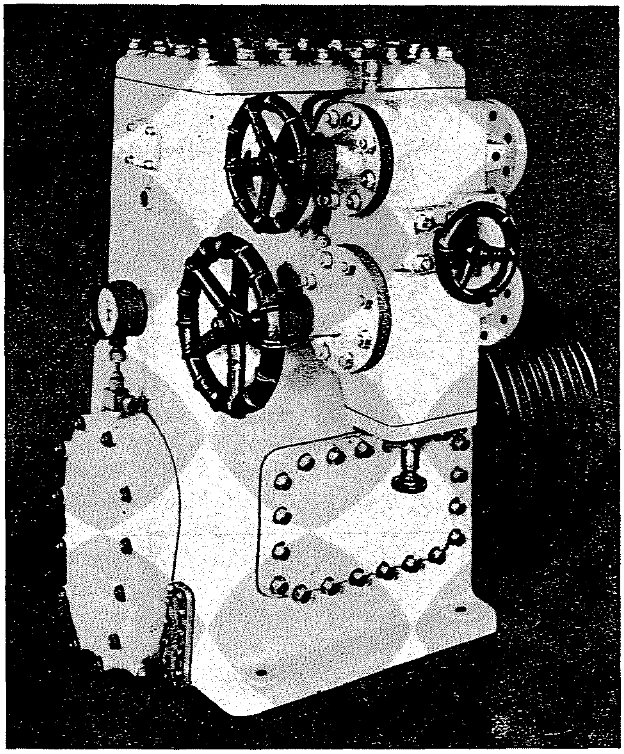

Fig. 1. Ammonia cooling compressor type 2E—180 V

or in the form of complete refrigerating plants (complemented with evaporator), those of the latter group are available either as aggregates of up to 200 000 kcal per hour output equipped with shaft-coupled electric motor or with flywheel shaped as a V-belt pulley and integral with oil separator and condenser, or else on the buyer's request, complete with evaporator as refrigerating plants.

From among the members of the "medium-output" machine family the G-25 type two-cylinder vertical compressor was the first to be built.

Its main technical characteristics are as follows:

Cylinder bore	90 mm
Stroke	80 mm
Speed	960 r. p. m.
Piston displacement	58.5 cu. m. per hr
Refrigerating output (—10° C and +25° C)	27 500 kcal per hr
Specific weight	6.9 kgs/1000 kcal/hr
Rated output	7.2 kW
Motor output	10.0 kW

As will be apparent from these data the G-25 type compressor is a light-weight high-speed machine, up-to-date even on an international scale.

Making use of the constructional parts of this same compressor and retaining as many elements as possible the G-15 (of a capacity of 15 000 kcal per hour and likewise keeping the main dimensions and many parts of the G-25-piston, cylinder sleeve, connecting rod etc.) and the 50 000 kcal per hour capacity G-50 have been developed. This latter type is a four-cylinder unit in V arrangement.

Through rendering these units suitable for

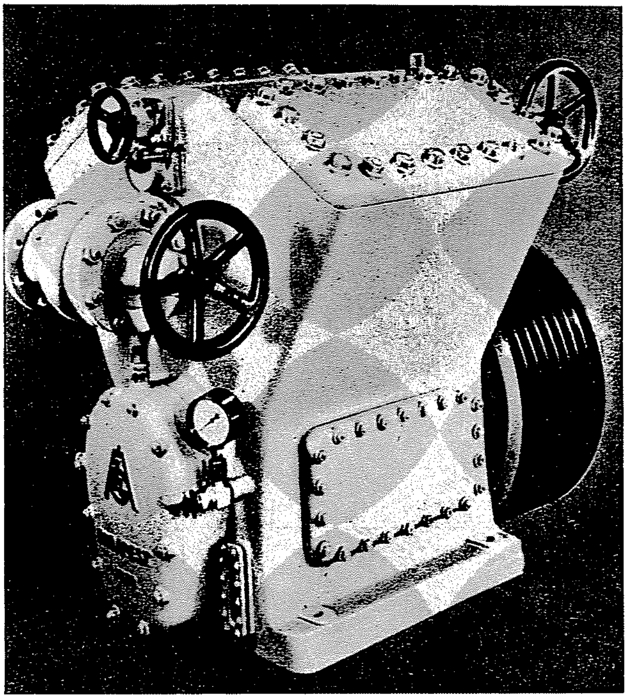

Fig. 2. Ammonia cooling compressor type 4E—180 V

operation with Freon 12 as coolant, the 16 000 kcal per hour capacity G-16 F and the 32 000 kcal per hour capacity G-32 F have been constructed as the Freon using versions of the G-25 and the four-cylinder G-50, respectively. Both types retain naturally as many component parts of the G-25 original as possible.

All the above-mentioned types are of the "block-crankcase" construction, *viz.* having integrated crankcase cylinder and gland bush in one cast. The stamped cylinder sleeve is of chromium-molybdenum alloy, made from electro-grey casting by centrifugal process which ensures best quality and long service life. The compressors are equipped with Höplate valves and protected against fluid impact. Crankshaft and connecting rod are of high-tensility die-cast steel, the slip ring gland packed with oil-resistant rubber gaskets. The main closing valves of the compressors are built into common casting with the safety valves and the instrument connections.

The oil separator is of the water-cooled spiral system which ensures efficient separation. Its lower portion is formed into a container whence an automatic valve passes the collected oil periodically into the compressor oil tank.

The arrangement, placing compressor, its driving motor and the oil separator on a horizontal tube-nest-type condenser, ensures minimal space requirement of the machine set.

The instrument board on the left-hand side of the aggregate comprises the control elements of the machine and the manometers. This arrangement makes possible the regulation of the set from a central point, if manual control is performed.

The here described sets are available also in fully automated version in which the control elements, depending on the pressure of

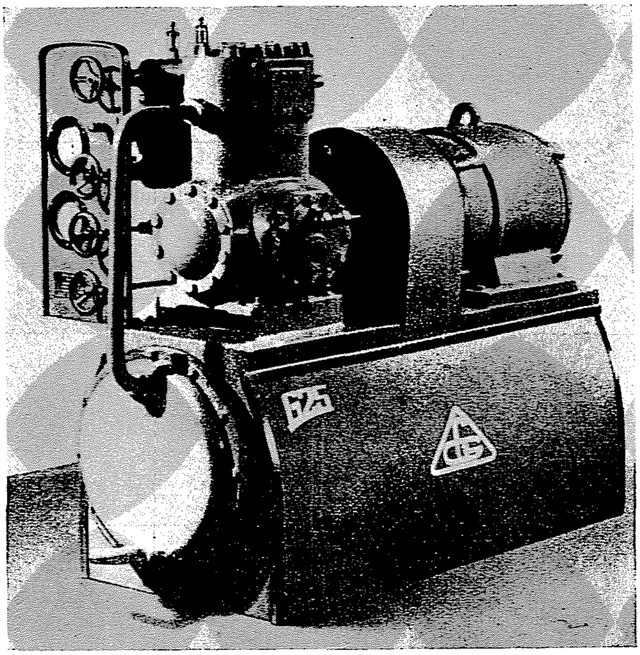

Fig. 3. Condensing Unit type G—25

evaporation, on the cooling water temperature etc., cut out or start the compressor, close or open the valves, etc., and perform every and all functions required for automatic, unattended operation.

The following table shows the main technical characteristics of cooling compressors in the capacity range of above 100 000 kcal per hour:

As it appears from the table, 150 and 180 mm diameter cylinders have been applied. This fact proves the interchangeability of the component parts of the single- and double-stage compressors.

Drawing a comparison between the above tabulated figures and those relating to the refrigerating compressors constructed by the manufacturers of world renown it will

Type	No. of cylinders	Bore, mm	Stroke, mm	Speed, rpm	Cooling output at −10° C evap. +25° C cond. and +15° C aftercool. temp., kcal/hr	Weight kg	Specific weight, kg per kcal per hr
2E-150	2	150	120	720	100 000	710	7,1
2E-180	2	180	150	800	200 000	1400	7.0
4E-180 V	4	180	150	800	400 000	1800	4.5
6E-180/150 W double stage	4+2	180 low p. 150 high p.	150	720	70 000 at —45° C evapor. and +25° C cond. temperature	2200	—

at once be apparent that Hungarian-made compressors can readily compete with units of similar capacity as regards their economical operation, speed, specific weight or regarding any other characteristics.

Single-stage compressors as well as double-stage units are of the block-crankcase type, *viz.* their crankcase and cylinder are in a common casting and equipped with easily interchangeable cylinder sleeves made of special alloy cast iron, through centrifugal casting. The pistons are of special aluminium alloy and are provided with three compressor rings and tow oil retaining rings. Connecting rods are diecast. The main shaft rests on self-aligning roller bearings and are equipped with counterweights for smoother running.

Since the flywheel rotates on the roller bearings located on the crankcase cover (the crankcase comprising the gland and its cover shaped as a hollow shaft), the weight of the flywheel and the draw of the belts will not bear upon the compressor. Flywheel and main shaft are connected through a rubber-plug coupling, an extremely advantageous arrangement since with eventual gland repairs neither the flywheel nor the driving V-belts need to be dismantled.

While compressor roller bearings are spray-lubricated, the sliding bearings have forced lubrication by means of an adjustable piston-type oil pump, actuated from the end of the main shaft. Oil pressure is adjustable by a valve and its supervision is ensured by a manometer.

100 000 and 200 000 kcal per hour capacity refrigerating compressors for direct refrigeration are available as aggregates, complete with electric motor drive, oil separator, horizontal tube-nest-type condenser, while for indirect cooling they are being built in the form of complete refrigerating plants with open or closed evaporator, to comply with the buyer's request.

Units of higher outputs are generally built as refrigerating plants, for direct or indirect cooling, with two or more compressors.

The common constructional parts are extensively utilized in the double-stage compressors, too. Besides other advantages this feature materially contributes to economical operation.

The compressors are used to good advantage in every field of refrigeration where low temperatures are aimed at, *e. g.* in deep freezing plants, quick-freezing tunnels, in the chemical industry, etc.

According to the buyer's choice compressors may be delivered with manual control and regulation equipped with cut-out device, or fully automated. Compressors with cut-out device are started manually, but on the setting in of certain conditions (excessive condenser pressure, too low evaporation pressure, lower brine temperature than the permissible minimum, too low oil pressure etc.), automatic control elements will stop the compressor and give a warning signal to the operator to shut the valves. In the fully automated version starting as well as stoppage or adjustment are carried out in an automatic way without the intermediary of any human help.

The compressors outlined in the foregoing are able to meet the most exacting demands and thanks to their extensive capacity range — be it for very small cold storage plants or for packing houses of many thousands of tons capacity — they are capable of coping with the requirements and to furnish the requisite temperatures along up-to-date methods, with very good economy.

Their light-weight construction and well balanced vibration free running enable considerable reduction in foundation sizes as compared with other machines of similar output; their compact design requires a possible minimum of area and their arrangement facilitates erection. All these advantages help to achieve substantial savings in first costs.

As an additional advantage the standardized component parts greatly simplify repair and maintenance and, finally, their high efficiency low power consumption and simple and easy manipulation render their operation inexpensive and comfortable.

Parallel with refrigerating compressors many other modern refrigerating machines have also been developed. Among others tube-nest-type condensers, ammonia vapour precoolers, evaporative condensers, closed evaporators, fan-equipped air-cooling elements for direct cooling, etc., have been added lately to the extensive range of our products, better to comply with the requirements and offer arrangements as best suited from point of view of economy.

The Hungarian industry manufactures large series of typified brine cooling plants, complete packing houses, quick-freezing, deep-freezing, etc. equipment, to satisfy the needs of the food and chemical industries.

The total capacity of Hungarian refrigerating machine exports amounted, in 1959 alone, to more than 95 million normal kcal per hour and by the virtue of the outstanding quality of our products and the conscientious execution of our export orders it is perhaps not unreasonable to feel entitled to hope for a further increase of this volume in the years to come.

HUNGARIAN METHOD FOR THE MASS PRODUCTION OF PRESTRESSED RAILWAY SLEEPERS

By

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Nearly all the countries of the world have to face an ever increasing shortage of wood. In view of the relatively short durability of wood, for railway sleepers there is quite a substantial quantity of wood needed each year. Therefore it is advisable to substitute wood sleepers by prestressed concrete sleepers of a rather longer durability and much more economical.

At first experiments have been made in Hungary with plain reinforced concrete sleepers. These experiments have been going on for more than 50 years and nearly 5 millions of such reinforced concrete sleepers have been laid into the Hungarian railway lines. Sleepers made with usual wire, however, do not fully meet the high requirements made by the railways, due to a great susceptibility to cracks. Therefore, in the year 1945, a development by experimenting test production and application in the railway tracks of the prestressed concrete sleepers fully conforming to the above requirements began in Hungary. Hungarian concrete technologists and railway specialists have also gained experiences of several decades as regards production and application of concrete sleepers. As a result they succeeded in developing types of prestressed concrete sleepers complying in any respect with the intricate static and dynamic loads (Fig. 1).

Before the mass application of prestressed concrete sleepers two essential problems had to be solved:

1. Development of the type of concrete sleepers to be manufactured.

2. Development of a technology suitable for mass production.

These two problems are, of course, closely correlated. As a result of the long period of experimenting an adhesive wire type *viz.* a prestressed type has been chosen where the stress is assured according to load by 48 to 60 wires of 2.5 mm diameter or an accordingly lower quantity dia. 3 mm but fluted steel wires. The wires are evenly distributed in the cross-section and experience shows it particularly advantageous with regard to dynamic load.

The sleepers in Fig. 1 are suited for a speed of 125 km/hour to an axle load of 26 tons. On the right side of the figure a sleeper is shown, similar to those made in Hungary but produced in a manufacturing plant supplied to Czechoslovakia. On this type rail fastening is effected by means of dowels. On the left of the figure the new Hungarian sleeper type is shown on which instead of the dowel the rail fastening is constructed with the aid of a special synthetic material or steel insert.

In both cases sleepers are 2.42 m long, a little more than necessary from statical viewpoint but in case of shorter sleepers the danger of the slipping of the wires would arise. The lower surface of the sleepers is grooved what favours the adhesion to the ballast.

The number of prestressed sleepers built-in into Hungarian railway tracks amounts to one million. For the lengthening of rails, *i. e.* the welding of rails to a length of 6 to 8 km between the stations, exclusively prestressed concrete sleepers are applied with full success.

Simultaneously with the development of the concrete sleeper type, as a result of 15

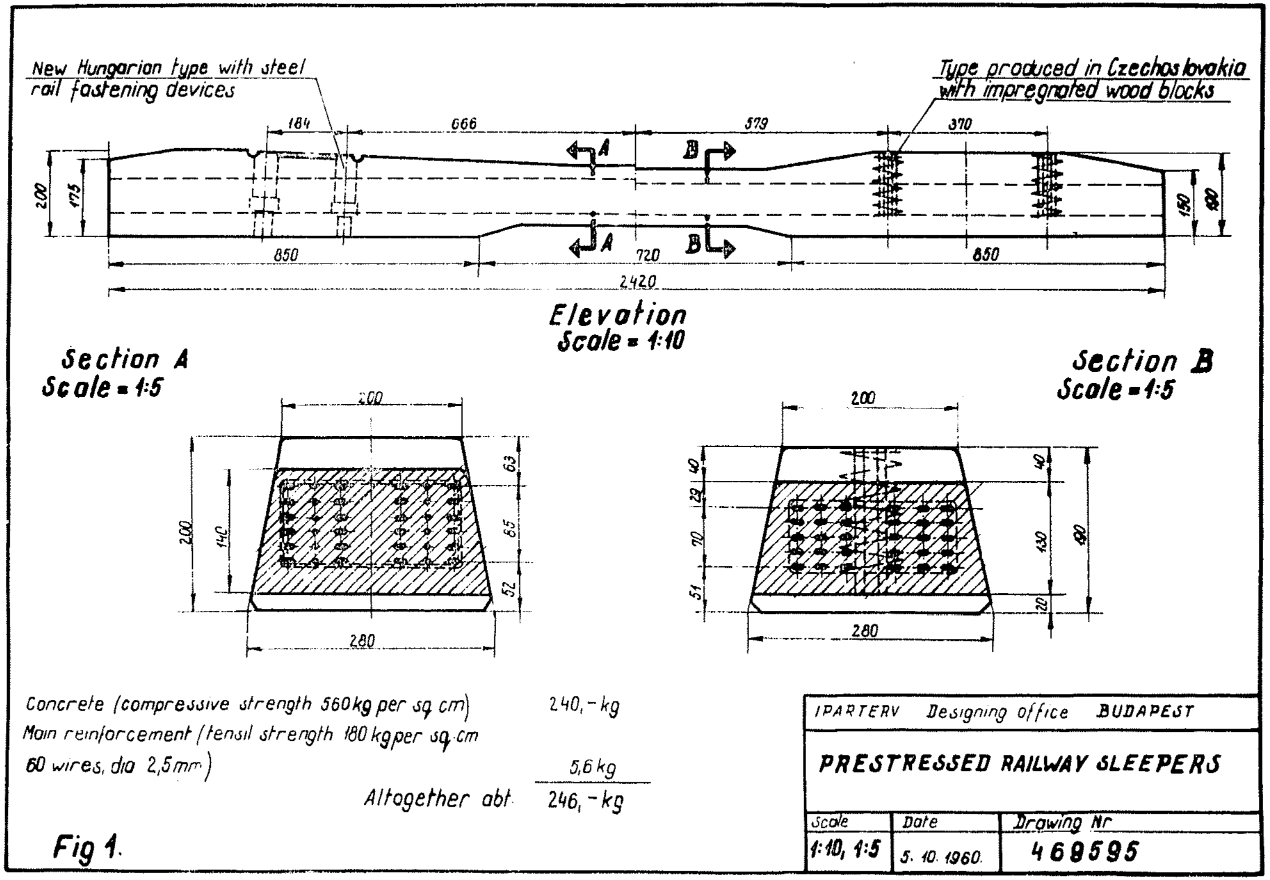

Fig. 1. Informative dimensions of the prestressed concrete sleepers. (On the left of the figure the new Hungarian type with special rail fastening mechanism, on the right a sleeper produced on the machinery supplied to Czechoslovakia are shown)

years' work, the mass production according to the system of "travelling stretch-bench" of prestressed concrete sleepers has been developed. The manufacturing process has been developed in a research plant step by step until it became suitable for economical mass production. In Hungary there are 3 plants working, with a total capacity of about 600 000 pieces per year.

The plant of an annual capacity of 150 000 pieces supplied to Bulgaria has been operating for more than 5 years, the manufacturing plants supplied to the Soviet Union and Czechoslovakia are now beginning production.

In the followoing we are giving the description of a plant of an annual capacity of 300 000 pieces it being, according to our calculation, the manufacturing unit with the most economical production. But the capacity of 150 000 pieces per year might be also very economical, particularly in an area with a sparse railway network.

General arrangement

Fig. 2 shows the general arrangement of a manufacturing plant as mentioned above.

If there are prospects for a later extension, the plant has to be established on a plane territory of at least 120×250 m. The sketch shows also the informative lay-out of the buildings but the definite arrangement depends, of course, greatly on the local conditions.

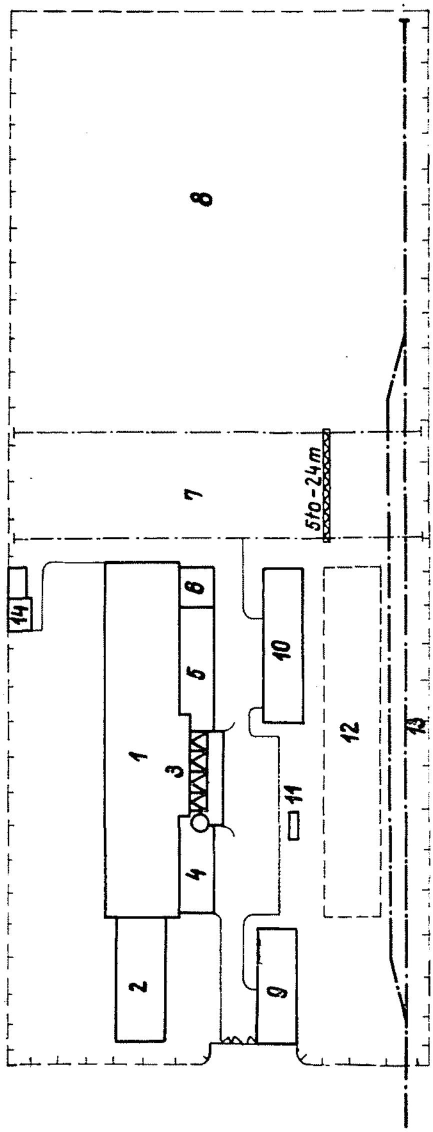

Fig. 2. General layout of a prestressed concrete sleeper manufacturing plant.
1. Manufacturing workshop; 2. Curing chambers; 3. Mixing plant with cement silo and aggregate bunker; 4. Boiler; 5. Store room for wires and fittings; 6. Laboratory; 7. Storage place; 8. Area reserved for future extension; 9. Offices, dressing rooms and mess rooms; 10. Workshops, storerooms; 11. Oil tank; 12. Auxiliary storage place for aggregates; 13. Side track; 14. Transformer substation and pump

Classifying and mixing plant

Local conditions are particularly decisive as regards the classifying plant which is necessary only where no classified material required for the production of first-class concrete, divided possibly into the size groups of

0.1— 1 mm (possibly 0.1—3 mm)
1 — 3 mm
3 — 7 mm
7 —15 mm and
15 —25 mm

is available.

Fig 3. shows the design of a free-air classifying plant which suits requirements of the concrete aggregates come from a gravel pit.

It is desirable to transport pneumatically the cement into the storing silo of the plant constructed of steel by means of a cement delivery truck similar to that shown in Fig. 4. From the silo it is forwarded, also by gravitation, into the cement balance and from there into the mixing machine. For mixing a concrete mixing machine has to be applied with positive mixing operation. From this machine the concrete passing through an intermediate container gets into the manufacturing moulds.

Since a concrete strength of at least 500, but preferably more than 600 kg/sq. cm is required, the choice and the handling of the aggregate material have to be made with utmost care. The cement, too, shall be of first-class quality, being suitable to realize with a steam curing of 7 to 9 hours a strength of 350 to 400 kg/sq. cm.

Let us mention here that a plant destined for the production of such prestressed concrete sleepers can well combine with a factory for production of prestressed poles. In one of the Hungarian concrete unit factories *e. g.* apart from yearly 150 000 sleepers, about 30 000 pieces of electric power

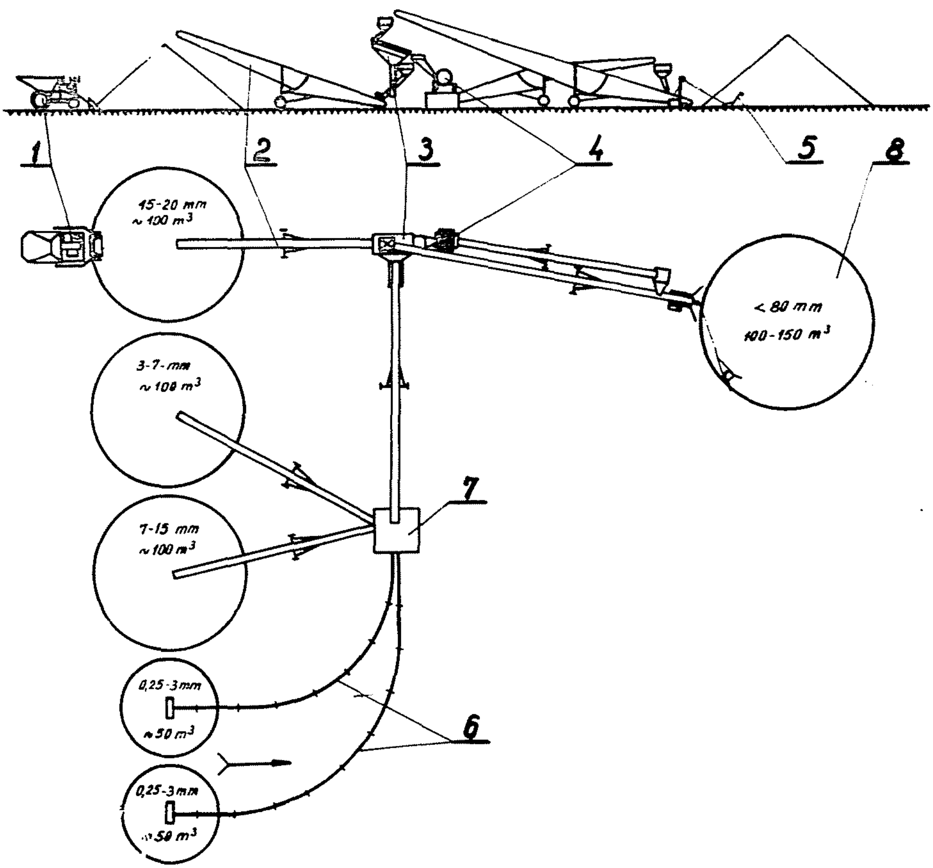

Fig. 3. Free-air classifying plant.
1. Self-loading dumper; 2. Band transporter; 3. Vibrating screen; 4. Jaw crusher; 5. Mechanical shovel; 6. Slurry pump; 7. Wet screen and possibly hydrocyclone; 8. Natural aggregates

Fig. 4. Cement delivery truck

line and other poles are manufactured. The maximum length of the poles manufactured in this plant amounts to 12.5 m, and these are used for the construction of power transmission lines of 35 kW.

Manufacturing plant

The production process of the manufacturing plant of prestressed concrete sleepers is shown in Fig. 5, the photograph of such a plant in Hungary appears in Fig. 6. The plants are composed of two manufacturing lines with a daily capacity of 500 pieces each, their total output being consequently 1000 pieces per day; supposing 300 working days a year it makes 300 000 pieces.

The primary condition of the production of prestressed concrete sleepers is that 5 sleepers be simultaneously manufactured. It is carried out in a way that a wire bundle of a length corresponding to that of 5 sleepers is fed into the stretch-bench. The curing chamber is also fed with stretch-benches containing 5 sleepers each.

The plant is working in 3 working shifts, thus an effective working time of 22.5 hours per day can be counted with. Accordingly every 13 minutes one stretch-bench has to be completed and conveyed further. Sleepers are made in mould-like stretch-benches of about 13 m length in straight-line production. (This manufacturing process affords, by changing the moulds, the production of other elements such as bars, beams, etc., too.)

The manufacturing process consists of the following stages:

wire arranging
wire stretching
filling and compacting
curing and
removal of the moulds.

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A. *Wire arranging*

Into the concrete sleepers the prescribed quantity of wires has to be placed. The

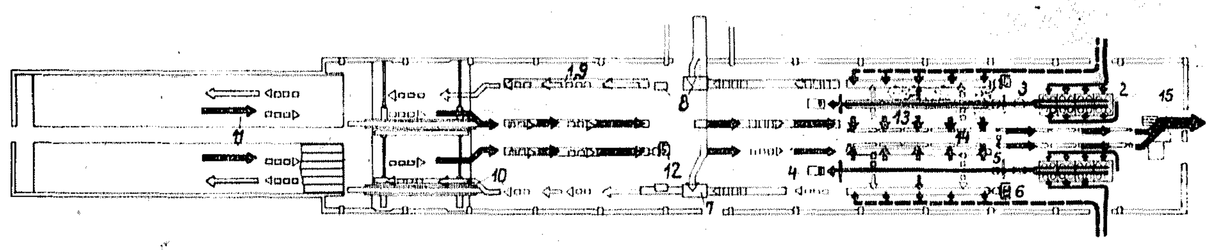

Fig. 5. Production process of a prestressed concrete sleeper manufacturing plant of an annual capacity of 300 000 pieces.

1. Stretch-bench removable on rollers; 2. Wire stand; 3. Crimping machine; 4. Wire drawing winch; 5. Clamping head press; 6. Stretching machine; 7. Cement filling tank; 8. Lower vibrator; 9. Upper vibrator; 10. Travelling table; 11. Curing chamber; 12. Stress releasing machine. 13. Equipment for stripping out of moulds; 14. Wire cutting equipment; 15. Roller conveyor for removal

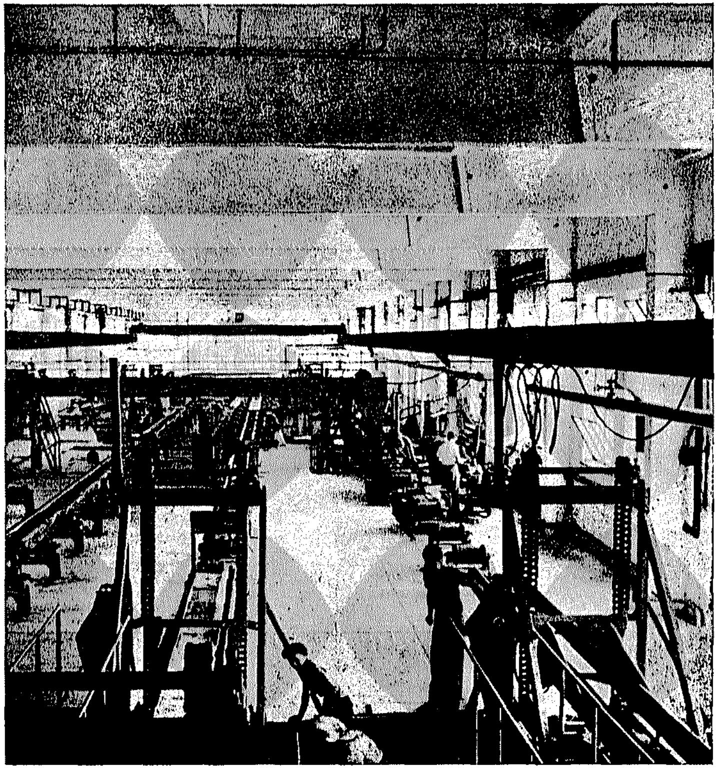

Fig. 6. Photograph of prestressed concrete sleeper manufacturing plant at Lábatlan

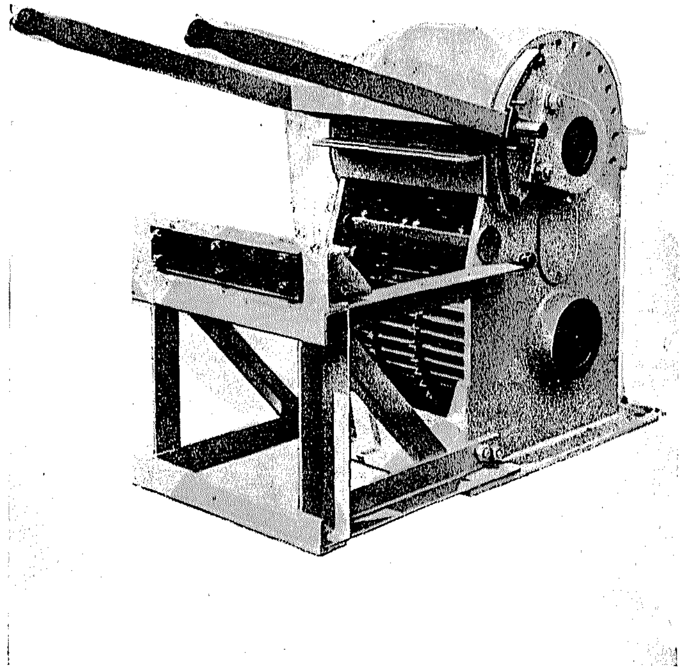

Fig. 7. Wire crimping machine

tensile strength of the wires has to be of 180 kg/sq.mm. Wires have to be stretched to 60 per cent of the tensile strength. The stretching force shall be measured by a dynamometer. The corresponding quantity of wires, in the weight of 50 to 60 kg, is stored on stands, in wind-up state. From there the wires are pulled in bounches through a crimper device (Fig. 7). This device warrants the uniform wire length promoting, at the same time, their adhesion to the concrete. The bundle of wires, drawn to the required length of abt. 13 m by means of a winch is provided in the clamping head press with fixing heads and then the wires are cut between the fixing heads. (This special system, called continuous wire handling, has been developed and mechanized after many experiments and with great difficulties.)

B. *Wire stretching*

The bundle of wires is then placed with the two clamping heads into the stretch-bench and stretched by the stretching machine of a load capacity of 40 tons (Fig. 8).

C. *Filling and compacting*

After the stretching of the wires the stretch-bench is filled by means of the filling bunker placed under the concrete mixing machine, and compacted by means of the lower vibrator. Finally compacting of the concrete is completed by vibrators applied from above, with simultaneous surface pressure.

D. *Curing*

The stretch-bench filled up with concrete is conveyed by means of a travelling table

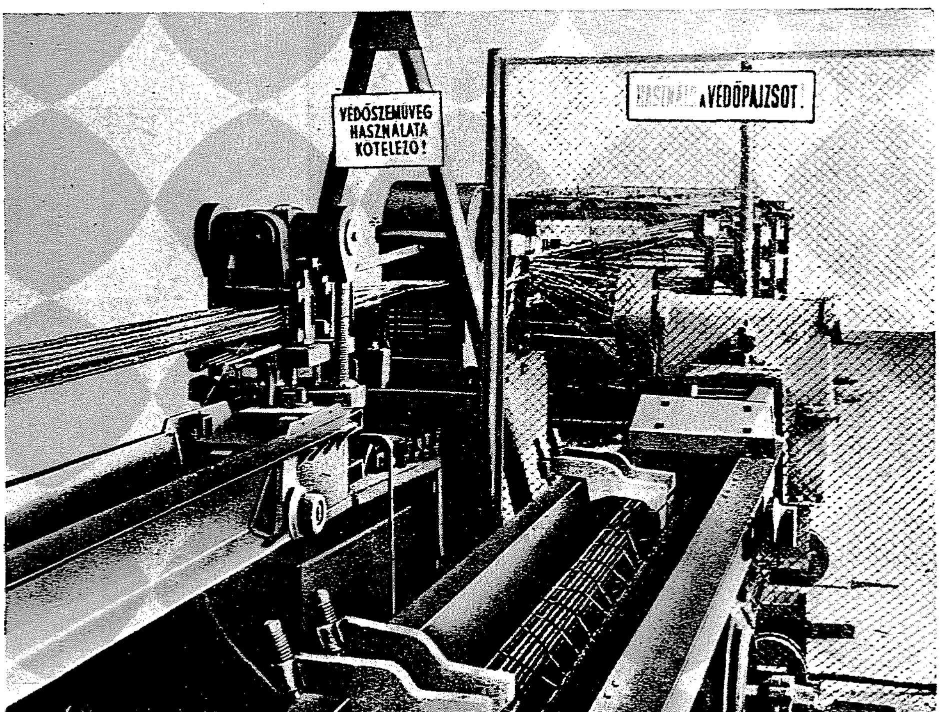

Fig. 8. Stretch-bench, clamping head press and stretching

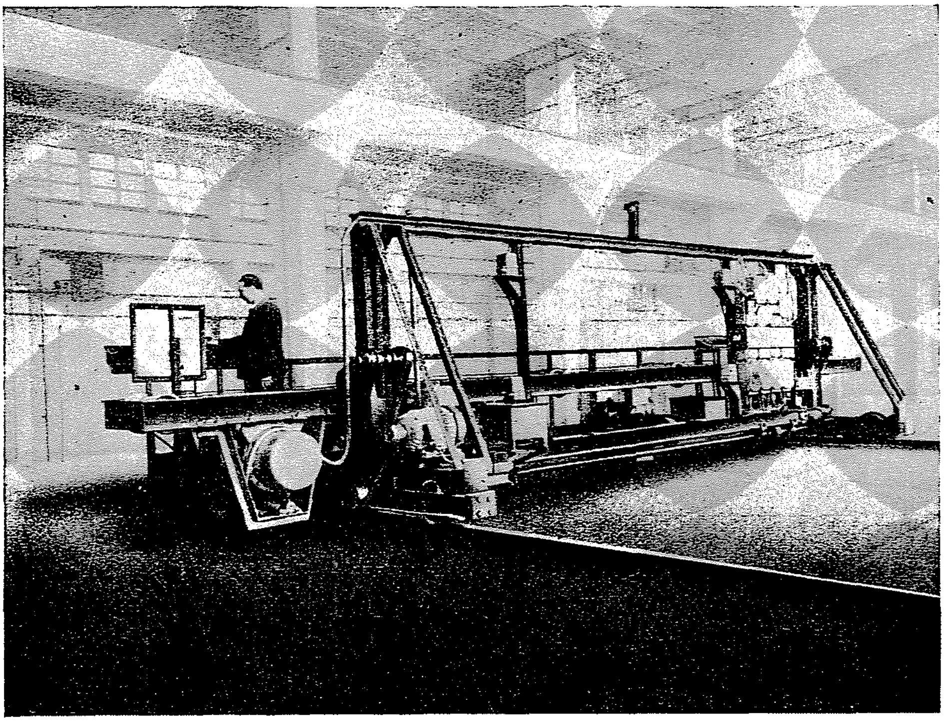

Fig. 9. Travelling table

(Fig. 9), into the steam chamber. This travelling table can be operated in 3 directions: longitudinally, transversally and vertically. In the curing chamber 3 or 4 rows can be formed vertically in each of which 6 stretch-benches can be placed in the width. Thus the possibility for steam curing of 7 to 9 hours prevails.

E. *Removal of the moulds*

After curing the stretch-benches are drawn out, the wires released, and the sleepers are stripped from the moulds by means of a semi-automatic machine. Then the wires between the sleepers are cut off with a special-purpose cutting machine and the finished sleepers are transported on a roller conveyor and subjected to the prescribed reception tests. Finally the sleepers are transported to the storage place and stacked by means of a crane.

The empty stretch-bench, cleaned and oiled, is replaced into the production circuit.

The production has a straight-line character, the workers are always at the same place, doing the same work. Due to the efficient double vibration by a relatively low cement consumption a concrete of high strength and consequently of good quality can be obtained.

Storage of finished goods

Fresh concrete units have to be stored in the manufacturing plant for at least 28 days. But considering the significant fluctuations in consumption it is advisable to ensure a storage place for storing the production of 2 or 3 months.

The equipment of the storage place depends much on local conditions. In smaller plants the loading of the sleepers can be

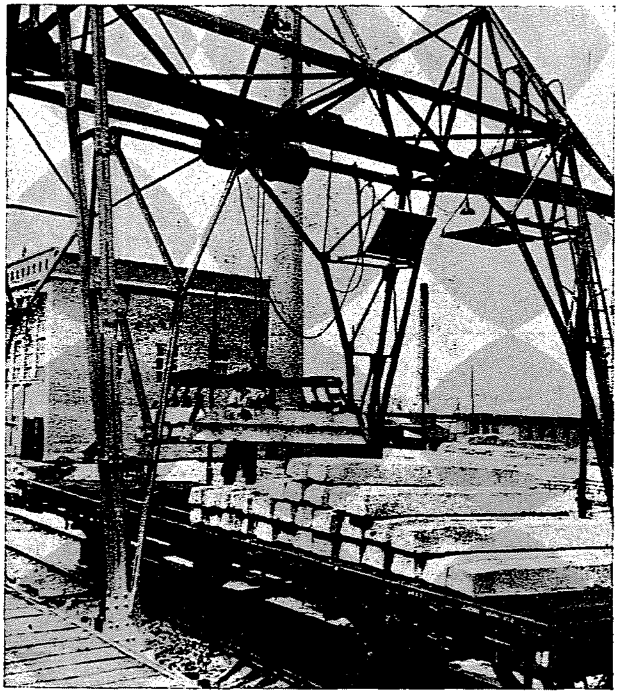

Fig. 10. Storage place with the crane of 5 tons loading capacity and 24 m span

carried out with a fork truck, in plants of a larger output it is preferable to provide the storage place with a travelling crane with a loading capacity of 5 tons and a span of 24 m (Fig. 10).

This arrangement is mostly needed where, due to climatic conditions, sleepers coming from the manufacture have to be kept in a water basin for some days. This is extremely advantageous from the view-point of afterhardening of the concrete and can be easily carried out in case of a storage place provided with a crane.

Production data

Finally we are giving below some production data of a Hungarian prestressed concrete sleeper manufacturing plant with an annual capacity of 300 000 pieces a year. In this plant the department for sleeper production operates over 300 working days a year in working shifts of 8 hours per day, and the auxiliary works in one shift per day.

Production data per day

Denomination	Classifying and mixing plant	Sleeper production	Storage
Production pcs		1000	
Cement consumption to	40—45		
Aggregate consumption to	180		
Steel consumption to		6	
Steam requirement to		20	
Manpower	25	3×40=120	15

MANUFACTURING PLANT FOR SEAMLESS TUBES IN CHINA, DELIVERED BY HUNGARY

By

I. Szanyi

On the basis of a contract, which had been reached in the autumn of 1957 between the Komplex Hungarian Trading Company For Factory Equipment and the China National Technical Import Corporation, by the end of 1960 it was completed the delivery of equipment — with the exception of some smaller items — manufactured in Hungary for the plant of seamless tubes in Cheng-tu (province Szechwan): this fact represented in comparison with the original term an abbreviation of nearly half a year.

Thus the delivery of the biggest plant exported by Hungary has been completed, and even the test operation in the push bench mill was finished by the second part of 1960, and production was started.

The plant designed for an annual production of more than 200 thousand tons of seamless tubes has three tube mills: push bench mill, medium Pilger-mill, large Pilger-mill.

Hungary delivered the complete machinery of the three tube mills as well as the whole machinery of the common hydraulic engine-house and of the mercury rectifier station of the three tube mills.

The supply of the Pilger roll turning lathes (Fig. 1) also belonged among the duties of the Hungarian party. The Push Bench Shop is suitable for the manufacturing of seamless tubes of ∅ 1″ to 5¼″ (33—133 mm).

As starting material 100—170 mm billets of rectangular cross section are used; these are first cut with shears, then heated, and subsequently calibrated and pierced on a vertically arranged hydraulic calibrating and piercing press, respectively.

The calibrating press is of 460 tons and the piercing press is of 550 tons. After reheating of the hollow bodies with closed bottom which arise from the piercing, they pass to the elongator (Fig. 2) and get here — by being worked between rolls standing in an angle of 5° to the horizontal — an about double elongation. The diameter of the working rolls are 500 mm.

The rolling out of the hollow bodies to tubes is done on the push bench. The push bench (Fig. 3) is equipped with roller dies based on a Hungarian patent of the thirties which since then had been the subject of many improvements and the rack pushes by means of the mandrel — which is mounted before it — the elongated hollow body through the roller dies, whilst it turns into a tube.

The tubes which run out together with the mandrel from the push bench are carried by a rollerway to the reeling mill, which loosens the tubes rolled up on the mandrel; this renders possible the extraction of the mandrel.

After cutting off the bottomed ends of the tubes with a hot saw, they are reheated in a walking-beam furnace to the rolling temperature.

To get the final size, the tubes are now fed either into the calibrating mill (Fig. 4) or into the reducing mill (Fig. 5).

The calibrating mill has 8 stands. Here final sizes for tubes of diameters from 2½″ to 5½″ are given. This solution with

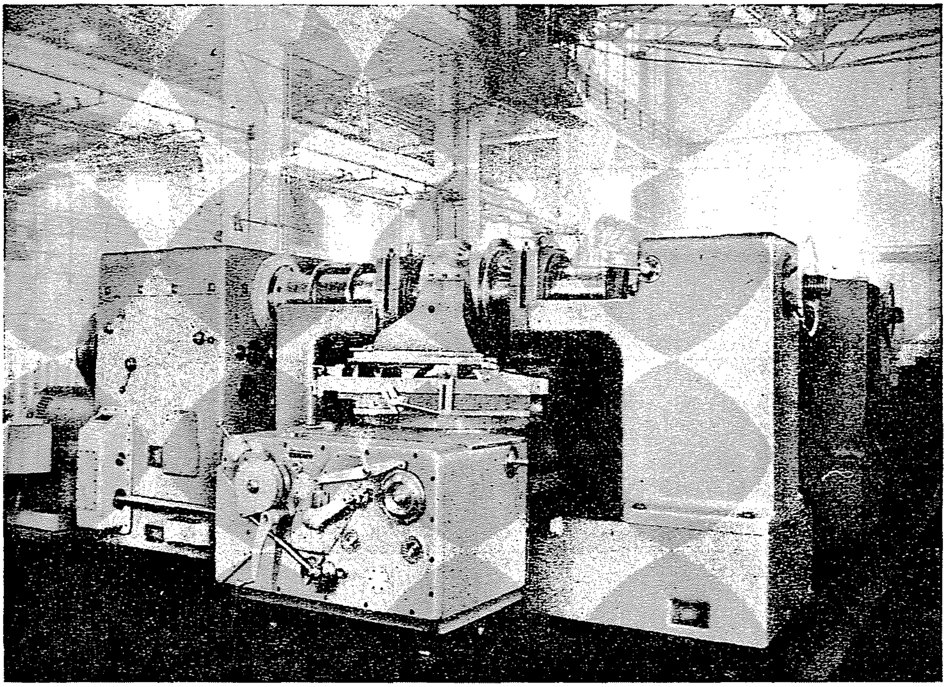

Fig. 1. Pilger roll turning lathe for the large Pilger mill

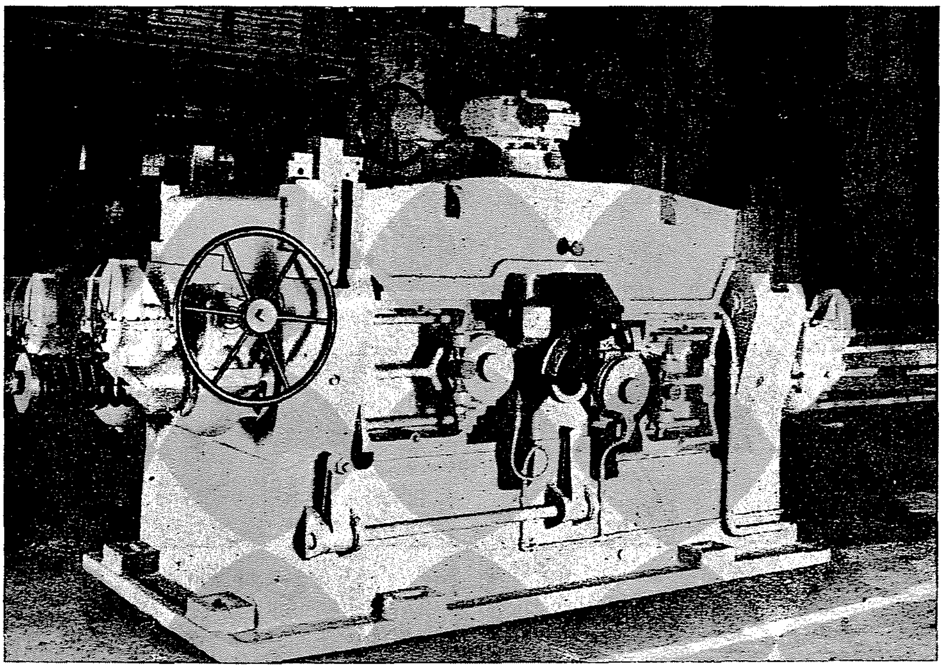

Fig. 2. Push bench elongator

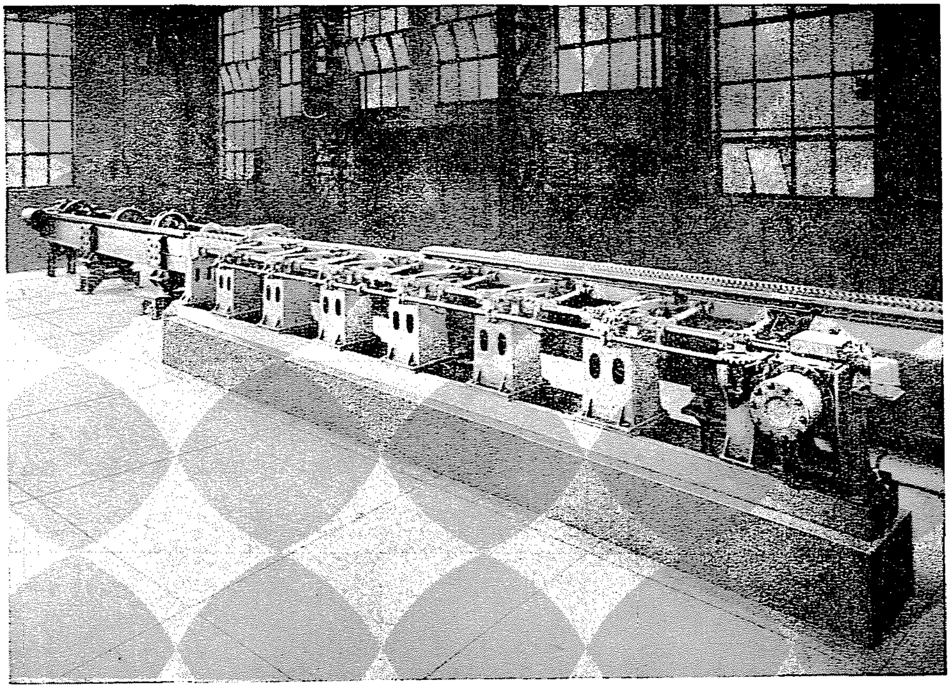

Fig. 3. One part of the push bench

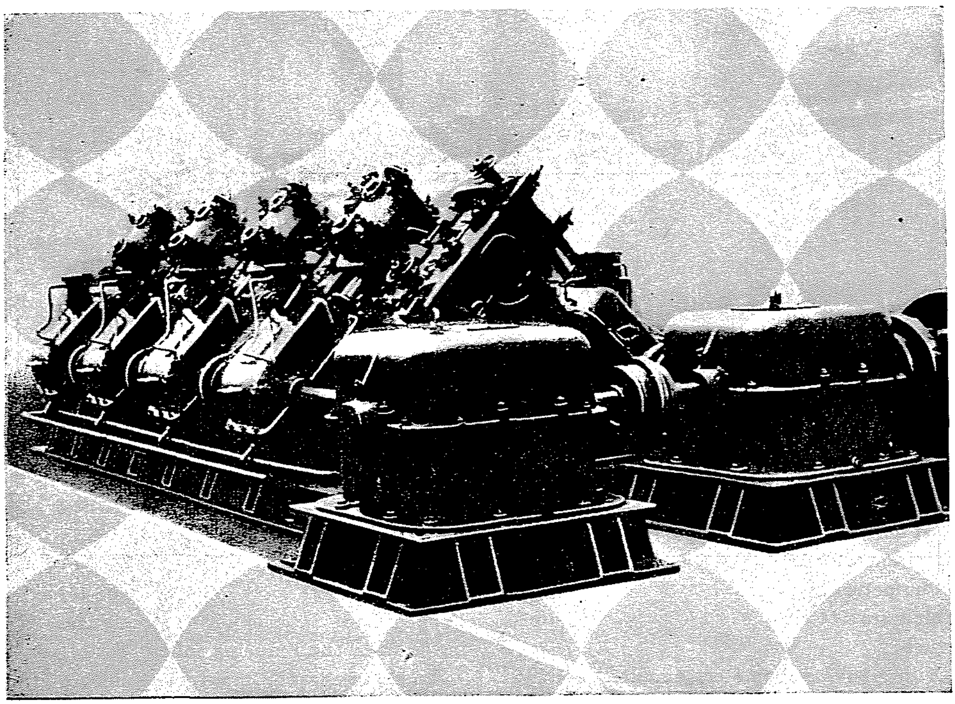

Fig. 4. Calibrating mill of 8 stands (for tubes of ⌀ 2½"—5½")

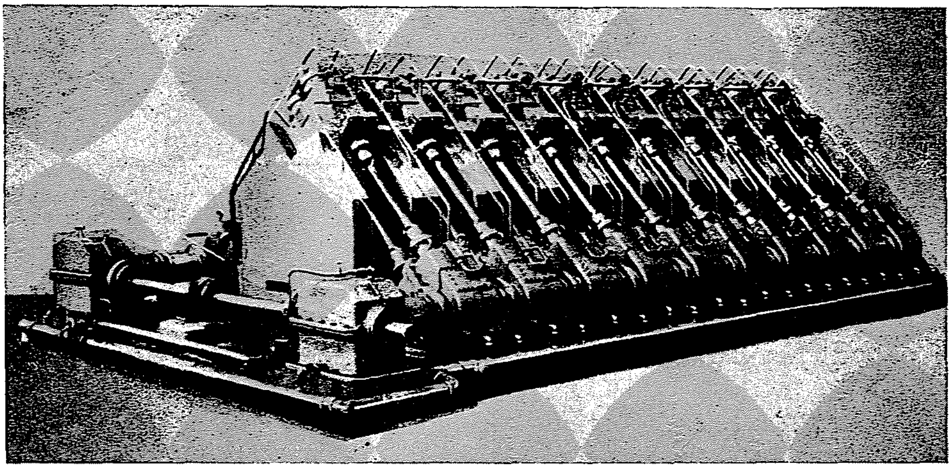

Fig. 5. Reducing mill of 20 stands

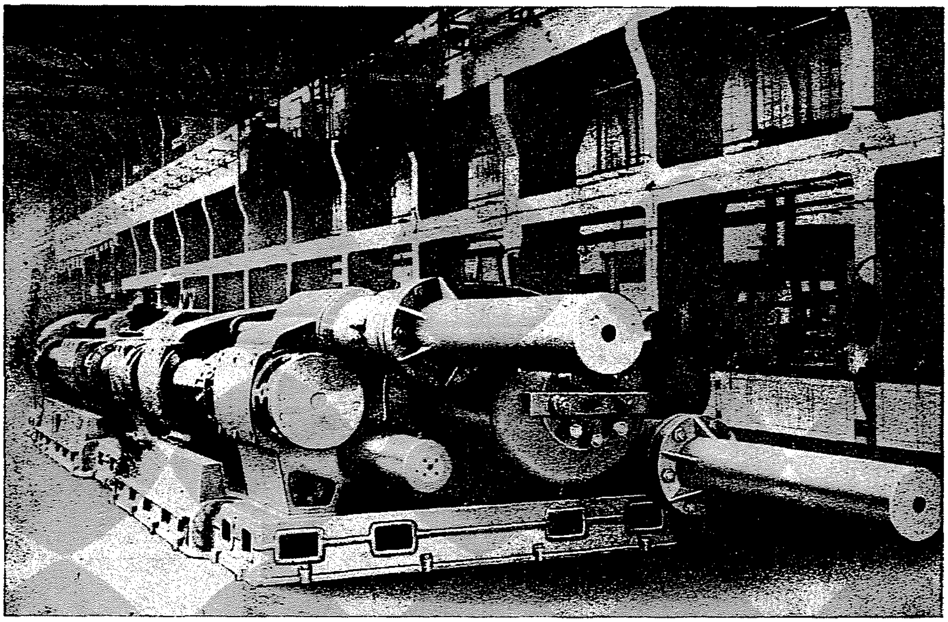

Fig. 6. Ingot piercing press of 1000 tons

8 stands renders possible to reduce tool requirement and to increase production by manufacturing tubes between said limits which are not produced directly on the push bench.

Tubes having diameters smaller than $2\frac{1}{2}''$ (60 mm) are passed to get their final size in the reducing mill of 20 stands.

The maximal speed of runout of tubes is 2 m/sec from the calibrating mill and 2.5 m/sec from the reducing mill.

From among the main equipment of the

push bench mill, the push bench machine unit itself is driven by a direct current twin-motor of 2×410 kW, the direct current supply being secured by a Ward—Leonard set. The direct current for other d. c. drives is supplied by the mercury rectifier station. The elongator is driven by a d. c. motor of 500 kW, the calibrating mill by one of 250 kW, and the reeling mill and the reducing mill by a d. c. motor of 180 kW.

The medium Pilger mill plant is suitable for the manufacturing of ∅ 4″∅8½″ (102 to 219 mm) seamless tubes in a maximum length of 28 m.

As starting material ingots having rectangular cross section and corrugated surface are used, which after having been heated in a rotary hearth furnace to the rolling temperature (1250° C) are pierced on a horizontally arranged hydraulic piercing press (Fig .6) to form hollow bottomed bodies with circular cross section.

The maximum pressing force of the press is 1000 tons. The maximum length of ingots to be pierced is 1550 mm. The maximum diameter of the pierced ingot is 415 mm, and the maximum diameter of the piercing mandrel is 220 mm. Working pressures are 100 and 200 atm.

After reheating the closed-bottomed hollow bodies, they are elongated by the elongator (Fig. 7) between two shaped rolls

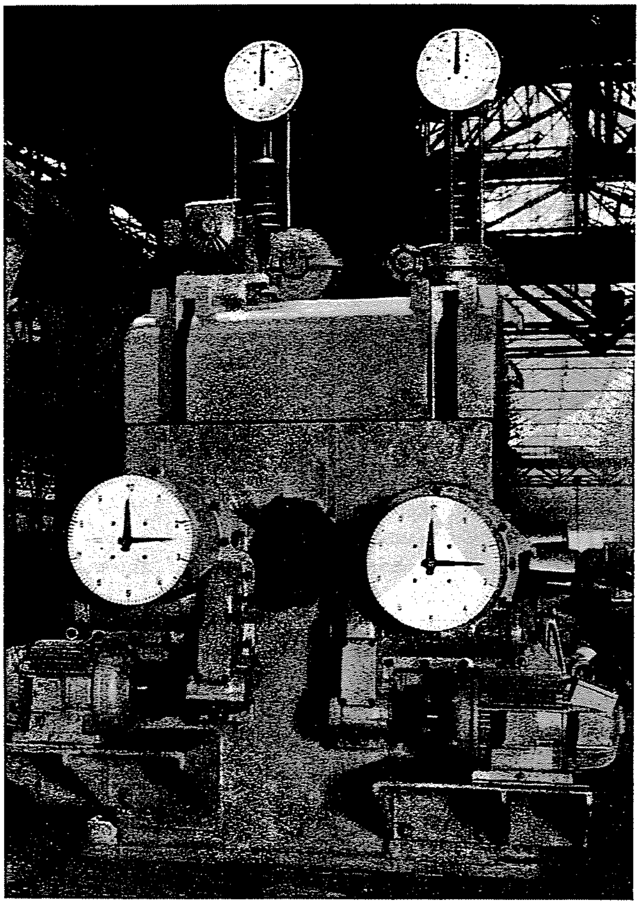

Fig. 7. Elongator for the medium Pilger-mill

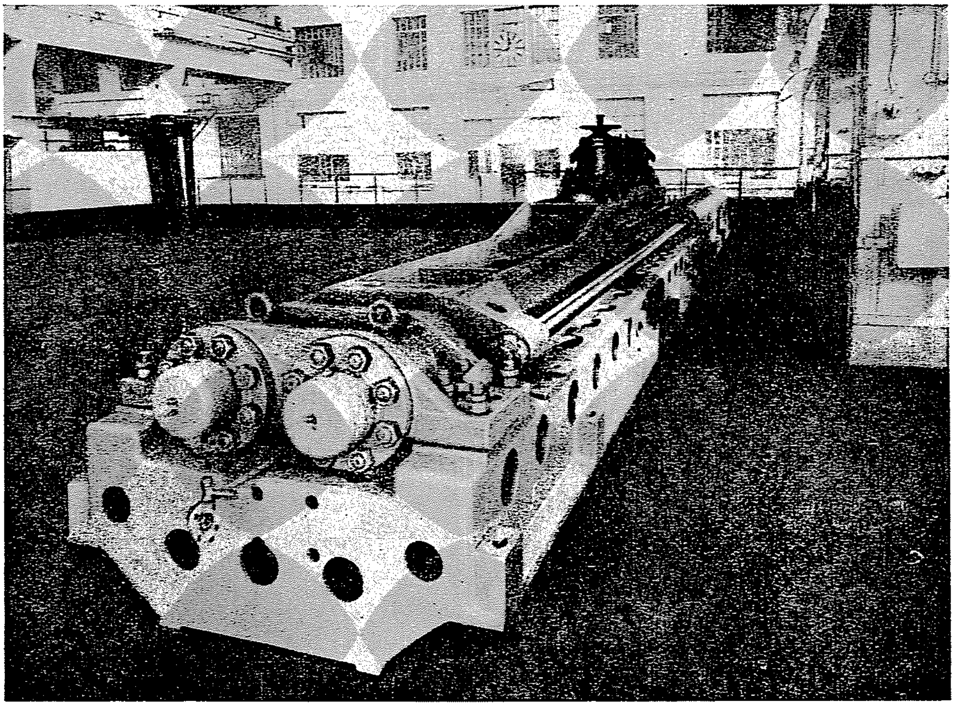

Fig. 8. Feeder for medium Pilger-mill

adjusted askew; here the bottom which remained after piercing is rolled out too.

The maximum diameter of the work roll of the elongator is 720 mm, while the maximum length of elongation is 3000 mm. The elongator supplies two Pilger mills with elongated raw tubes, where specially shaped Pilger-rolls hammer and stretch them intermittently by rotating against the course of advancing.

Fig. 8 shows the feeding mechanism, which represents one of the most important part of the Pilger-mill. The maximum stroke of the feeder's hydraulic cylinder is about 8000 mm, while the maximum stroke of the air cylinder is about 1400 mm.

The speed of the Pilger-roll is 60—100 r. p. m., its maximum diameter being 600 mm. After cutting off the destructed ends and the pilgerheads with a hot saw, the tubes are passed into a walking beam reheating furnace and they get their final size in the 5-stand calibrating mill.

The tubes leave the calibrating mill with a speed of 1.5 mm/sec.

From among the main machinery of medium Pilger-mill plant the elongator and the two Pilger-mills are driven by a d. c. motor of 1300 kW each, and the 5-stand calibrating mill by a d. c. motor of 250 kW. Direct current supply comes from the common rectifier station belonging to all the three mills.

The large Pilger mill plant is suitable for the manufacturing of $\varnothing 6\frac{1}{2}''-12\frac{1}{2}''$ (168 to 325 mm) tubes in a maximum length of 28 m.

After heating the ingots of rectangular cross section with maximum weight of 2100 kg in a rotary hearth furnace to the rolling temperature, the piercing takes place in a press of 1800 tons (Fig. 9). Maximum diameter of the pierced piece is 540 mm and the maximum diameter of the piercing mandrel is 310 mm.

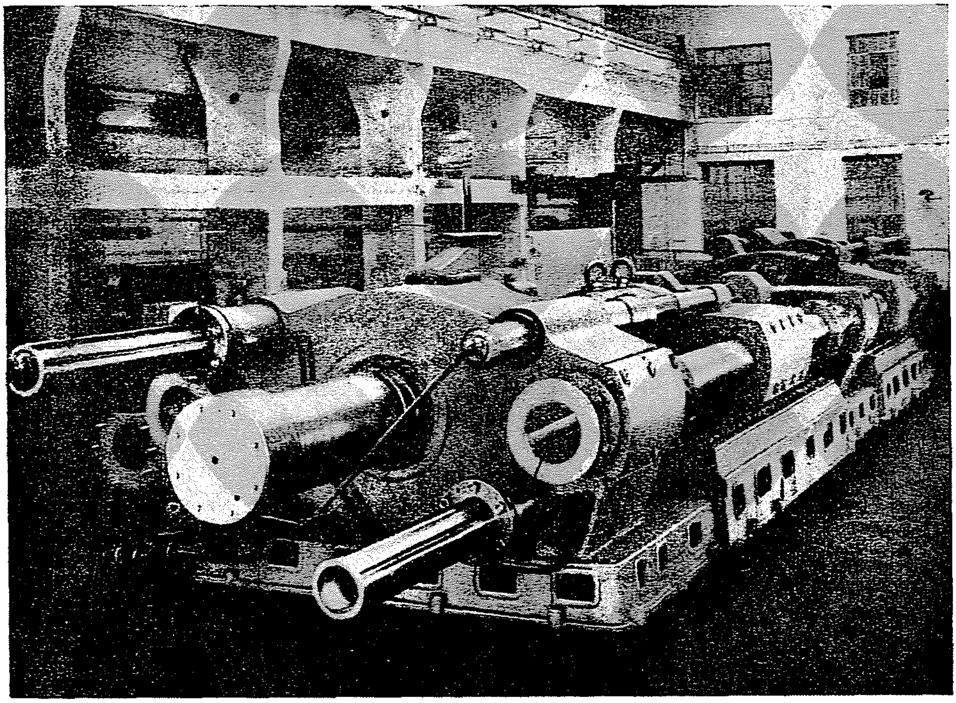

Fig. 9. Ingot piercing press of 1800 tons

Working pressure is 100 and 200 atm. Before elongation the hollow bodies are also here heated in a rotary hearth furnace to the rolling temperature.

The maximum length of elongation is 3600 mm. The maximum diameter of the elongator work roll is 775 mm, its maximum length being 960 mm. The speed of the work roll is 38—68. r. p. m.

The elongator supplies also here two Pilger-mills. Fig. 10 shows the roll stand, shaft and pinion stand in shop assembly. The diameters of the Pilger-rolls are 650—850 mm, and their speed is 40 to 70 r. p. m. The working pressure of the hydraulic cylinders of the feeders is 100 and 200 atm. here too, while the working pressure of the air cylinder is 12 atm. The maximum feed is 20 mm per rotation.

The final size of tubes is ensured also in this case by a 5-stand calibrating mill (Fig. 11). The diameter of the rolls is 750 mm and the maximum run-out speed of the tubes is 1.2 m/sec.

Among the main motors supplied by the rectifier station are the motors of the elongator and of the Pilger-mills, each of 2000 kW, and the one of the calibrating mill of 250 kW.

In addition to the main technological equipment described above, Hungary supplied also some machine units for the finishing shop, *e. g.* hydraulic tube test presses, cold straighteners, tube-end calibrating presses, and tube-end upsetting presses. Fig. 12 illustrates a press used for the purpose of calibrating the ends of tubes with diameters of 6½″—12½″.

Hydraulic plant

The complete machinery of the common hydraulic plant supplying press water to operate the hydraulic presses and other

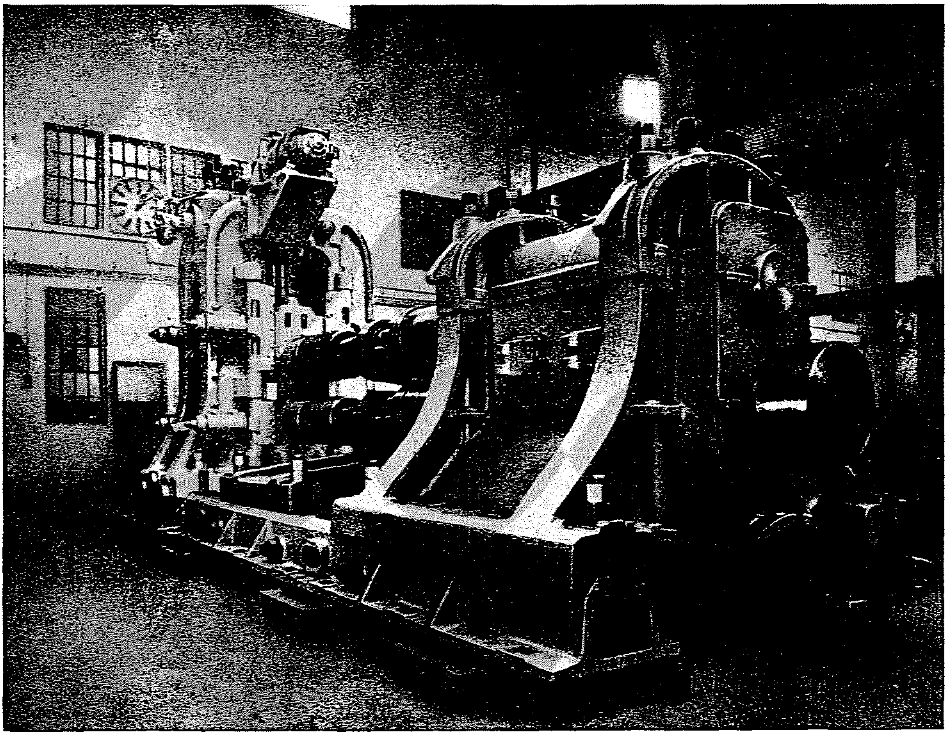

Fig. 10. Roll stand, driving shaft and pinion stand for the large Pilger-mill

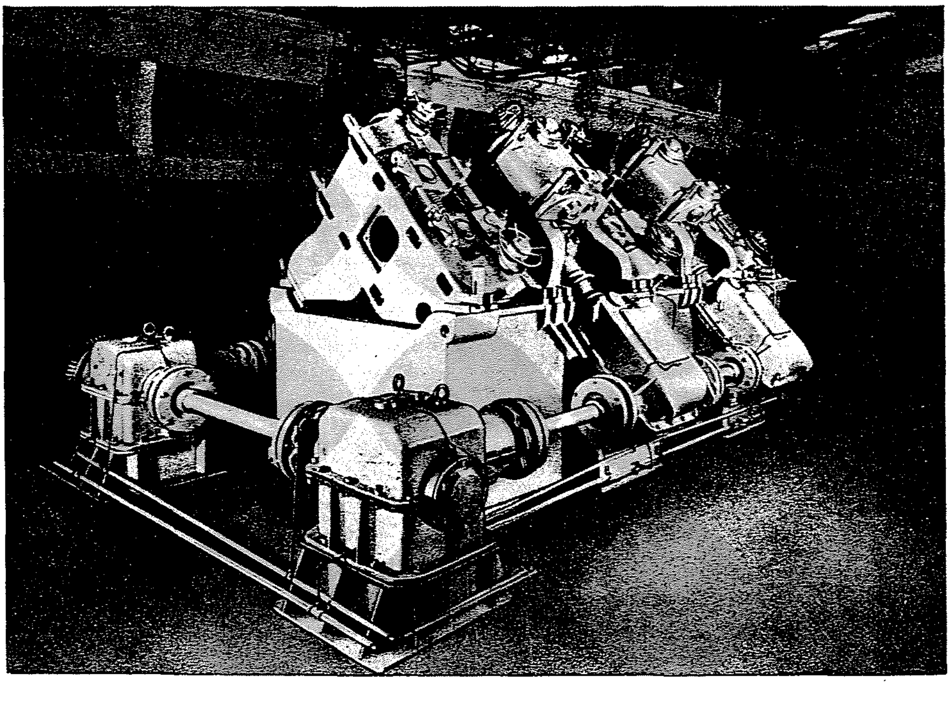

Fig. 11. Calibrating mill of 5 stands (for tubes of ⌀ 6½″—12½″)

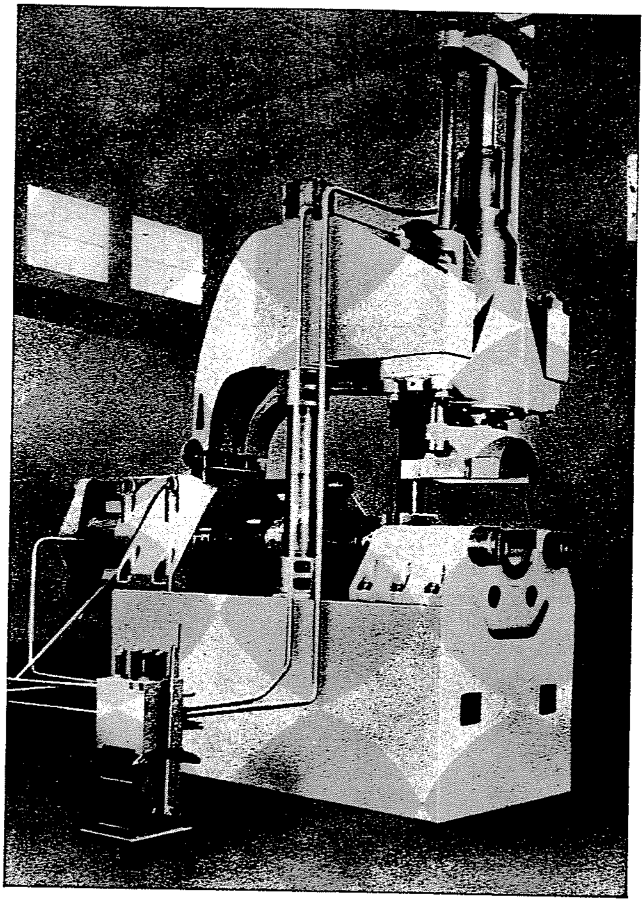

Fig. 12. Tube-end calibrating press (for tubes of ∅6½″—12½″)

hydraulic equipments of the three tube mills, was also supplied from Hungary.

The main pumps and accumulators for the press hydraulic consists of two independent systems with separate control gear.

Each system of 100 atm. and 200 atm. comprises eight strip wound air vessels and one strip wound water vessel (Fig. 13) which are charged by separate air compressors. The accumulator system of 200 atm. is fed by nine horizontal press pumps of triple cylinder, single-operation and single-stage design (Fig. 14). The capacity of each pump is 500 l/min. at a working pressure of 200 atm. The diameters of plungers are 82 mm, and the length of stroke is 300 mm. Each pump is driven by a motor of 280 kW at 720 r. p. m., through a driving gear (Fig. 15).

The accumulator system of 100 atm. is fed by 8 pumps, similar to the former ones, but having a capacity of 600 l/min. The pumps of the 100 atm. system are driven by motors of 180 kW at 720 r. p. m.

Scores of Hungarian factories participated in supplying the equipments of the Manufacturing Plant For Seamless Steel Tubes of Cheng-tu.

The most important mechanical equipments were supplied by famous Hungarian factories,

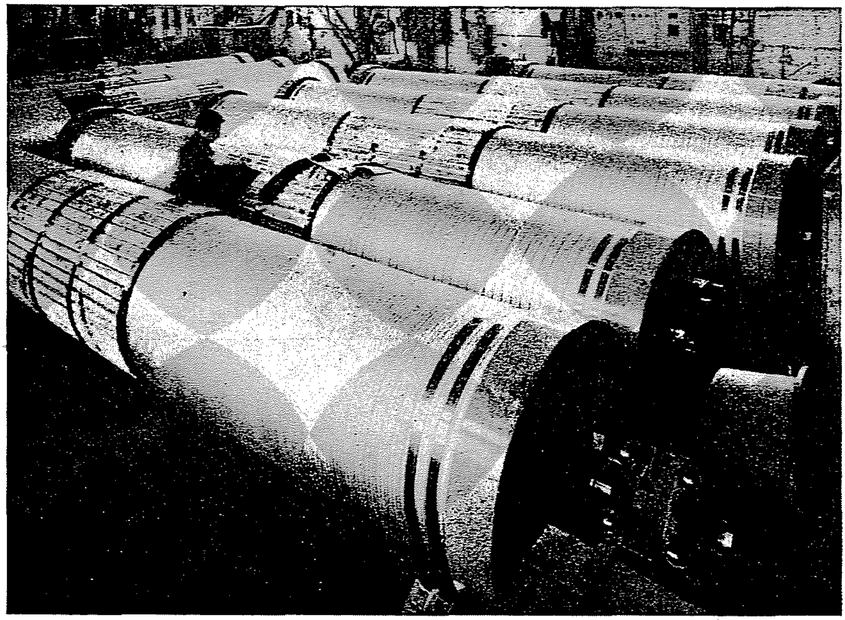

Fig. 13. Strip wound air vessels to the accumulator system

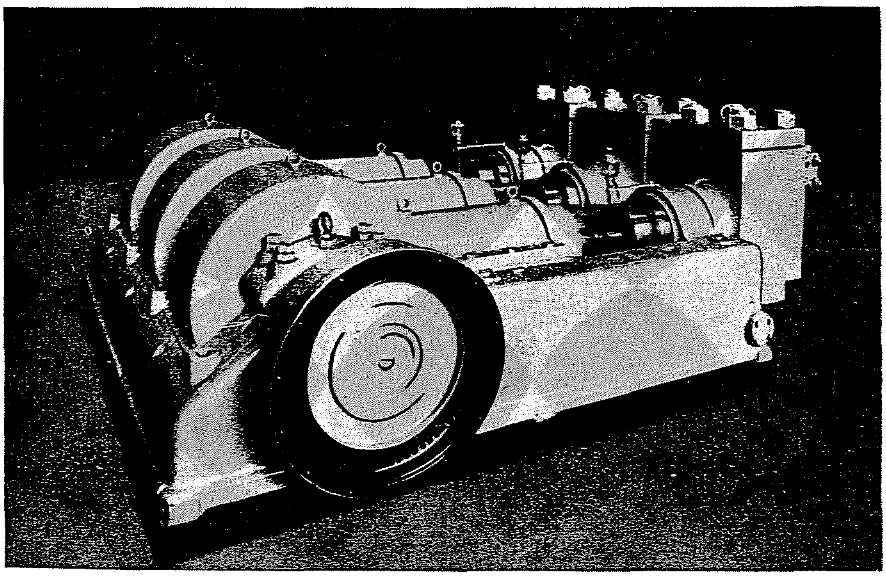

Fig. 14. Reciprocating pump of 200 atm.

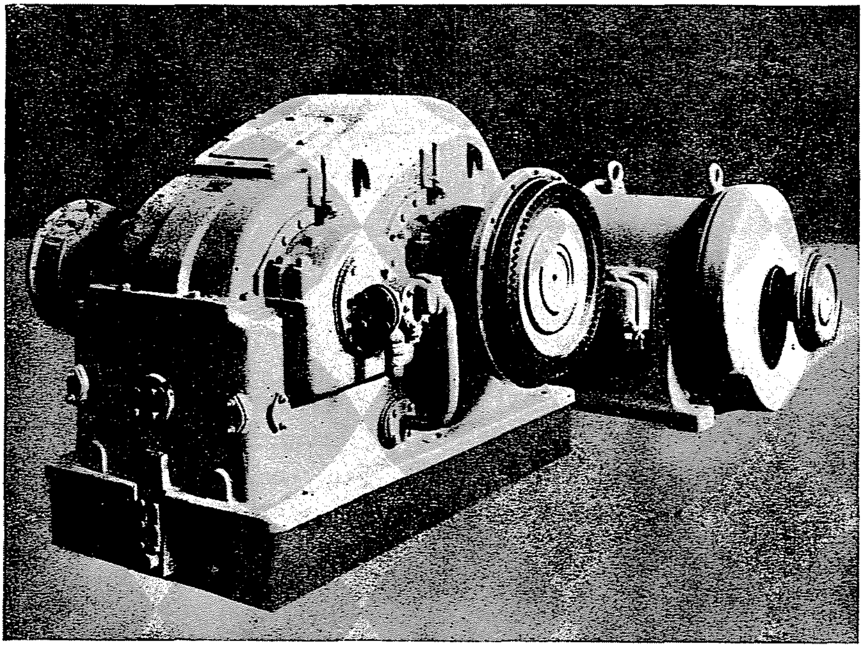

Fig. 15. Driving gear and motor to the reciprocating pump of 200 atm.

well-know also in foreign countries, such as the Csepel Iron and Metal Works, DIMÁVAG Machine Works, and GANZ-MÁVAG. The greatest part of the electrical equipment, *i. e.* motors, were manufactured by the world famous GANZ Electrical Factory.

The successful delivery of the equipments of the plant described above, affords convincing proof to show that the Komplex Hungarian Trading Company is in the position to assist industrial development in countries which require it also by furnishing installations of seamless tube plants.

Considering the advantages in economy and investment offered by employing the technology of manufacturing seamless tubes in the described machinery, the hope may be expressed that in the coming years Hungary will be able to help more and more countries under way of industrialization to establish or develop their tube manufacturing industry.

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