## OCCASION

This publication has been made available to the public on the occasion of the 50th anniversary of the United Nations Industrial Development Organisation.

## DISCLAIMER

This document has been produced without formal United Nations editing. The designations employed and the presentation of the material in this document do not imply the expression of any opinion whatsoever on the part of the Secretariat of the United Nations Industrial Development Organization (UNIDO) concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries, or its economic system or degree of development. Designations such as "developed", "industrialized" and "developing" are intended for statistical convenience and do not necessarily express a judgment about the stage reached by a particular country or area in the development process. Mention of firm names or commercial products does not constitute an endorsement by UNIDO.

## FAIR USE POLICY

Any part of this publication may be quoted and referenced for educational and research purposes without additional permission from UNIDO. However, those who make use of quoting and referencing this publication are requested to follow the Fair Use Policy of giving due credit to UNIDO.

## CONTACT

Please contact publications@unido.org for further information concerning UNIDO publications.

For more information about UNIDO, please visit us at www.unido.org

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna International Centre, P.O. Box 300, 1400 Vienna, Austria
Tel: (+43-1) 26026-0 · www.unido.org · unido@unido.org

D01310

United Nations Industrial Development Organization

Distribution
LIMITED

ID/WG.14/45
5 July 1968

ORIGINAL: ENGLISH

Second Interregional Symposium
on the Iron and Steel Industry

Moscow, USSR, 19 September – 9 October 1968

D-6-3

# NEW DEVELOPMENT ON THE SECTOR OF TUBE MANUFACTURING [1]

by

J.Mietzner

Fed.Rep. of Germany

---

[1] The views and opinions expressed in this paper are those of the author and do not necessarily reflect the views of the secretariat of UNIDO. The document is presented as submitted by the author, without re-editing.

We regret that some of the pages in the microfiche copy of this report may not be up to the proper legibility standards, even though the best possible copy was used for preparing the master fiche.

United Nations Industrial Development Organization

Distribution
LIMITED

ID/WG.14/45 Summary*
5 July 1968

ORIGINAL: ENGLISH

Second Interregional Symposium
on the Iron and Steel Industry

Moscow, USSR, 19 September – 9 October 1968

D-6-3

# NEW DEVELOPMENT ON THE SECTOR OF TUBE MANUFACTURING [1]

by

J. Mietzner, FRG

## SUMMARY

The construction of plants for the production of seamless tubes in the developing countries have to allow on the one hand for later expansion, and at the same time be able to cope with a diversified programme. The present paper shows that such demands can be met by push bench installations. Even when compared with the modern continuous tube mills, the modern push benches are by all means an economic proposition.

The working principle of the push bench is explained. A thick-walled, thimble-like bottle is processed to a thin-walled shell by being slipped over a powered mandrel and passed through several dies arranged in series.

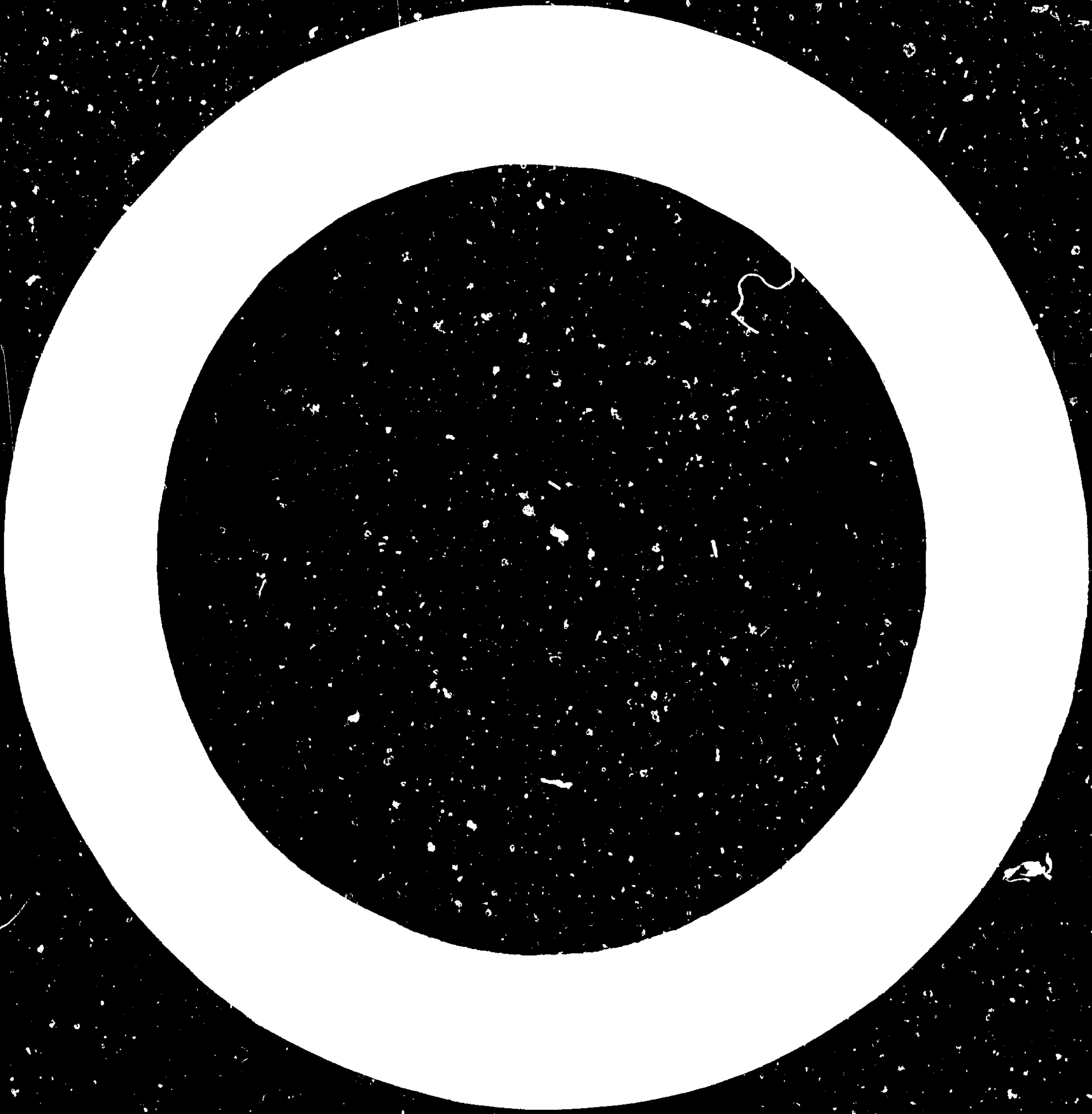
After the Second World War the shell lengths were raised from 6 to 14 m. Such rates of progress were only possible as a result of a number of important

---

* This is a summary of a paper issued under the same title as ID/WG.14/45.

[1] The document is presented as submitted, without re-editing.

id.68-2698



innovations, such as the introduction of roller dies instead of annular dies, increase of total elongation resulting from the inclusion of three-roll elongators and new reeler techniques.

An arrangement diagram and several pictures demonstrate the layout of a modern push bench plant. Also shown is a typical rolling programme as well as the plant output capacities and their present-day limits.

A special analysis of the actual push bench process reveals possibilities for the expansion of the process later on. A comparison of the maximum load-carrying capacities of the push bench end and the maximum push forces discloses that the significance of the push bench end has been overrated in the past. The result is the possibility of producing still longer shells than have been usual to date. Such a development will be necessary to enable the overall output from this process to be substantially improved.

By employing a stretch-reducing mill, in which all the desired final dimensions are rolled down from the least possible number of initial dimensions, the output is considerably influenced. In the process technology, based on pull, it is an established fact that the head and tail pieces of the tubes go for scrap. The output per cent can only be improved by extending the lengths of the initial shells.

If only the total output is to be considered, then preference is to be given to the continuous tube mill, since shells of 22m in length can be rolled to this process. The layout, the technology and the capacity of the continuous tube mill is explained with the aid of arrangement diagrams, and compared with the distinctive features of the conventional push bench.

A comparison of the performance figures of the tube push bench with those of the continuous tube mill indicates the engineering prerequisites for the development of a 19-metre push bench.

From a consideration of the force system balance arising during the push process we arrive at ways for solving the problem. With the aid of measured data proof is given that the construction of a 19-metre bench is possible in principle.

For the planning of the 19-metre push bench there are two different solutions available:

1. The combination of mill with oblique rolls, dishing press and push bench.
2. The combination piercing press, 2 elongators and push bench.

Both these solutions are possible in principle. Depending on whatever scope of duties is required, preference will be given to the one or other solution. A modern 19-m push bank is demonstrated with the aid of an arrangement diagram. This push bench is planned in such a way that it can be expanded in several stages, a fact that is of special importance to developing countries, since installations to operate there must have a built-in allowance for expansion.

While the continuous mill as single-purpose mill serves its purpose where very high production targets are set, in the future the modern push bench will be employed everywhere, where a high degree of flexibility is required as regards the large size range and wide variety of material grades.

## List of figures

Just imagine, gentlemen, that tomorrow you had to build the first seamless tube production plant in your country, a country which is perhaps only on the threshold of a substantial upward economic swing.

Do you think that at this time you have such a clear picture of the development trend of your market that you can commit yourself unconditionally for years in advance as regards production volume and extent of the programme?

If you purchase an installation which must be tailored to suit your specific needs, so as to be able to overcome the technical and economic difficulties more easily, you should nevertheless retain flexibility for the future. If the demand for seamless tubes were one day to increase substantially or the emphasis shift more towards thick-walled and/or high-alloy tubes, one must be able to extend or modify the installation without high additional investments being necessary. It would be embarrassing if the process selected would not permit, for example, a changeover to high-alloy steels. The possibility is not too far-fetched that one day because of excess capacities in strip steel and consequent price reductions for welded tubes you would have to suddenly change over your production of seamless tubes to alloy grades!

You will ask whether such an ideal plant can be built. We say that it can.

See for yourself that modern push bench installations have the flexibility you wish and are quite capable of competing with the most modern high-production mills.

In the course of this paper you will hear about the development of push benches over the last 17 years, the most recent plans being compared with the results obtained with continuous mills.

You can see the fundamental push bench process from the first picture. The initial material is a rolled or continuously-cast billet of square cross section which is heated in a furnace after being cut into lengths of about 1 metre and is then pierced on a piercing press to form a thimble-like bottle. During this piercing process the cavities of the recipient are filled. After piercing, the bottle is slid over a mandrel and passed through several dies/roller dies in series, forming the finished shell.

Before the Second World War this classical Erhardt process could be employed for producing shells with a maximum length of 6 metres and maximum outside diameter of 200 mm. The short lengths were the cause of unsatisfactory yield.

Only after the Second World War were the weight of the initial material and the shell length substantially increased by a large number of improvements incorporated. Whereas the first push benches were built for shell lengths of 10 metres, about the middle of the 1950's it was possible to produce shells 14 metres long. By using an additional elongator between piercing press and push bench the billet weight was increased by about 30 %. In principle the elongators were two or three-roll mills with oblique rolls (Fig. 2). All rolls rotated in the same sense and follow a helical path when rolling the bottle over a cylindrical rotating mandrel.

The elongators increased the length in the ratio of 1.5:1, the push bench proper in the ratio of 20:1, so that the total or overall ratio of initial to finished cross sections was about 30:1.

As could already be seen from the first picture, the first push benches employed annular dies which were later replaced by roller dies, since a maximum surface area reduction of only 10 to 15 % could only be obtained with the annular die. Moreover, it frequently caused flaws in the outer surface. The reduction obtained with the roller dies is between 20 and 25 %, thus permitting the number of working dies to be reduced from 20 to 15. All these developments provided the necessary basis for the production of shells having greater lengths.

In the third picture you see a roller die bed with several roller dies. You can clearly see the three non-driven rolls. From roller die to roller die the rolls are staggered by 180° so that the size steps are bridged. On completion of the stretching process the shell is firmly shrunk onto the mandrel bar, and both shell and mandrel bar have to be passed through a reeler so that the mandrel bar can be withdrawn. A modern reeler employs the principle of a multi-roll straightening machine (Fig. 4).

What would be the layout of a modern push bench installation employing the mode of operation thus described?

Let us have a look at Fig. 5, on which an installation for maximum and minimum outside diameters of 4" and 1/2" respectively and a maximum furnace capacity of 45 tons/hr was planned.

The hot plant equipment, including the cooling bed - not shown here - would require a total area of 15,000 square metres. The billets are divided into lengths of about 1 metre by a cold shear designed for a maximum shearing force of 1,400 tons. With this shear one can divide billets having cross sections of up to 190 x 190 mm and a maximum strength of 50 kg/mm$^2$. Higher alloyed grades have to be cold sawn. The billets are charged into the rotary hearth furnace in a single row or in multiple rows and heated to about 1,250 °C. Before entering the piercing press (5) they have to be sized diagonally and are therefore passed through an ordinary two-high stand with round passes. Accurate guiding of the billets in the press container is absolutely necessary. This may strongly influence the wall thickness accuracy. A further factor which causes wall eccentricity is due to the critical L/D ratio being exceeded. This is understood to mean the ratio of billet length L to the mandrel diameter D. It is conceivable that the diameter of the mandrel increases with increasing penetration into the material. In practice, certain limiting values have been established which, when adhered to, enable the necessary wall tolerances to be attained.

The induction reheating furnace (6) is not used in all cases. It would be too expensive for ordinary commercial steels - and it is also not necessary. However, it has given good service when dealing with high-alloy steels because here in particular exact rolling temperatures have to be adhered to. In addition, it is a help when starting up again after trouble when the material was not heated sufficiently.

By interposing a three-roll elongator with oblique rolls between piercing press and push bench. the billet initial weight was increased for the same finished dimensions, since

1. the total elongation in the push bench installation was increased,
2. the wall thickness eccentricities of the bottles are reduced and a higher L/D ratio (7.0:1) can be employed, also
3. larger piercing punches an be used in the press because of free internal deformation.

After elongation, the bottle is transferred to the push bench.

On the positioning roller table it is cleaned of internal scale and positioned and then passes through the push bench. The shell is released from the mandrel bar in the multi-roll reeler. After withdrawal, the mandrel bar is returned to a mandrel heating table.

Precise heating of the mandrel to about 550 °C is imperative for reliable functioning of the push bench process.

Before the shell enters the reheating furnace the head and tail are cut off. After reheating to 1,000 °C the shells are reduced to hot finished dimensions in a multi-stand stretch reducing mill.

Let us again visualize the push bench process proper, so that later we can better recognize the potential available for expansion of push bench installations.

Several roller dies have been entered in the roller die bed in Fig. 6. The so-called arrangement diagram serves for exact distribution of the work of deformation during rack travel. You will see that at the beginning only three roller dies are in use at the same time, while towards the end up to seven are in use at the same time. The push forces such as have been calculated and in many cases actually measured are plotted beneath the diagram. For a 90-mm mandrel bar they go up to a maximum of 70 tons. The lower dashed line indicates the force at which the end should theoretically be penetrated. The critical end load-carrying capacity can be determined from the admissible shearing stress and the shearing surfaces.

The fact that the end is nevertheless not penetrated shows that the full push force is not solely transmitted via the end of the push bench. On the contrary, frictional and clamping forces assist the pushing process. This is one of the reasons for the mandrel bars having to be preheated.

Mandrel bars are tools which have to be reconditioned again at certain intervals. Reconditioning is carried out at a temperature in the region of 850$^{o}$C. The mandrel bars are passed through a reeling machine until they are cold and a smooth surface has been formed. During reeling, the diameter is reduced by about 0.3 mm. The mandrel bars can normally be reconditioned about twelve to fifteen times until the core becomes fatigued and they have to be rejected.

After you have had an opportunity of familiarising yourselves with the deformation process and material flow in push bench installations, let us have a look at the size ranges and the capacity of such installations.

Modern push benches employ mandrel bars having diameters ranging from 70 to 156 mm. The outside diameters are obtained by adding the mandrel bar diameter and twice the wall thickness. The most usual mandrel bar diameters are between 90 and 127 mm.

The minimum wall thicknesses may be given as 2.6 mm to 3.2 mm, provided that small mandrel bars are used with a maximum size of 12 to 15 mm.

A typical mill schedule is shown in Fig. 7. The initial material is a billet measuring 150 x 150 mm and with a maximum weight of 233 kg. The maximum sheel length for this installation had been fixed at 14 metres.

With a wall thickness of 5 mm the maximum initial weight was reached. From that point on, the shells became shorter corresponding to the increasing weight per metre.

The output rate of such installations is a maximum of 4.5 units per minute. Calculated over a period of one month, 4 units per minute on the average have already been produced on a smaller installation.

The annual output of modern push bench installations may be stated as being 125,000 tons. The economic minimum outputs are, of course, dependent on the market and on the plant itself. They could be quoted as being about 40,000 tons per annum.

The same information on production is summarized in the form of a diagram in Fig. 8. We shall show this diagram several times, so as to be able to compare the various push bench installations with the continuous trains. The wall thickness is plotted on the X-axis, the shell length on the Y-axis. The point at which the horizontal curve becomes a hyperbola is the point at which the maximum initial weight is attained.

The difference between the shell length for the conventional push bench (14 metres) and for the continuous train is substantial. It makes itself directly felt by lower total yield, since the reducing mill is supplied with shorter initial shells. The mean difference is about 5 %. However, we cannot do without the degree of reduction of the stretch reducing mill, because the performance and flexibility of the push bench are improved by its use.

Stretch reducing mills as shown in Fig. 9 reduce the outside diameter by up to 75 %. When the size is changed, a few stands are removed and new finishing stands added. Changeover time can be cut to 5 minutes by means of quick-change equipment. When the finished wall thickness is changed, in many cases the pass does not have to be changed at all. It suffices to vary the speeds and thus the pull within the permissible limits, to produce a new finished wall thickness.

You will notice that the stands are very close together. The compact design was chosen so as to keep the thickened ends as short as possible. The principle of rolling with pull is the reason for the head and tail of the rolled product being thickened in the wall thickness.

Just imagine, gentlemen, you wish to test a bar to destruction in a tensile testing machine; at all points, with the exception of the clamping points, you would find necking had taken place. The same thing occurs during rolling in the stretch reducing mill. The length of the thickened end is a function of the reduction in diameter and wall thickness and of stand spacing. For this reason one tries to design the finish rolling mill as compactly as possible. Since the length of the thickened end is constant for a given tube reduction, the percentage yield can be increased only by increasing the initial pass length preceding the stretch reducing mill. This is why the main aim of all seamless tube installations is to produce longer initial shells for the stretch reducing mill. And it is here that at the moment one of the advantages of the continuous tube train is to be found.

Fig. 10 shows the fundamental layout of a continuous tube mill. These high-output trains are suitable for annual production rates of from 300 to a maximum of 400,000 tons. In simplified form one may imagine a continuous tube mill train as employing the forming process of the push bench in reverse; whereas the mandrel bar of the push bench is driven and the rolls are not driven, in the continuous tube train exactly the opposite is the case.

The rolling mill shown here needs an area of about 22,000 square metres for the hot equipment. The initial material is round billets which are hot flame scarfed before entering the installation. They are heated to about 1,250 °C in a 100-ton rotary hearth furnace, centred in the centring machine (No. 4) and rolled into a thick-walled shell in one of the two rotary piercing mills (No. 6).

Shaping of the thick-walled shells is carried out in a nine-stand continuous mill over a mandrel bar which travels through with the stock.

The shell from the rotary piercing mill is held in the shell entry guide until the mandrel bar has been introduced. The shell and mandrel bar then enter the first stand together. The continuous stands (Fig. 11) are arranged crosswise. Main shaping is carried out in the first stands, while the last stands serve for sizing and releasing the shells from the mandrel bar. On completion of rolling, the mandrel bar is withdrawn with a chain puller and is returned to the mandrel bar cooling tank and grid. The shell is cropped at both ends and then takes the same path as already described for the push bench.

The maximum diameter of the shells is between 130 and 140 mm, their length about 22 metres, the wall thickness - depending on mandrel diameter - being a minimum of 3.25 to 3.75 and a maximum of 12 mm. The elongation obtained in the continuous mill overall is about 15:1.

It is therefore 50% of that in the push bench.

Whereas rolling has to be carried out with relatively high elongation (3:1) in the rotary piercing mill, the elongation in the continuous mill is a maximum of 5:1. Because of the high degree of deformation in the rotary piercing mill, the initial material has to meet more stringent requirements.

Is it worth developing other processes when such good results are obtained with the continuous mill train? Through which cost factors can the reduced yield of the push bench be compensated? Where are its advantages as compared with the continuous mill?

The initial material is not stressed so severely by the piercing process on the push bench as it is by the rotary piercing mill of the continuous mill train. The cost of the initial materials for the push bench is lower, this resulting from the quality, preparation and form of the material. Moreover, high-alloy steels can be dealt with which would present great difficulties in the continuous mill. Finally, the push bench can be changed over more easily.

If the yield of the push bench were to be improved by further increasing the shell length, we would then have a process for medium output which is equal to the continuous mill. Our target, which we set ourselves three years ago, was to increase the shell length for the push bench to 19 metres. If this were achieved, the difference in the yield as compared with the continuous mill would be only 2.5 %. A low figure which could be compensated by other cost advantages.

The bottleneck in the push bench process is piercing, because in the present form a certain L/D ratio may not be exceeded.

If, however, we were to depart from conventional piercing processes and feed the push bench with a longer initial bottle than before (1.5 metres), the target set could be attained.

The second problem consisted in fully testing the entirely new initial pass conditions. Particularly at the beginning of the push bench process the end of the push bench is most strongly stressed. We did not know how it would behave if we were to further increase the degree of deformation at the beginning. We therefore had to carefully study the method by which the push force is transmitted. The complicated processes are summarized in Fig. 12 in simplified form. Merely one roll, which reduces the wall thickness by an amount $\Delta h$, is shown. The rolling force $P_R$ occurring acts on the mandrel bar as a frictional force $P_{\varrho di}$ and opposes the deforming force $P_A$. In addition, behind the pass clamping forces $P_{Kli}$ are produced which only disappear on the way to the following roller dies. The formula shows that forces are mainly transmitted via the friction and clamping forces. Only a fraction passes through the push bench end and the wall of the bottle. Observing continuous operation we established that only in the first passes did penetration sometimes occur. Once these had taken place, tearings of the wall at the most - but no bottom penetrations - were noticed.

Such observations clearly showed that the problem of push bench shells 19 metres long could be solved by revising the arrangement diagram for the first stands. These investigations served as preparation for building a 19-metre push bench.

With the new push bench process we start with a bottle 2.7 metres long, to produce a shell 19 metres long on the push bench. Particularly for the large wall thicknesses, the difference between this concept and the continuous mill was only 15 %. There are a number of ways of rolling the larger bottles preceding the push bench:

One can either

> increase the elongation produced by the three-roll elongator by a second pass, while retaining the classical method

Or

> pierce round billets in a two or three-roll rotary piercing mill to form thick-walled bottles of any length.

Both methods are possible in principle. Before rolling in the rotary piercing mill the open end of the bottle must be pressed shut before insertion into the push bench, so that the push force can be transmitted via this collar during the pass. The bottle is pressed shut in a dishing device as shown in Fig. 13. This consists of non-driven rolls arranged at an angle of 45°. The rolls are sized so that when the tool rotates a parabolic rotation body is formed. While the machine is fed forward the front end of the bottle is closed.

As may be seen from Fig. 8, it is completely irrelevant which of the two processes is chosen for producing the shell 19 metres long. Other factors, such as the nature, preparation and cost of the initial material - and the ability to shape high-alloy steels - are decisive for the piercing process used previously.

In two-year trials and tests we have investigated the loads on the push benches and the force system balance of the push bench mandrel bar, so as to obtain the basis for the 19-metre push bank process. What we had earlier anticipated from operating experience was now confirmed by measured data. Fig. 14 plots the push bench end loading as a function of the number of passes. It can clearly be discerned that the loading on the end of the push bench is reduced after only the first few stands have been passed through. Theoretically, after the seventh stand the process could have been performed without push bench end.

Since the arrangement diagrams for 19-metre push bench shells only differ at the beginning from conventional arrangement diagrams, we have concentrated only on these in further investigations. By elongating twice in the three-roll stretch reduction mill we produced bottles which were identical with those of the 19-metre push bench. With this material we produced shells 10.7 metres long with a wall thickness of 5.5 mm. It was not technically possible to produce on the push bench a tube 19 metres long, since increased rack travel would have been necessary to do this.

From the knowledge gained through the tests and trials we can today say that development of the 19-metre push benches is complete and can be realized in the future.

Fig. 15 shows the fundamental layout of a tube push bench installation for tubes 19 metres long. Merely the piercing process has been modified, the layout being otherwise the same in principle as the conventional push bench. The material coming from the rotary hearth furnace is first precentred in a centring machine (3) and then pierced to form a thick-walled bottle in the rotary piercing mill.

After piercing, the one end has to be closed by dishing; for this purpose the mandrel bar is introduced and the stock dished on the mandrel bar. The latter is introduced next to the push bench so as to reduce push bench idle time. Owing to the longer travel of the rack, the output of units per minute is reduced for certain, but the rate of production can nevertheless be raised by such a process. Compared with a conventional with an annual production rate of 125,000 tons, a 19-metre push bench would be able to produce 250,000 tons per year of the same dimensions. The investment costs referred to year tons are thus comparable with those for the continuous tube mill.

In the same way, the conventional plant could be planned for 19-metre shells. Instead of the rotary piercing mill there would be 1 piercing press with two elongators.

If the return stroke of the rack were also to be utilized by having the push bench working with two die beds in parallel, a substantial further production increase could be obtained.

This course has only been considered theoretically. It is mentioned so as to make clear the development potential in the more distant future.

Push bench installations can be planned so that an increase in output can be realized quite easily in one or two phases. For example, one could start with a simple installation consisting only of piercing press and push bench. At a later date the elongators could be added and the rack stroke increased. You would thus buy a large-scale installation in instalments.

Installations for the production of seamless tubes in developing countries should be designed for growth. They must be flexible enough to deal with a large size range and a comprehensive variety of material grades. In the push bench you find a process which meets these requirements. The continuous tube mill will find its place where a single-purpose facility is needed for very high production rates.

Figure 1

Principle operations of push-bench process

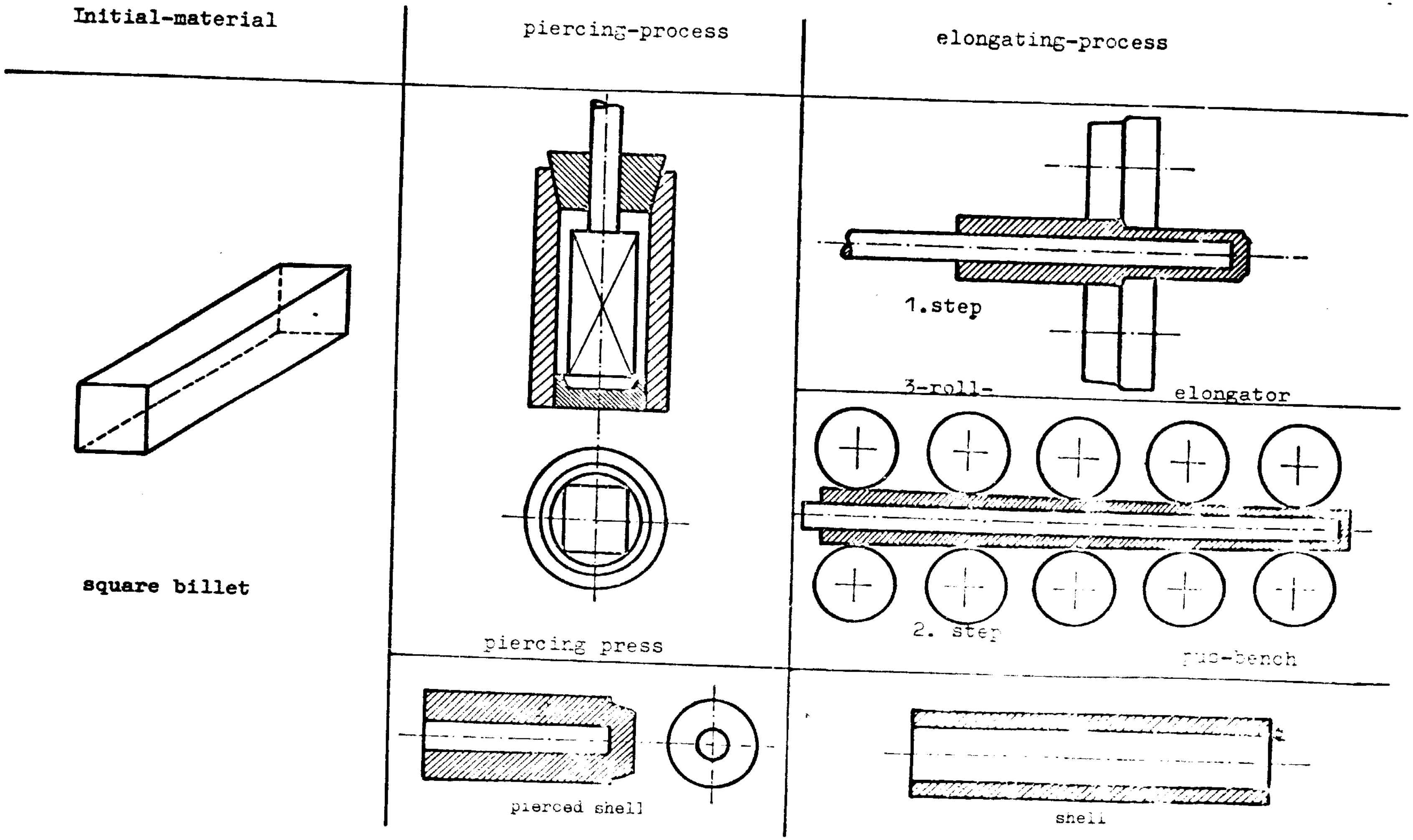


Figure 2

Three-roll elongator

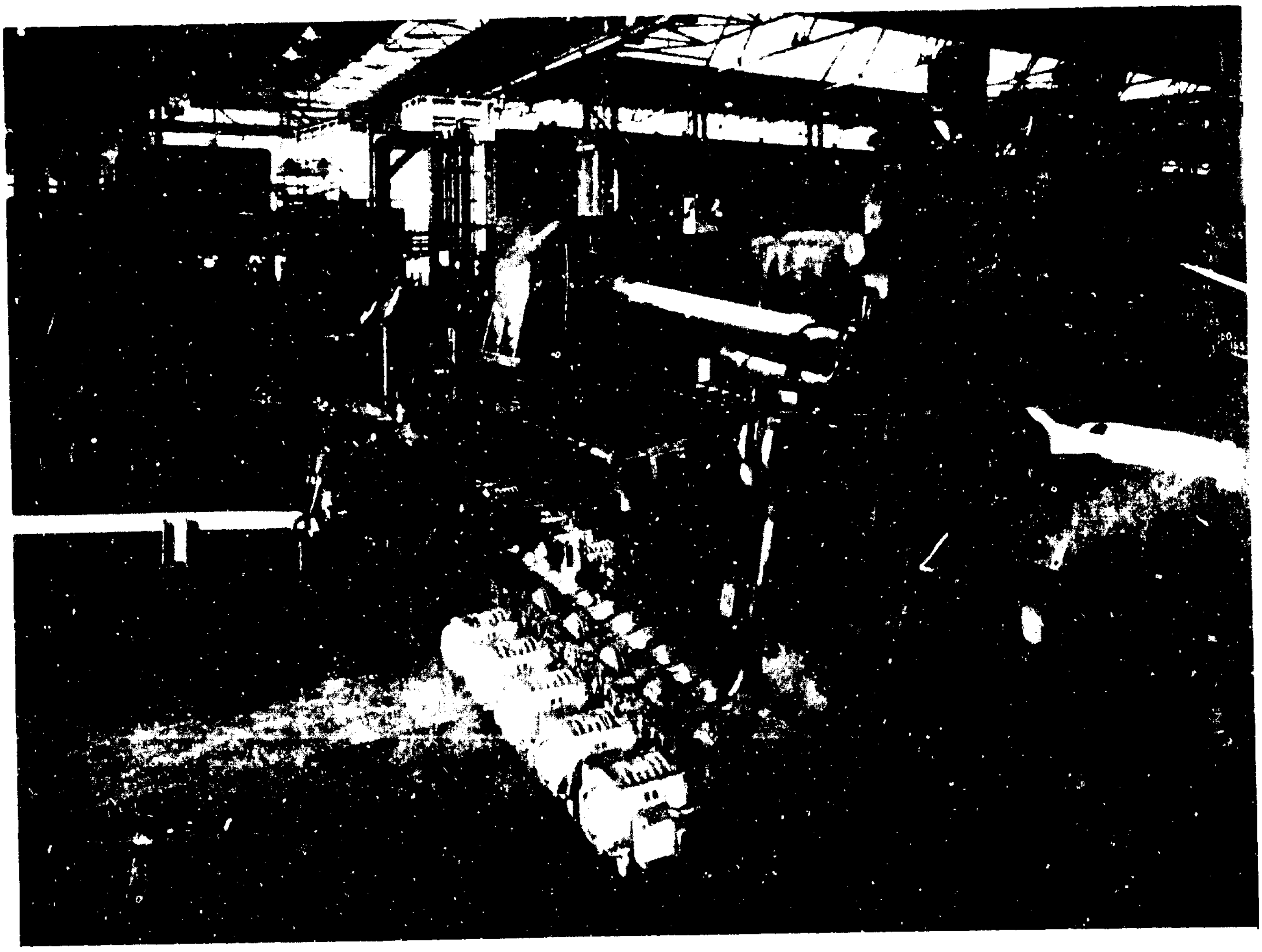


Figure 3

Die bed of a push bench with roller dies installed

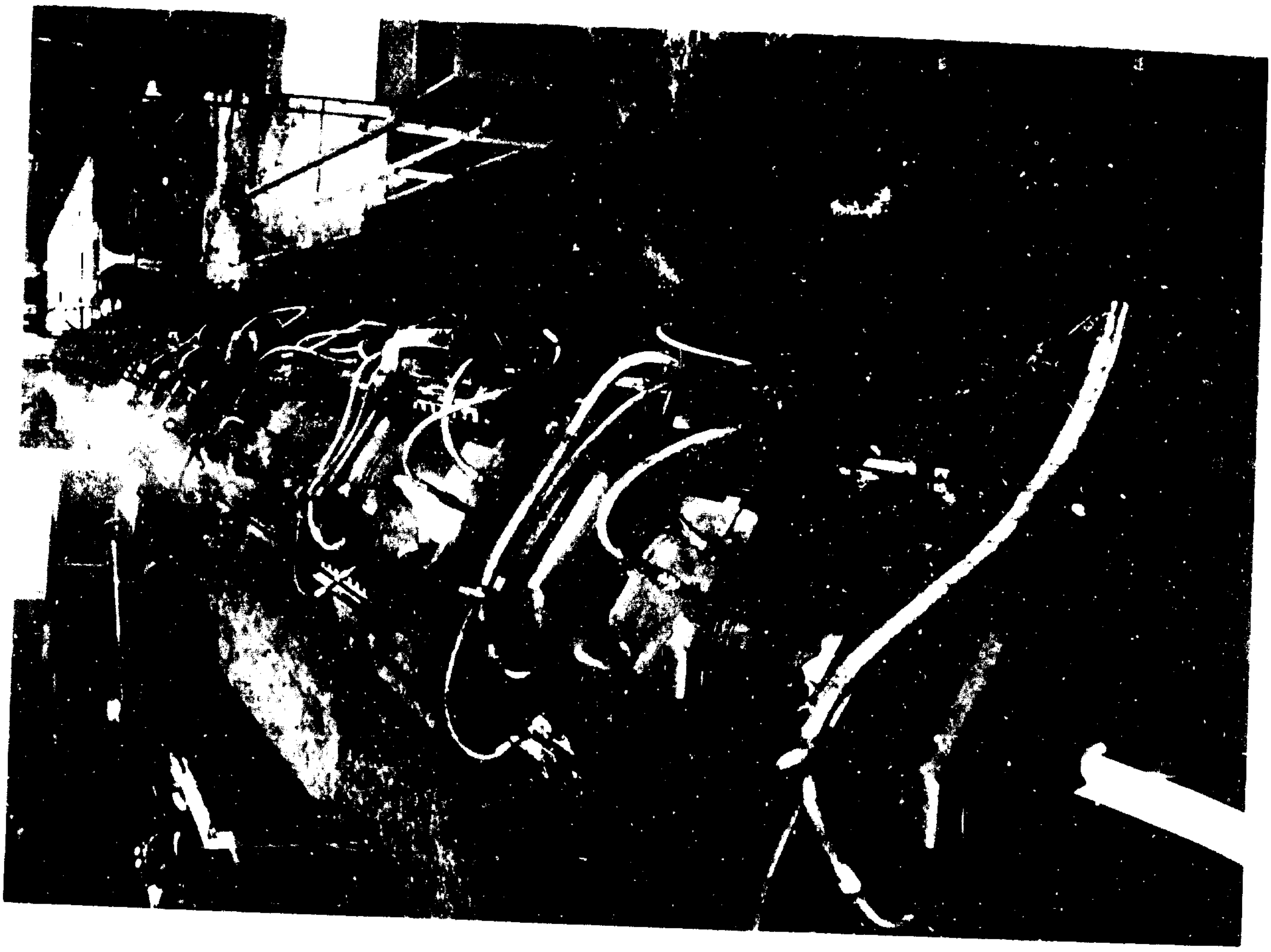
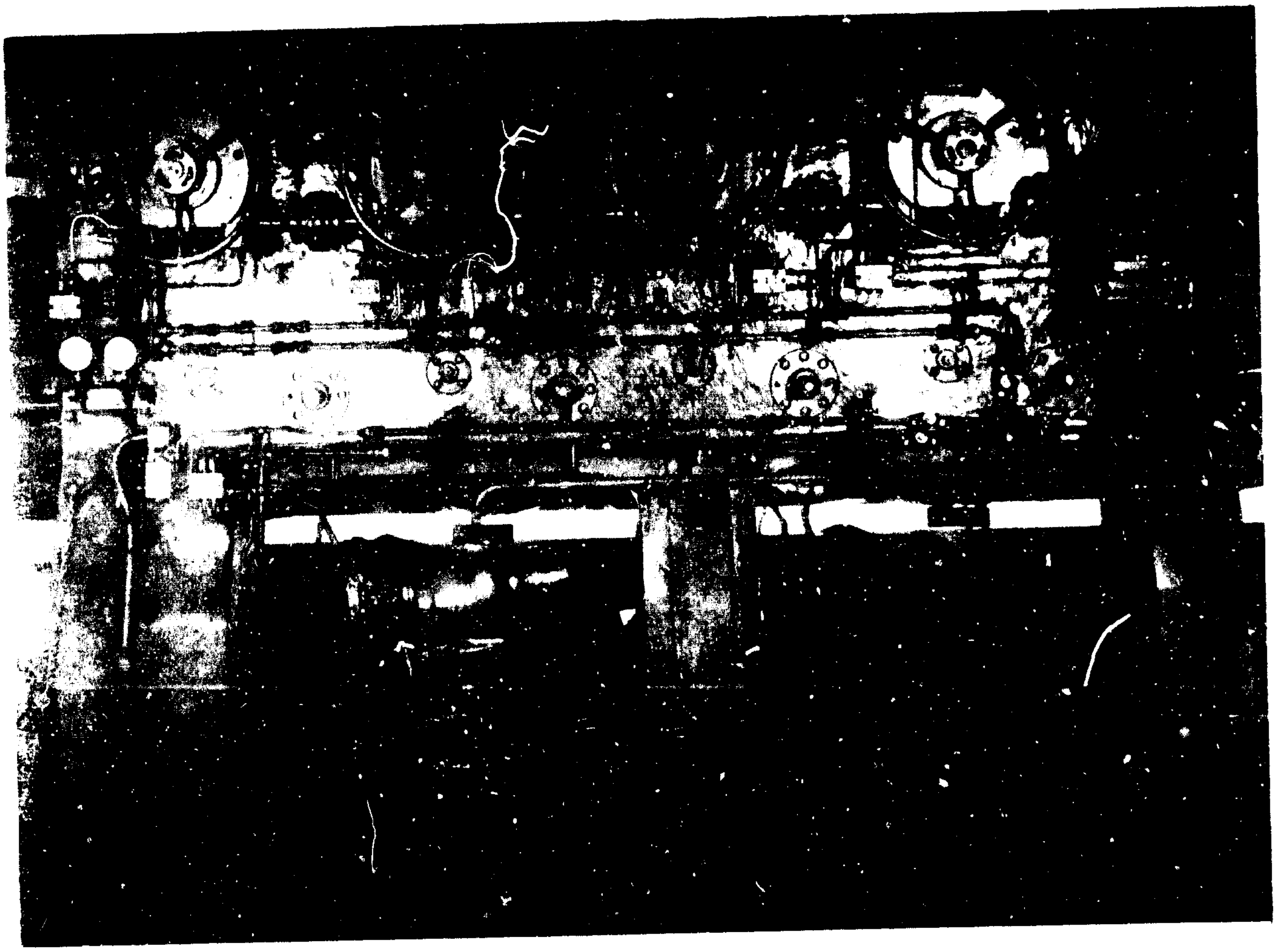


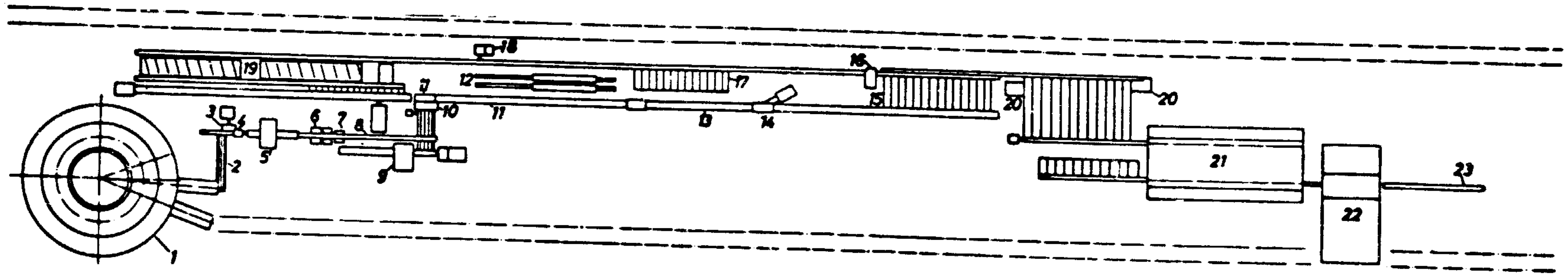
Figure 4

Mode of operation of a new reeler



## Figure 5

## Layout of a conventional push bench installation for shells, 14 metres long

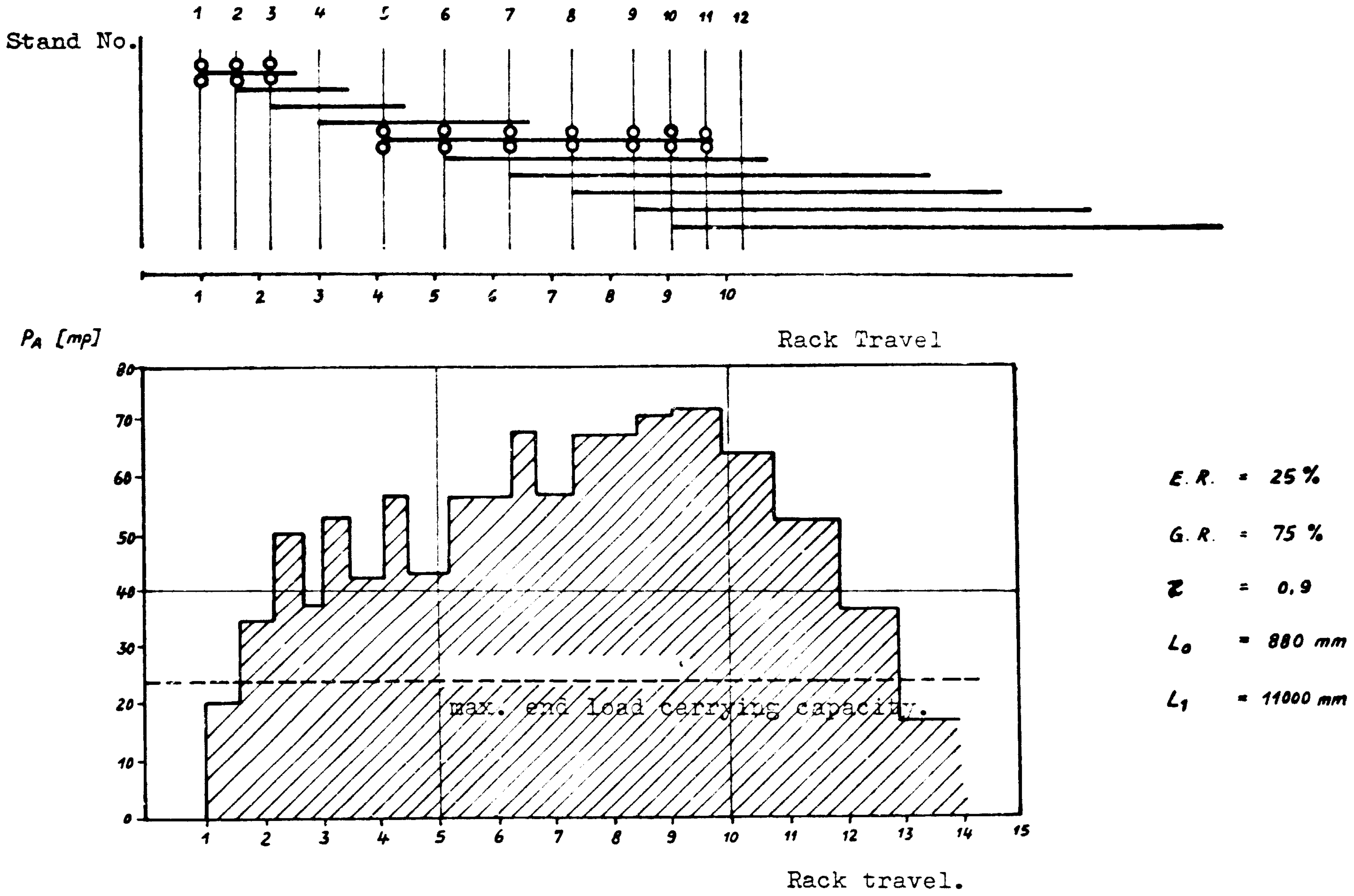


1 Rotary Hearth furnace
2 Transfer
3 Sizing mill
4 descaling plan
5 piercing presse
6 Reheating induction furnace
7 Transfer
8 Roller table
9 3-roll elongator
10 Shell tilter
11 Push bench with rack guide bed, billet table and die bed

12 roller dies
13 Delivery roller table
14 Reeler
15 Transfer grid
16 Mandrel bar exractor
17 Mandrel bar store
18 Mandrel bar lubricating equipment
19 Heated mandrel bar table
20 Cropping saw
21 Reheating furnace
22 Stretch reducing mill
23 Delivery roller table

Figure 6

**Arrangement diagram and loading characteristics**



## Figure 7

## Rolling schedule, conventional push bench, mandrel bar dia: 127 mm

| Initial material | | | | Piercing press | | | | Elongator | | | | | Push bench | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| K mm | MG kg/m | L m | G kg | $D_o$ mm | $d_o$ mm | $L_o$ m | $L_o/d_o$ | $D_1$ mm | $d_1$ mm | $L_1$ m | d2 mm | $s_2$ mm | $MG_2$ kg/m | $L_2$ m | $G_2$ kg | $LAMBDA_2$ – |
| 180 | 251 | 0,6 | 145 | 238 | 135 | 0,6 | 4,3 | 200 | 129 | 1,0 | 127 | 3,0 | 9,6 | 14,0 | 134 | 15,0 |
| | | 0,7 | 169 | | | 0,7 | 5,0 | | | 1,1 | | 3,5 | 11,3 | 14,0 | 157 | 12,8 |
| | | 0,8 | 193 | | | 0,8 | 5,8 | | | 1,3 | | 4,0 | 12,9 | 14,0 | 181 | 11,1 |
| | | 0,9 | 218 | | | 0,9 | 6,5 | | | 1,4 | | 4,5 | 14,6 | 14,0 | 204 | 9,9 |
| | | 0,9 | 233 | | | 0,9 | 7,0 | | | 1,6 | | 5,0 | 16,3 | 13,5 | 219 | 8,8 |
| | | | | | | | | | | | | 5,5 | 17,9 | 12,2 | 218 | 8,0 |
| | | | | | | | | | | | | 6,0 | 19,7 | 11,1 | 218 | 7,3 |
| | | | | | | | | | | | | 6,5 | 21,4 | 10,2 | 217 | 6,7 |
| | | | | | | | | | | | | 7,0 | 23,1 | 9,4 | 217 | 6,2 |
| | | | | | | | | | | | | 7,5 | 24,8 | 8,7 | 216 | 5,8 |
| | | | | | | | | | | | | 8,0 | 26,6 | 8,1 | 216 | 5,4 |
| | | | | | | | | | | | | 8,5 | 28,4 | 7,6 | 215 | 5,1 |
| | | | | | | | | | | | | 9,0 | 30,1 | 7,1 | 215 | 4,8 |
| | | | | | | | | | | | | 9,5 | 31,9 | 6,7 | 214 | 4,5 |
| | | | | | | | | | | | | 10,0 | 33,7 | 6,3 | 213 | 4,3 |
| | | | | | | | | | | | | 10,5 | 35,6 | 6,0 | 213 | 4,0 |
| | | | | | | | | | | | | 11,0 | 37,4 | 5,7 | 212 | 3,8 |
| | | | | | | | | | | | | 11,5 | 39,2 | 5,4 | 212 | 3,7 |
| 180 | 251 | 0,9 | 233 | 238 | 135 | 0,9 | 7,0 | 200 | 129 | 1,6 | 127 | 12,0 | 41,1 | 5,1 | 211 | 3,5 |

Figure 8

Shell length preceding elongator as a function of wall thickness

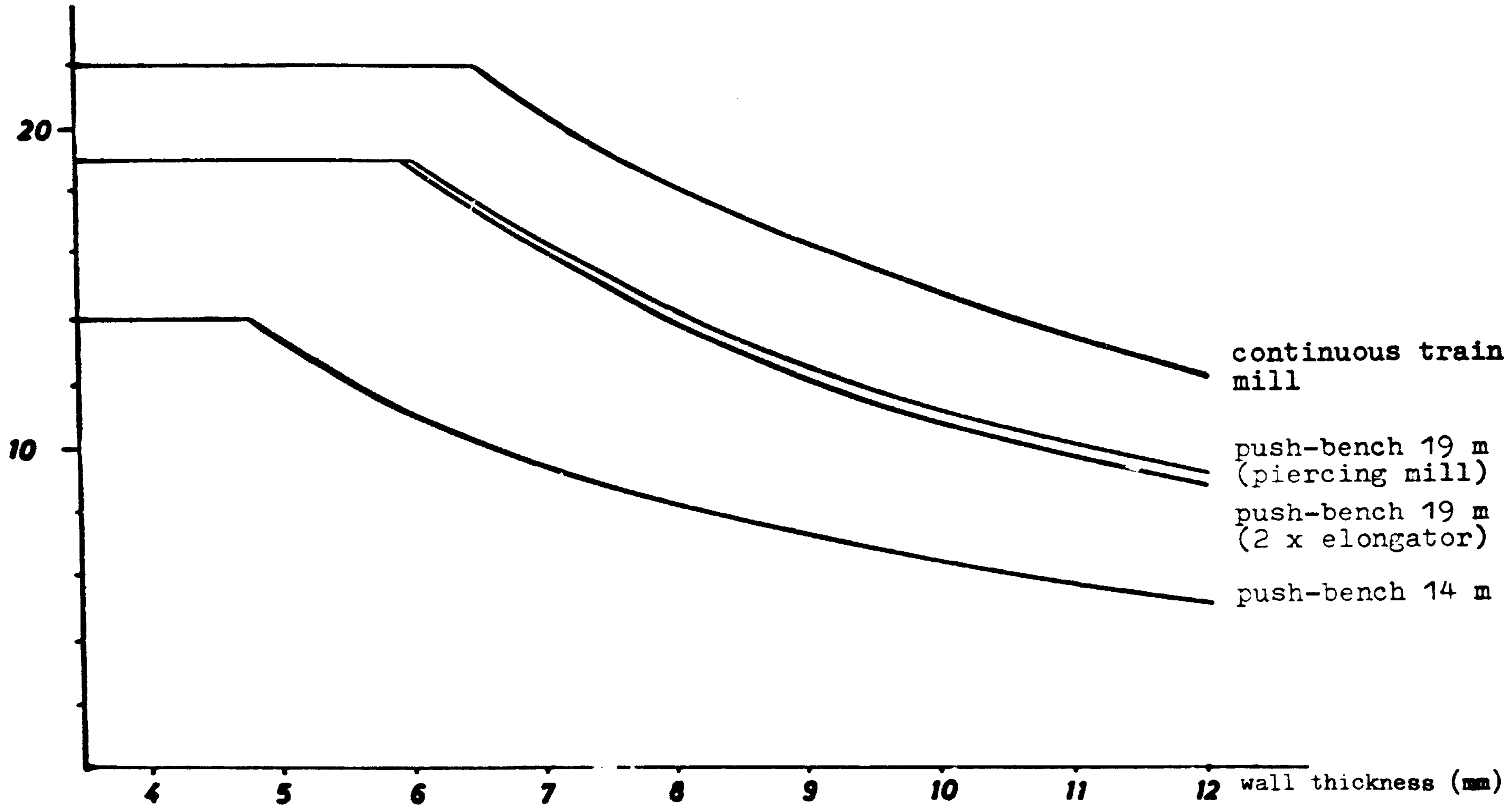
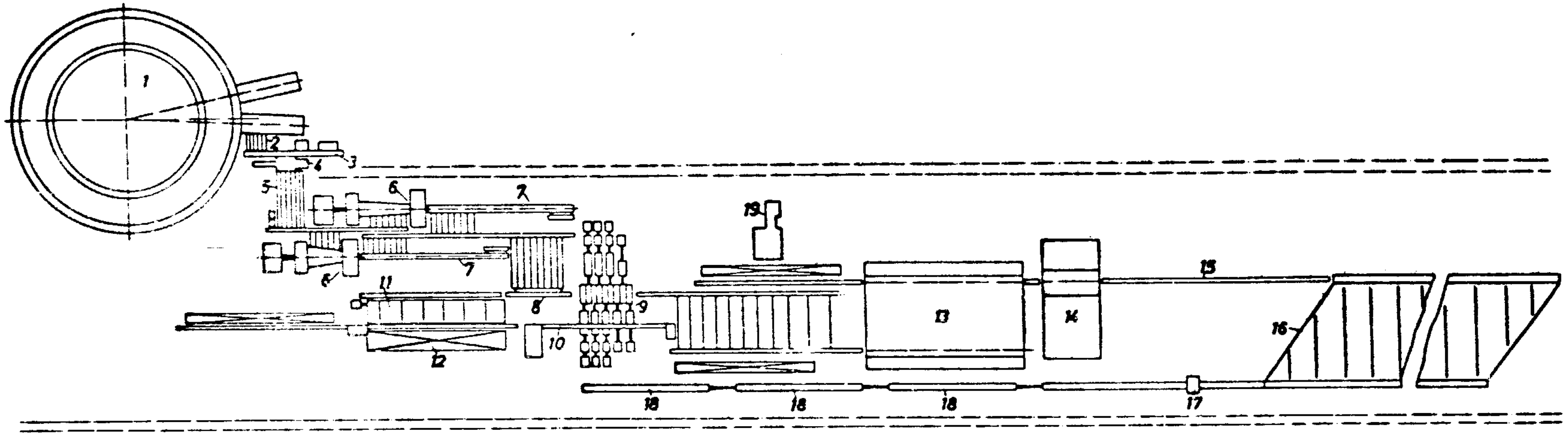


Figure 9

Twenty-four-stand elongator with individual electric drive and quick-change stand equipment

## Figure 10

## Layout of continuous tube mill



| | |
|---|---|
| 1 | Rotary hearth furnace |
| 2 | Transfer |
| 3 | Roller table |
| 4 | Centring machine |
| 5 | Transfer |
| 6 | Rotary piercing mill |
| 7 | Mandrel bar and shell guide bed |
| 8 | Bottle guide device |
| 9 | Continuous rolling mill |
| 10 | Mandrel bar extractor and hot saw |
| 11 | cooling containers for mandel bars |
| 12 | Mandrel bar store |
| 13 | Reheating furnace |
| 14 | Stretch reducing mill |
| 15 | Delivery roller table |
| 16 | Cooling bed |
| 17 | Saw |
| 18 | Intermediate pocket |
| 19 | Location for continuous stan |

Figure 11

Nine-stand continuous rolling mill viewed from the delivery side

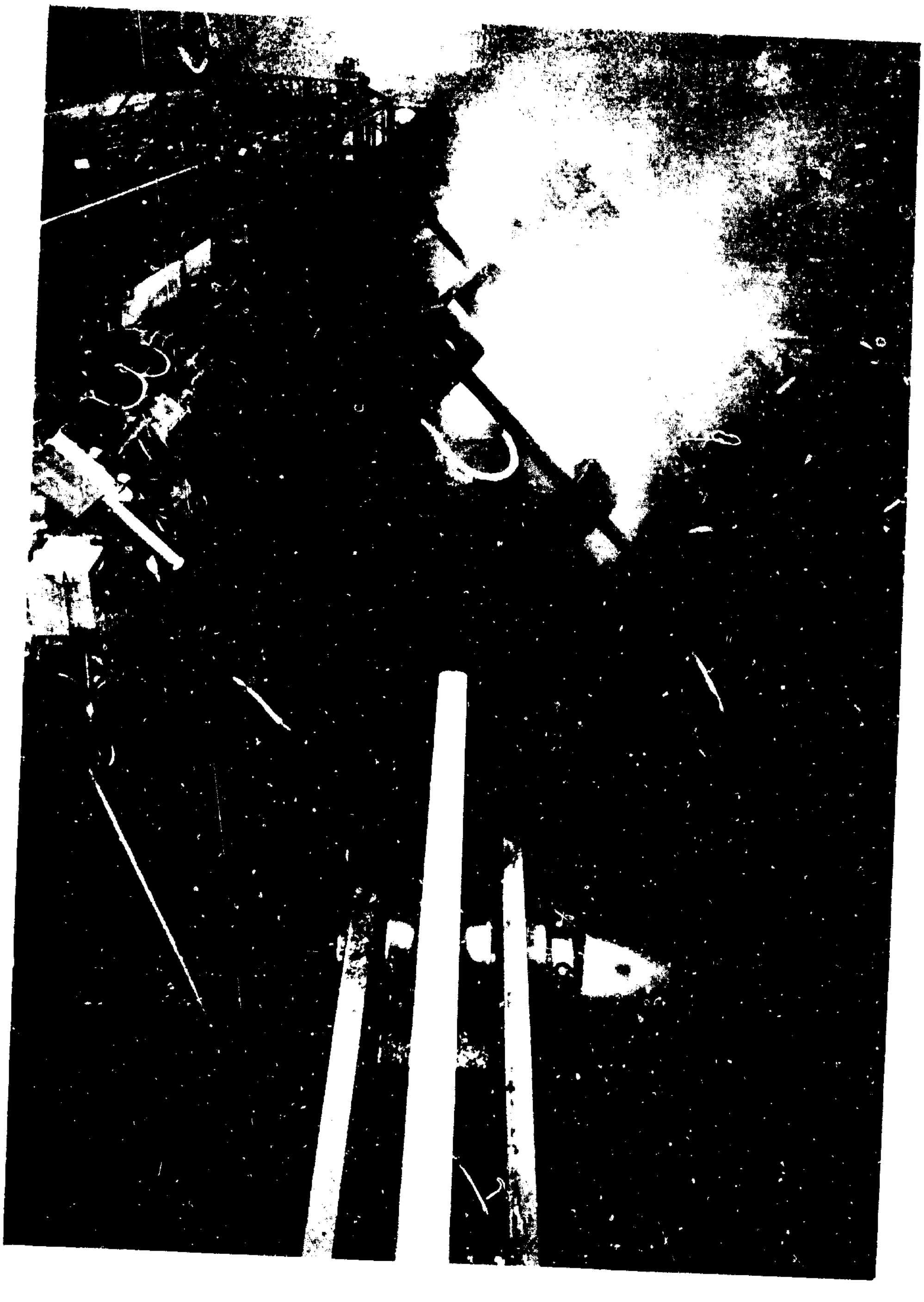
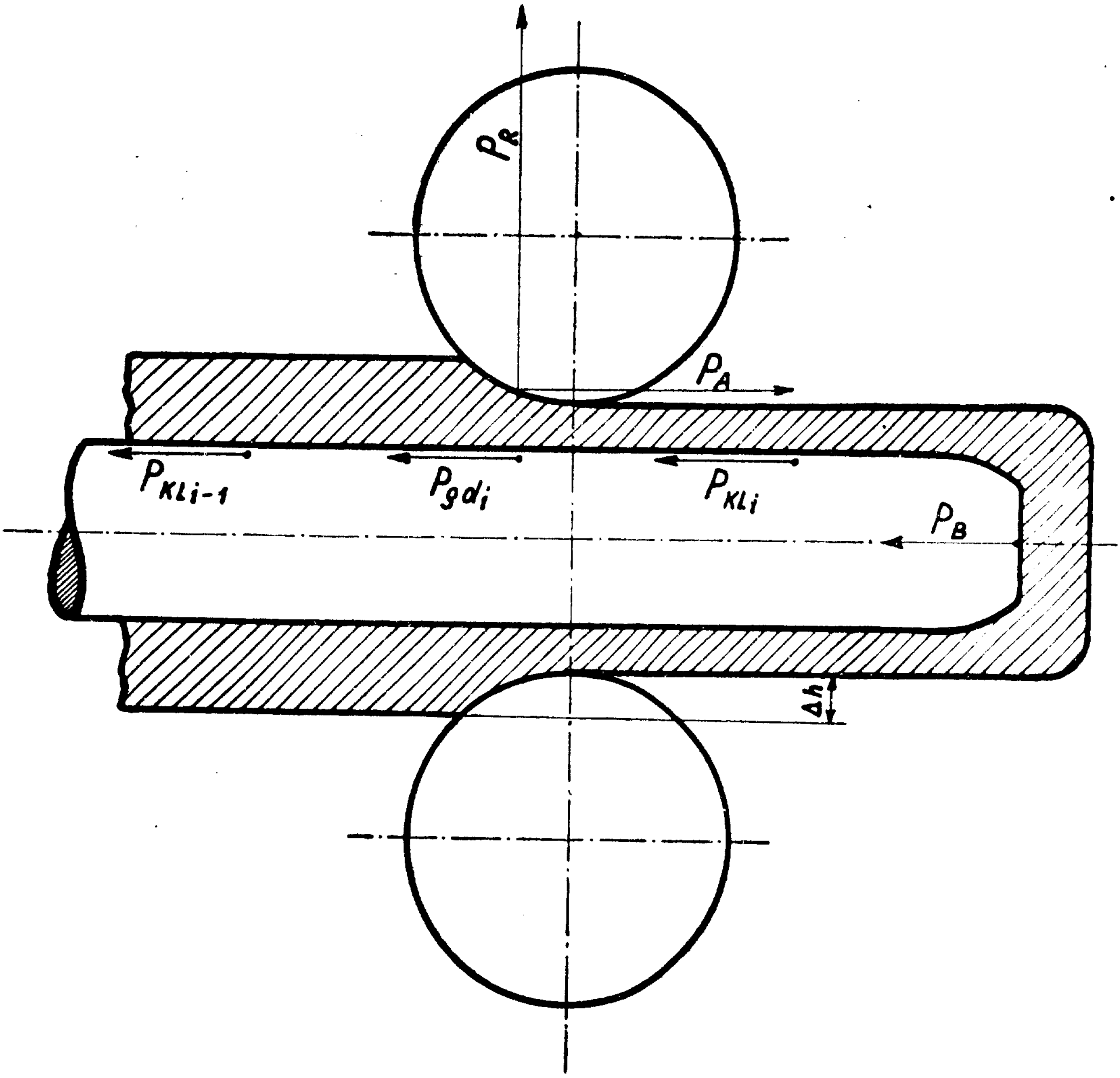


Figure 12

Transmission of push forces



Force system acting on mandrel bar

$$P = P_B + \sum_{1}^{M} P_{KL_i} + \sum_{1}^{M} P_{gd_i}$$

Figure 13

Principle of a dishing machine for closing the bottles from the rotary piercing mill

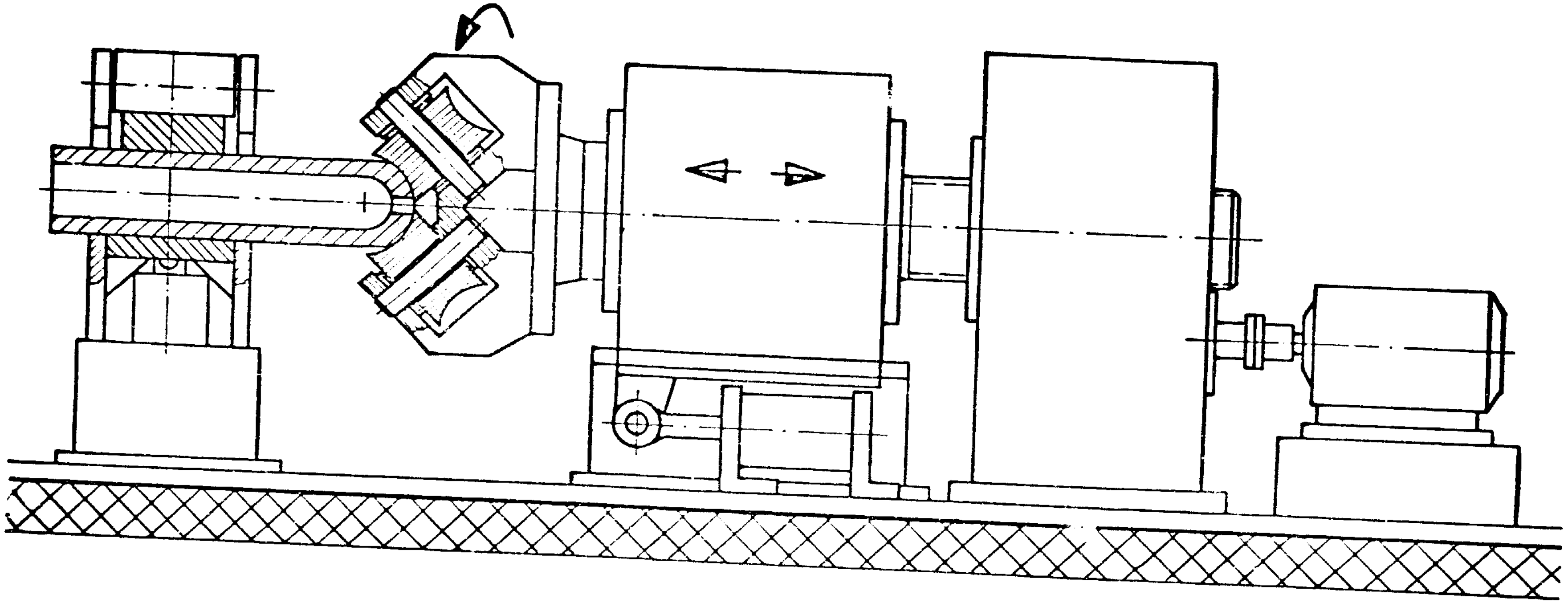
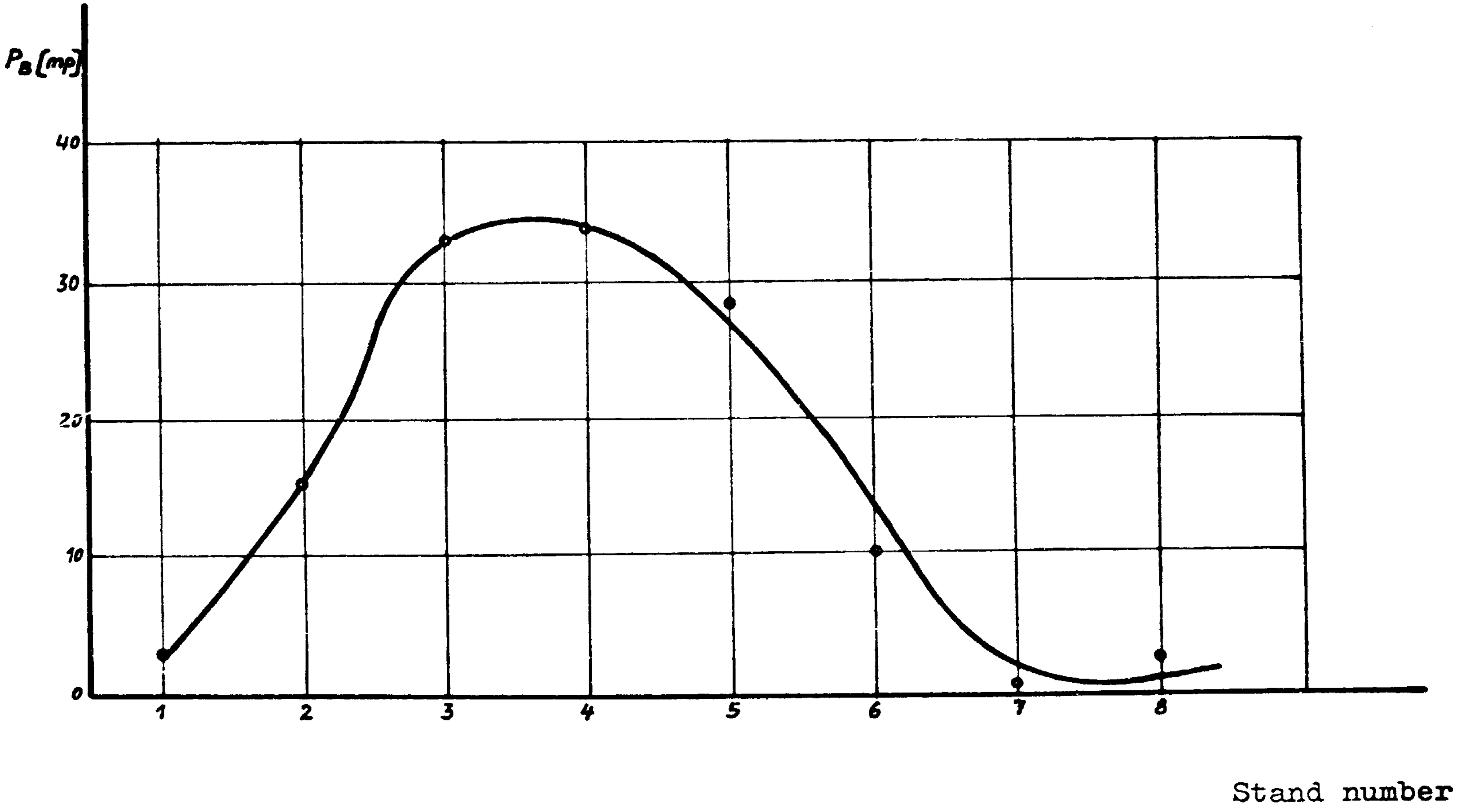


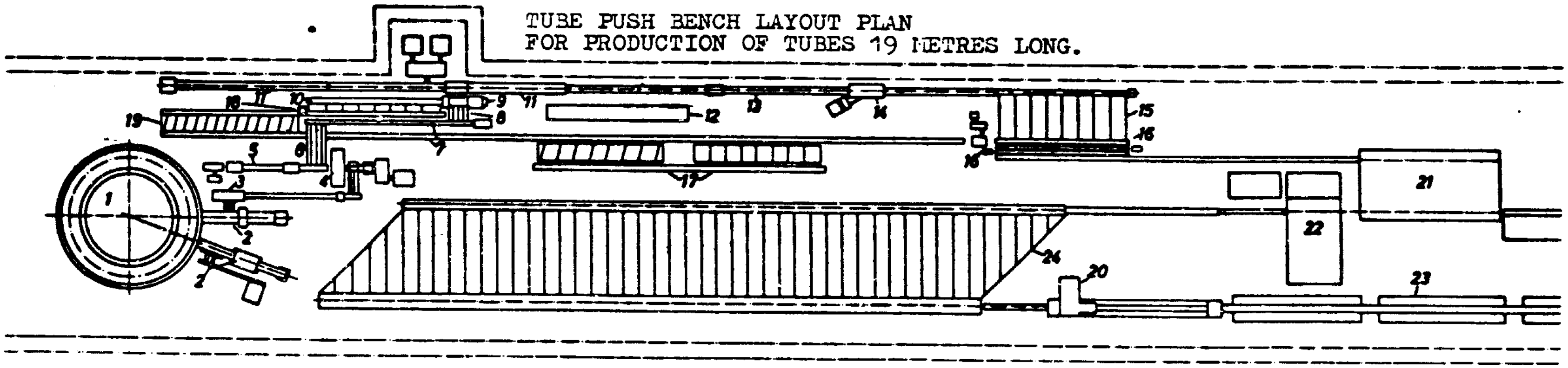
Figure 14

Decline in loading on end during the push bench process



## Figure 15

## Layout plan of a 19-metre push bench installation



| | |
|---|---|
| 1 | Rotary hearth furnace |
| 2 | Charging machine |
| 3 | Centring machine |
| 4 | 3-roll rotary piercing mill |
| 5 | Mandrel bar and shell guide bed |
| 6 | Transfer grid |
| 7 | Roller table |
| 8 | Transfer |
| 9 | Dishing machine |
| 10 | Mandrel bar insertion devic |
| 11 | Push bench with rack guide bed bottle table and die bed. |
| 12 | Roller dies |
| 13 | Delivery roller table |
| 14 | Reeler |
| 15 | Transfer grid |
| 16 | Mandrel bar extractor |
| 17 | Mandrel bar store |
| 18 | Mandrel bar lubricating equipment |
| 19 | Heated mandrel bar table |
| 20 | Cropping saw |
| 21 | Reheating furnace |
| 22 | Stretch reducing mill |
| 23 | Delivery roller table and intermediate pockets |
| 24 | Cooling bed |

74.10.15