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

FAIR USE POLICY

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

05263

United Nations Industrial Development Organization

Distr.
LIMITED

ID/WG.146/80
13 June 1973

ORIGINAL: ENGLISH

Third Interregional Symposium
on the Iron and Steel Industry

Brasilia, Brazil, 14 - 21 October 1973

Agenda item 7

TECHNOLOGICAL IMPROVEMENTS IN ROLLING-MILL EQUIPMENT[1]

by

Jean Ficat
SECIM, France

[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. This document has been reproduced without formal editing.

id.73-4348

SUMMARY

The technological progress in the field of rolling-mill equipment over the past few years has resulted from the need to satisfy product quality requirements and also requirements of optimum plant profitability.

For this reason, in the non-flat rolled products field, apparatus for rapid changes of programme have been developed, together with finishing equipment that requires a smaller operator force, which leads to improvements in working conditions proper. Controlled cooling equipment, which produces superior metallurgical qualities in rounds especially, and more stringent control of rolled products at the finishing stage have had a considerable influence on the development of new equipment.

So far as flat rolled products are concerned, the development of automatic gauge control has led to greatly increased application of hydraulic equipment. Conventional electro-mechanical screwdown devices have been replaced by hydraulic screwdown, which permits precise control of the roll gap and thereby accurate regulation of the strip gauge. At the same time, hydraulic work-roll or backup-roll bending makes accurate control of product flatness possible.

These hydraulic processes are illustrated by describing a heavy plate mill of 4.300 m width which has been in operation with this equipment for some months.

Hot and cold strip mills are characterized by a significant increase in rolling power and speed, which has important effects on the size and type of materials used in these mills.

The quality requirements for flat-rolled products in terms of flatness have led to the development of a new type of mill, known as the stretch rolling mill, using which it is possible to level or to skin-pass at elongation rates that exceed the elastic limit of the metal without any danger of breaking the product.

Technological progress in the field of rolling mills has led to the application of automatic control, which calls in the assistance of the highest scientific displines - electrical, electronic, hydraulic, etc.

The operators needed to run plant of this kind have also developed in the same way to take account of this fact.

The quality requirements have resulted in corresponding demands for high quality in the operators of this type of equipment.

The traditional roller is increasingly being replaced by teams of specialist technicians. Paradoxically, personnel recruitment is perhaps somewhat easier, especially for countries without a traditional iron and steel industry and which are undertaking the establishment of this basic industry.

1. INTRODUCTION

An examination of improvements achieved during these last years in the field of transformation of ingots or continuous casting products into finished products shows that the objectives, which are at the origin of these improvements, may be classified in two main classes :

1.1 Necessity to satisfy imposed requirements on quality of finished products (regularity of sizes, flatness, good surface, high and constant mechanical properties).

1.2 Necessity to ensure the best capacity of the installations from an economic point of view.

The provision of better working conditions to operating personnel must be added to these two main conditions and will become more and more important in all countries, during the coming years.

The above conditions apply to projected new plants and to modernization of existing plants.

One must also notice that, contrary to steel melting and continuous casting equipments, it is difficult to speak of profound changes ges in processes, in the matter of rolling technology.

It would be a too great a task to make an exhaustive inventory of all technological improvements in the different types of rolling mills, which would necessitate the work of many experts. We shall only describe what we think to our manufacturer's view, to be the most important aspects of achieved technological improvements, in the field we know. We shall not cover finishing and processing lines of flat products.

2 [illegible]

2.1 Wire rod mills

Problems of size tolerances, good surface and low scale content, required for hot rolled wire, have made the equipments which produce this wire a particularly favourable field to researches and developments of many manufacturers.

Most of them have been studying and manufacturing finishing mills for more than 10 years, with the following characteristics :

. Multi-stands blocks, for one strand, with small roller discs (Ø 150 to 200 mm)

. Disposition at 90° of successive stands, avoiding twisting

. Overhanging roller discs allowing quick changing within a few minutes

. One common drive for several stands by cylindrical and bevel gears giving fixed reduction without spindles and couplings.

These equipments allow high speeds at the end of rolling (60 m/sec) owing to the high percentage of reduction permitted by small-diameter rollers. These finishing blocks are completed by coiling equipment allowing a controlled cooling of the rod reducing percentage of calamine to extremely low values.

Technological improvements on these mills are tending to give the user a possibility of speed variation between stands for mills producing alloyed steels, with the aim of reducing operating costs; for instance carbide rollers may be replaced by rings fitted in carbon steel hubs, this being particularly interesting for those countries that do not possess economical recovery devices of this expensive material.

However, a sophisticated wire-finishing mill such as those described above will not be able to produce a wire having close tolerances, if it does not receive an entering bar of a regular section from the preceding mill. It is for this purpose that stands of roughing mills and intermediate mills have been subject to studies in order to improve their rigidity :

. closed stands

. Prestressing hydraulic devices

(a stand of this type is shown on Fig. 1)

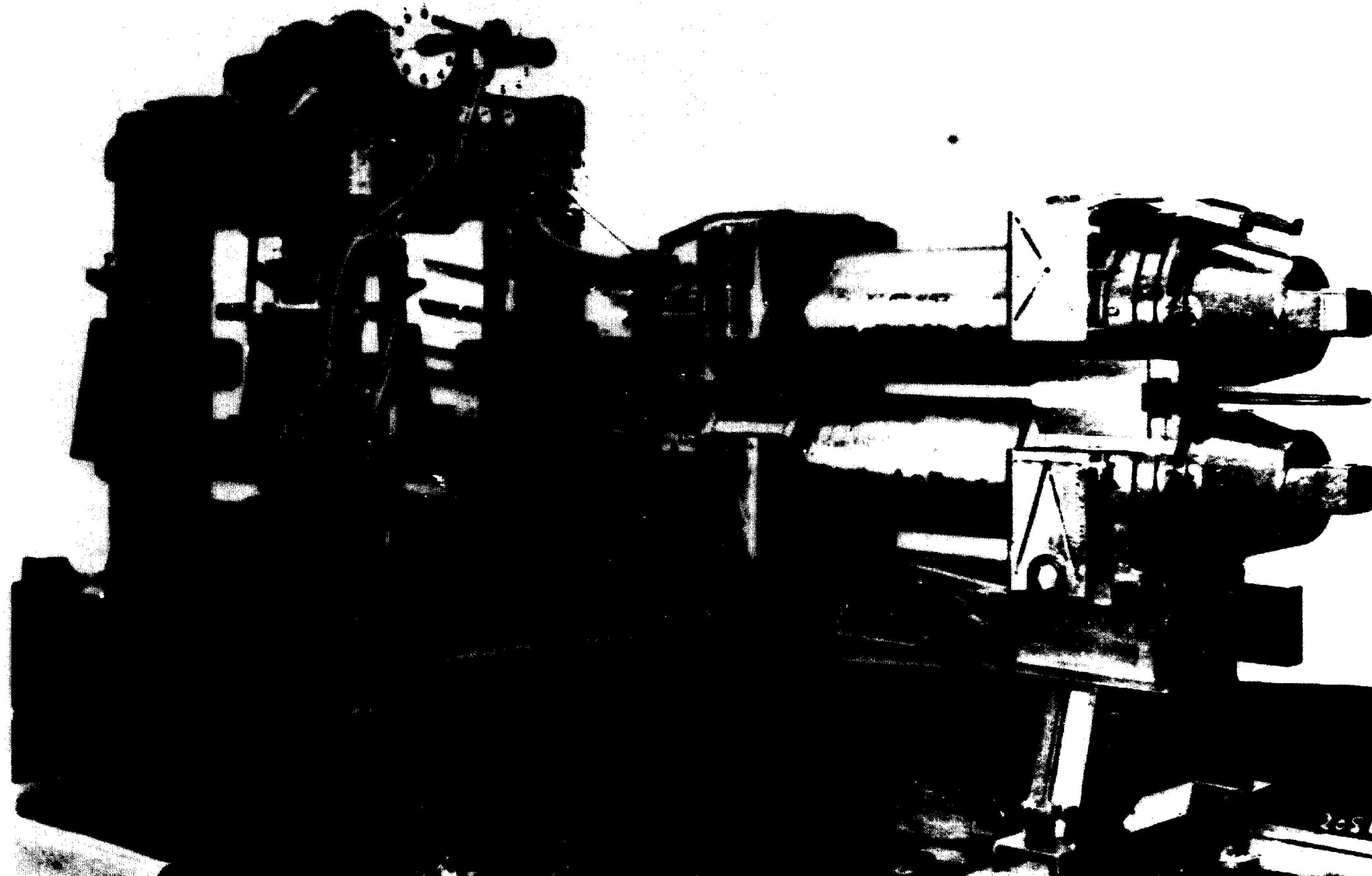


Fig. 1 - Prestressed rolling-mill stand

2.2 Merchant mills

Contrary to specialized rod mills, whose line of products is rather limited and includes often less than 10 products (Ø 5,5 to 18 mm), merchant mills are covering very large rolling programmes, in type of products as well as sizes. In order to meet this characteristic, everything must be set to effect a change of the programme as quickly as possible ; so complete automatic devices for changing stands have been developed. These devices allow to shift a complete stand outside the line by hydraulically or mechanically driven equipment in order to bring it on a conveyor parallel to the longitudinal centerline of the mill. This conveyor, which has been equipped with new stands corresponding to the new rolling programme, is then shifted as a whole to bring the new stands in the position to be inserted in the pass-line. Guides and rest bars are mounted on mill housings and are pre-aligned with rolls.

A lay-out as represented on Fig. 2 involves particular mechanical equipments such as :

. Spindles automatic couplings

. Roll stand positionning locking device.

(See Fig. 3 and 4).

Stands are of the conventional type, horizontal or vertical, pre-stressing being also used on this kind of mill with a research in order to simplify realisations already known at the present.

Flying shears before cooling may allow a perfect cut of profiles and are, in this purpose, of the parallel cut type. Shear of Fig. 5 answers to this condition and incorporates a so-called "with miscut" device, which permits reduction of the installed electrical power.

Cooling beds, of rack-type, are fitted with automatic devices to align billet front ends. They may be single or double, or single with possibility of 2-bar entry, as shown on Fig. 6.

Finishing equipments for merchant mills have been subject to many improvements during the last 15 years and installations for counting, piling up, and bundling of bars and profiles become general after a rather long period of improvement. This is obviously in this field that savings in manpower and improvements of personnel working conditions are the most spectacular.

A study of working shift and profiles piling using a piling machine as shown of Fig. 7 is given in the schedule of Fig. 8.

Fig. 2 - Automatic roll-stand changing device

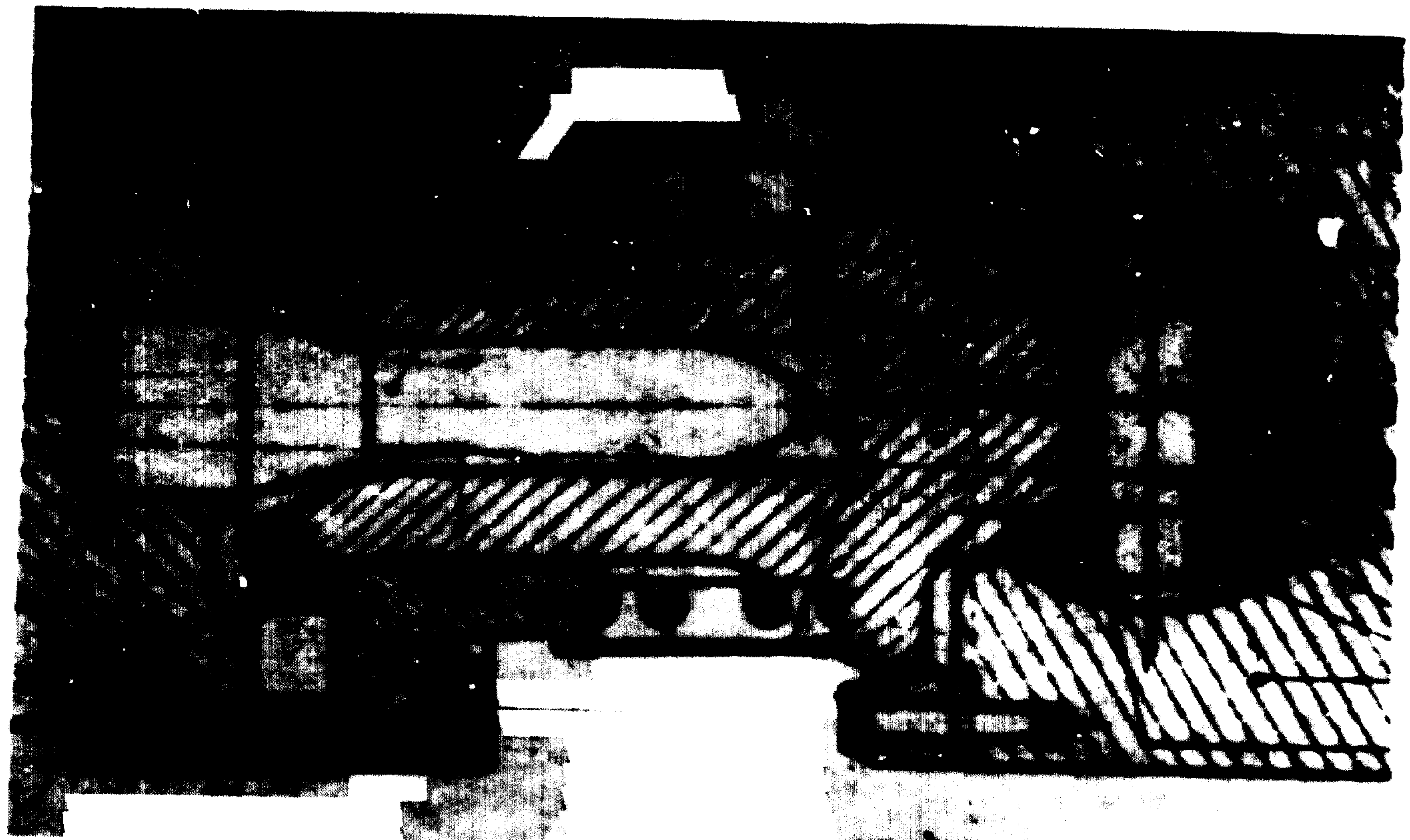


Fig. 3 – **Spindle** automatic coupling

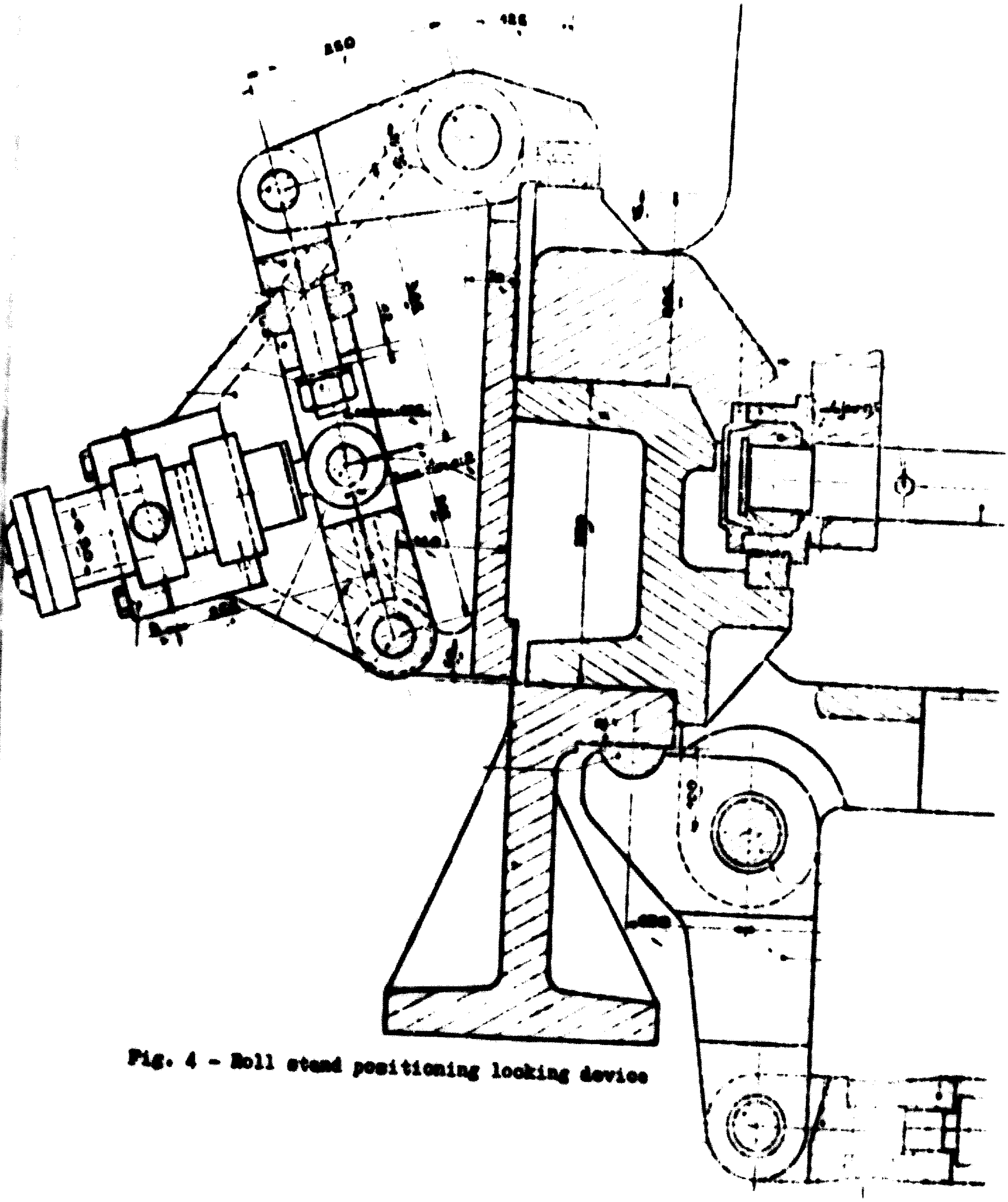


Fig. 4 - Roll stand positioning looking device

Fig. 5 - Flying shear on merchant bar mill

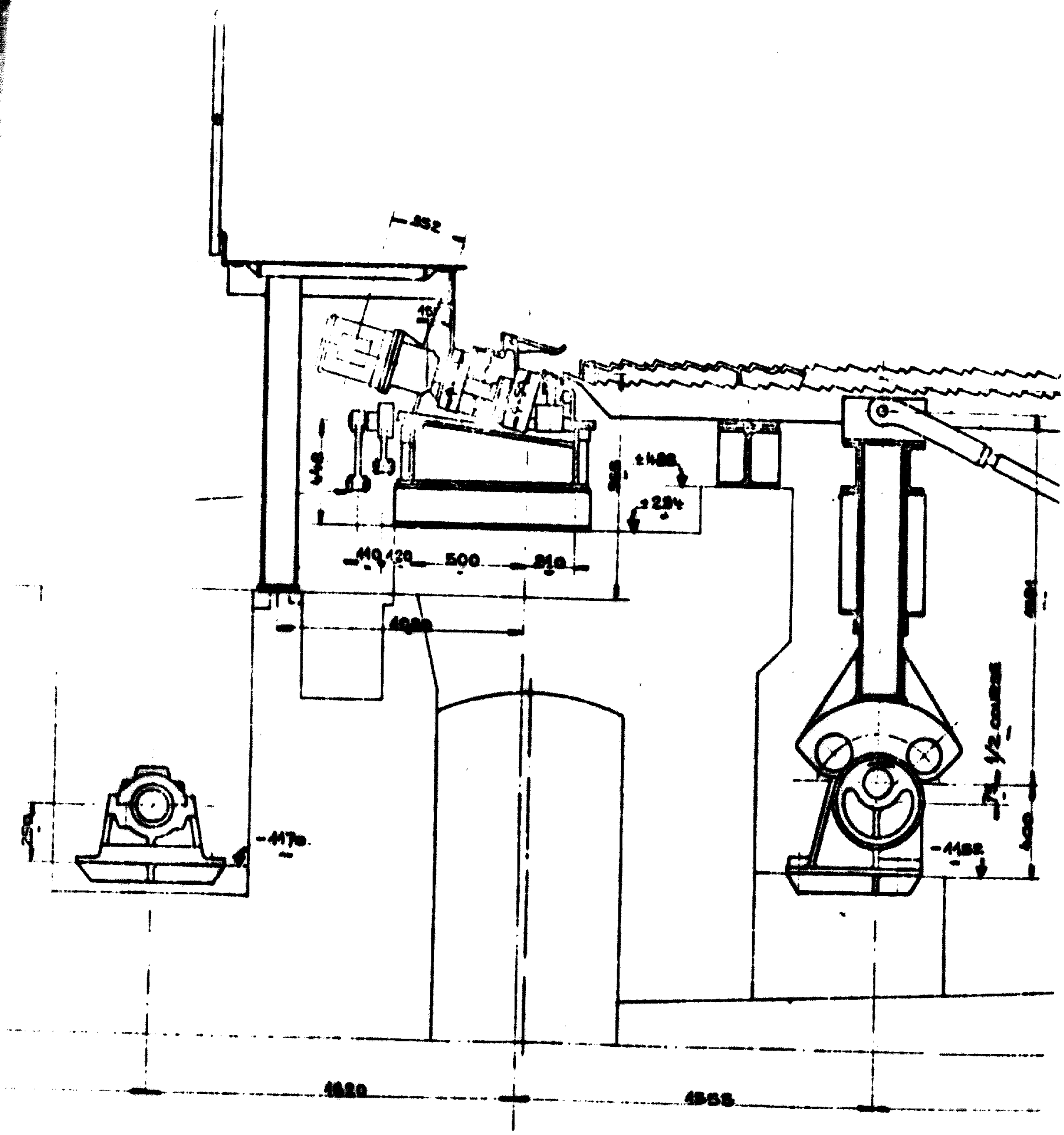


Fig. 6 - Double-entry cooling bed (cross-sectional arrangement)

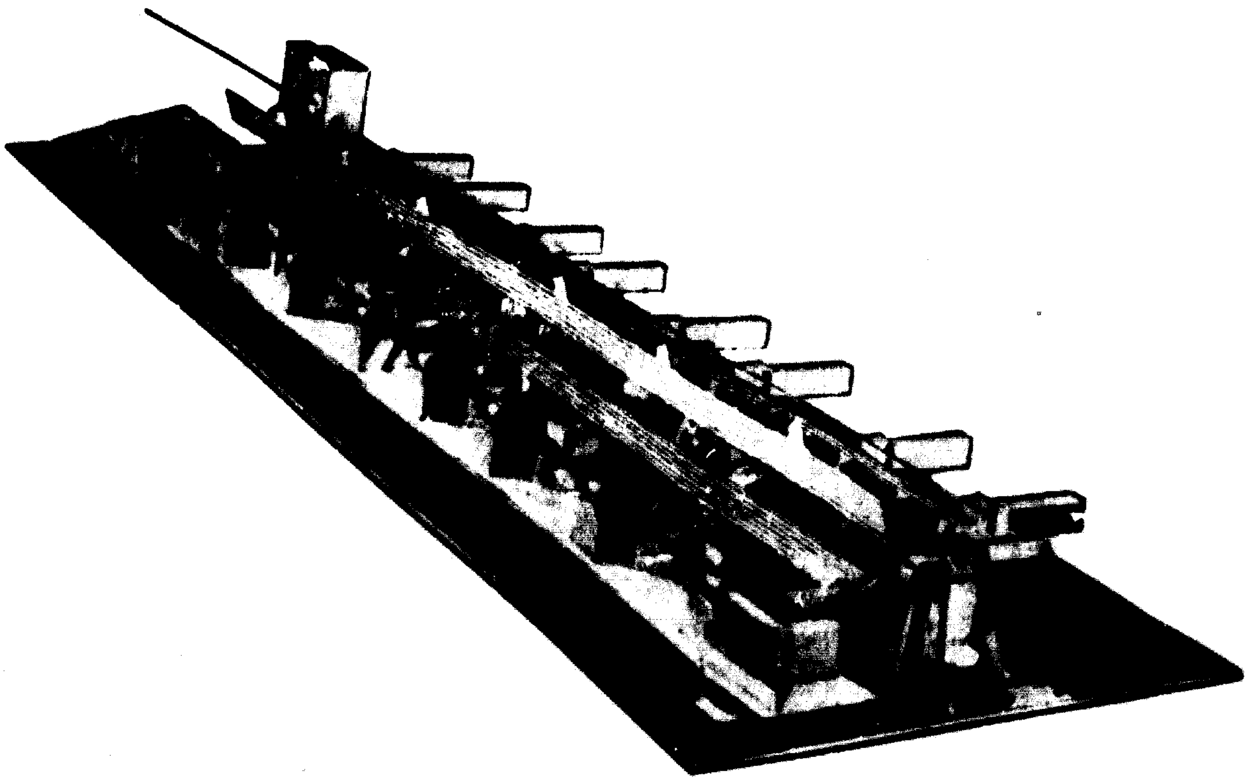


Fig. 7 - Automatic stacking machine for structurals

MANUAL FINISHING		SEMI-AUTOMATIC FINISHING	
Personnel qualification	Number	Personnel qualification	Number
- Foreman	1	- Foreman	1
- Foreman assistant	1	- Foreman assistant	1
- Crane operator (for straighteners entry)	1	- Crane operator (for delivery side)	1
- Crane operator (for straightener delivery)	1	- Secondary cooling bed supervisor	1
- Bundle hooker	2	- Bundle hooker	1
- 1st Straightener operators	6	- Straightener operator	1
- 2nd Straightener operators	6		
- Binders	6	- Binders	4
- Saw operators	1	- Saw operator	1
* Total	25	* Total	11

FIG. 8

COMPARISON BETWEEN MANUAL BAR FINISHING AND SEMI-AUTOMATIC FINISHING USING AUTOMATIC PILER AND CONTINUOUS STRAIGHTENING

* Above figures are valid for one shift.

Other finishing units have been subject to improvements in order to keep pace with high productions of the latest merchant mills. In that manner, straighteners allowing straightening up to 10 m/sec. have been built and machines permitting simultaneous straightening of 2 or more bars are being studied.

2.3 Billet mills

It seems interesting to give some details on mills allowing production of semi-finished products to be rolled on merchant mills described above, because modern mills of this type allowing high productions (of about 5 million ton/year) show some important technological features.

In this field also, research of product quality imposes the development of sophisticated rolling equipments as vertical or horizontal stands with roll necks on roller bearings mounted in rigid frames and hydraulic balances. At the same time, high productions impose roll quick-changing devices.

Conventional -type cooling beds or water cooling by immersion of billets require large areas as well as inspection and control installations which have been, too, subject to many improvements.

The mill whose lay-out is given in Fig. 9 allows a production of 4.5 million tons for products ranging from 60 x 60 mm to 130 x 130 mm.

Fig. 10 gives an example of lay-out of control equipments including :

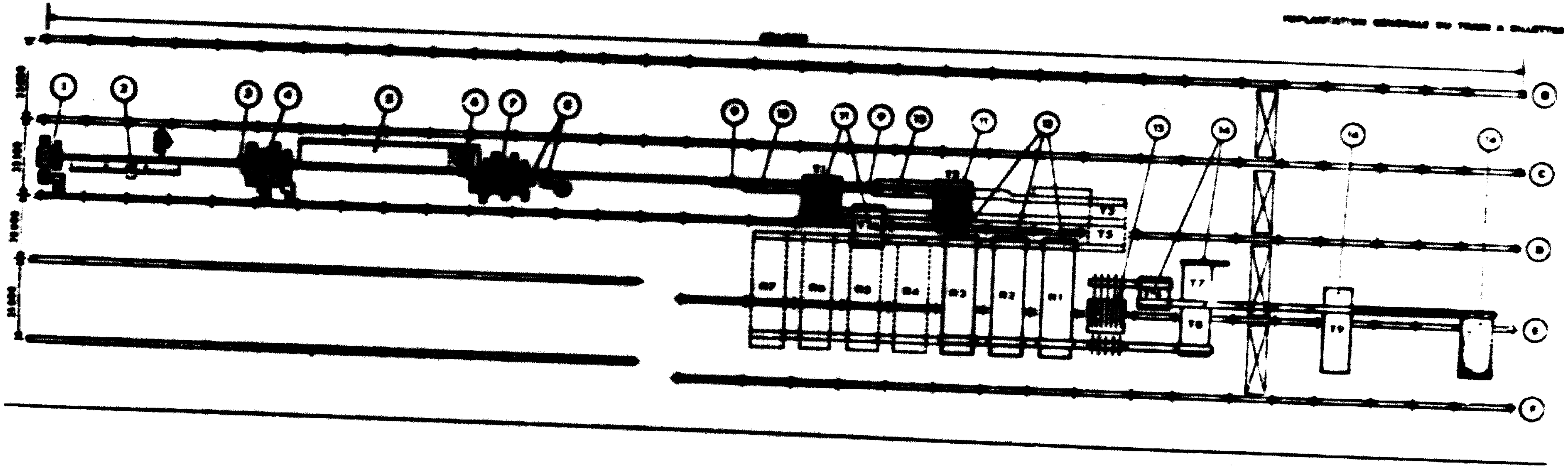
. Cooling bed run-out tables

. Inspection and repairing line including :

- Feeding tables
- Visual inspection in-line
- Ultra-sonic control
- Marking of products before repairing
- Repairing station

. Run-out tables

The plant shown is capable to handle 700.000t/year of billets in 6000 h.



Légende

1 Intermediate rolling mill - Stands No. I-1 V & I-2 H
2 Scarfing machine
3 Billet turner
4 Roughing rolling mill - Stands No. 1V-2H-3V-4H
5 Semi-products runout transfer (future)
6 Reciprocating shear
7 Finishing rolling mill - Stands No. 5V-6H-7V-8H-9V-10H

8 Pinch rolls and dividing flying shear
9 No. 1 and No. 2 billet switches
10 No. 1 and No. 2 gathering tables
11 Delivery transfers T1 - T2 - T4 b's (T3 and T5 future)
12 Air cooling beds R1 - R2 - R3 (R4 - R5 - R6 - R7 future)
13 Water cooling bed
14 Dispatching and runout transfers T6 - T7 - T8 - T9 - T10

1re phase
2e phase

Fig. 9 - High-production billet mill

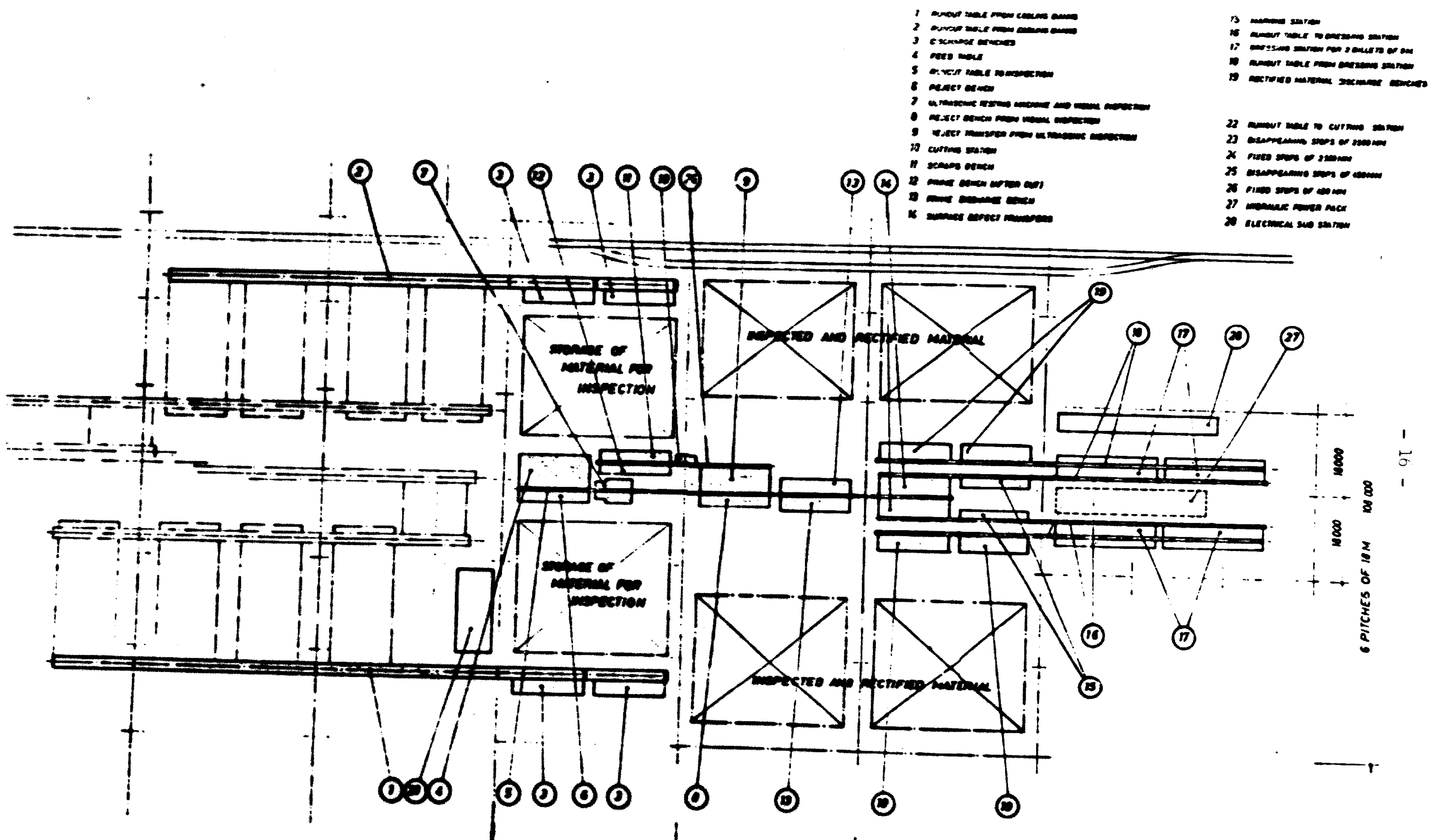


Fig. 10 - Continuous billet mill, finishing end, general arrangement

3. FLAT PRODUCTS MILLS

It is in this field that quality requirements have become greater and have involved modifications and technological improvements of rolling-mill equipments.

The most significant feature in this area is undoubtedly the development of automatic gauge control and back-up roll bending systems inducing widely the application of hydraulic devices.

These hydraulic devices which were used for screw-down purposes more than 30 years ago for the first time are now in use for all types of rolling mill for steel or non-ferrous including :

. Plate mills
. Hot strip mills
. Tandem cold mills
. Reversing cold and hot mills

We shall describe first the advantages of hydraulic screw-downs compared to conventional electro-mechanical screw-downs and, after description of a back-up roll bending system, we shall give the features of a 4.300 mm reversing plate mill :

3.1 Description of A.G.C. on "hydraulic mills"

The hydraulic screw-down consists of hydraulic force cylinders mounted at the top of the mill window between the top screw-down and the top back-up chucks, or on the bottom part of the mill window, between the bottom and the bottom back-up chucks. Also mounted between screw-down and the force cylinders or between bottom back-up chucks and cylinders are load cells which measure the actual rolling load on the mill.

Fastened to the force cylinders are position transducers commonly called L.V.D.T.'s(Linear Variable Differential Transformers) which are used to measure accurately any movement between the cylinder piston and the cylinder rolls. Since the mill-stand mechanical parts act as a spring when they are subjected to a rolling load, the actual mill stretch at any instant is accurately recorded by means of the load cells reading as related to the mill stiffness. In operation, the system accurately measures the variations in mill stretch which is synonymous with off-gauge strip and accurately moves the hydraulic force cylinder an equal and opposite amount to maintain a fixed roll gap and produces very accurate strip gauge. The movement of force cylinder is actuated by servo-valves which transform the electric signals in oil flow,so permitting the accurate control of the position of the hydraulic force cylinders. Development of these servo-valves has been considerably extended during the last years; the first applications were developed in the aircraft industry. It can be stated now that the servo-valves have a very high standard of reliability and they will extend to many new areas of application in the field of rolling-mill equipment (See Fig. 11).

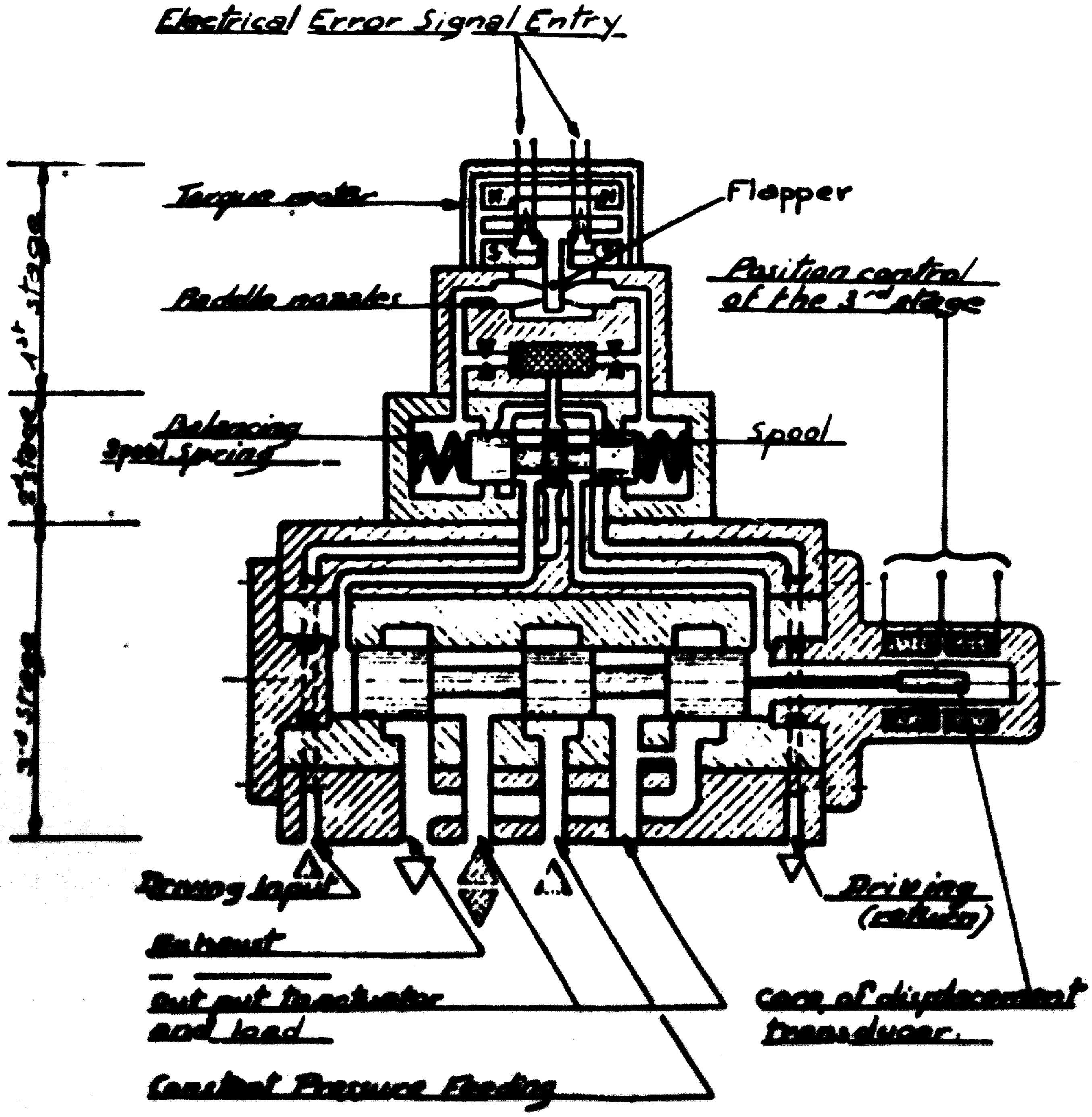


Fig. 11 - three-stage electrohydraulic servo-valve

The hydraulic screw-down with A.G.C. offers the following advantages :

1. Hydraulic screw-downs are up to 10 times faster than electro-mechanical screw-downs,

2. Acceleration rates of hydraulic screw-downs are more than 150 times faster that those of electro-mechanical screw-downs,

3. Response times of hydraulic screw-downs with servo-valves are faster than those of electro-mechanical screw-downs,

4. hydraulic screw-downs give the possibility of two different modes of operation :

   a) automatic gauge control operation
   b) hydraulic constant roll-pressure operation

5. The hydraulic screw-down allows a pre-setting of roll gap to the desired thickness,

6. The mill modulus can be adjusted to compensate for back-up roll diameter and strip width to be rolled,

7. The variation of equivalent mill modulus can be set to any value from infinity to zero,

8. The compensation for speed effects (acceleration or deceleration) or for oil-film thickness (when oil-film bearings are used for back-up rolls) is automatically achieved,

9. Automatic zeroing of roll gap and roll leveling is automatically achieved, this allowing a compensation for mill thermal changes,

10. The hydraulic screw-down gives the possibility of quick roll opening for emergency.

Hydraulic screw-down and A.G.C. schematic is given on Fig. 12.

The necessary hydraulic power unit which is used for all the stands, when used on tandem mills includes :

. 1 stainless-steel reservoir for mineral oil
. 2 variable-volume pumps (one operating and one stand-by)
. all the necessary control equipments for pressure and safety
. 1 heat exchanger with regulating valve
. 1 filter unit

All the above equipments to be mounted and piped with stainless-steel pipes and fittings on a common steel base.

Each mill stand is equipped with

. 2 accumulators nitrogen charged
. 4 servo-valves (2 operating and 2 stand-by)
. Pressure and safety control equipments.

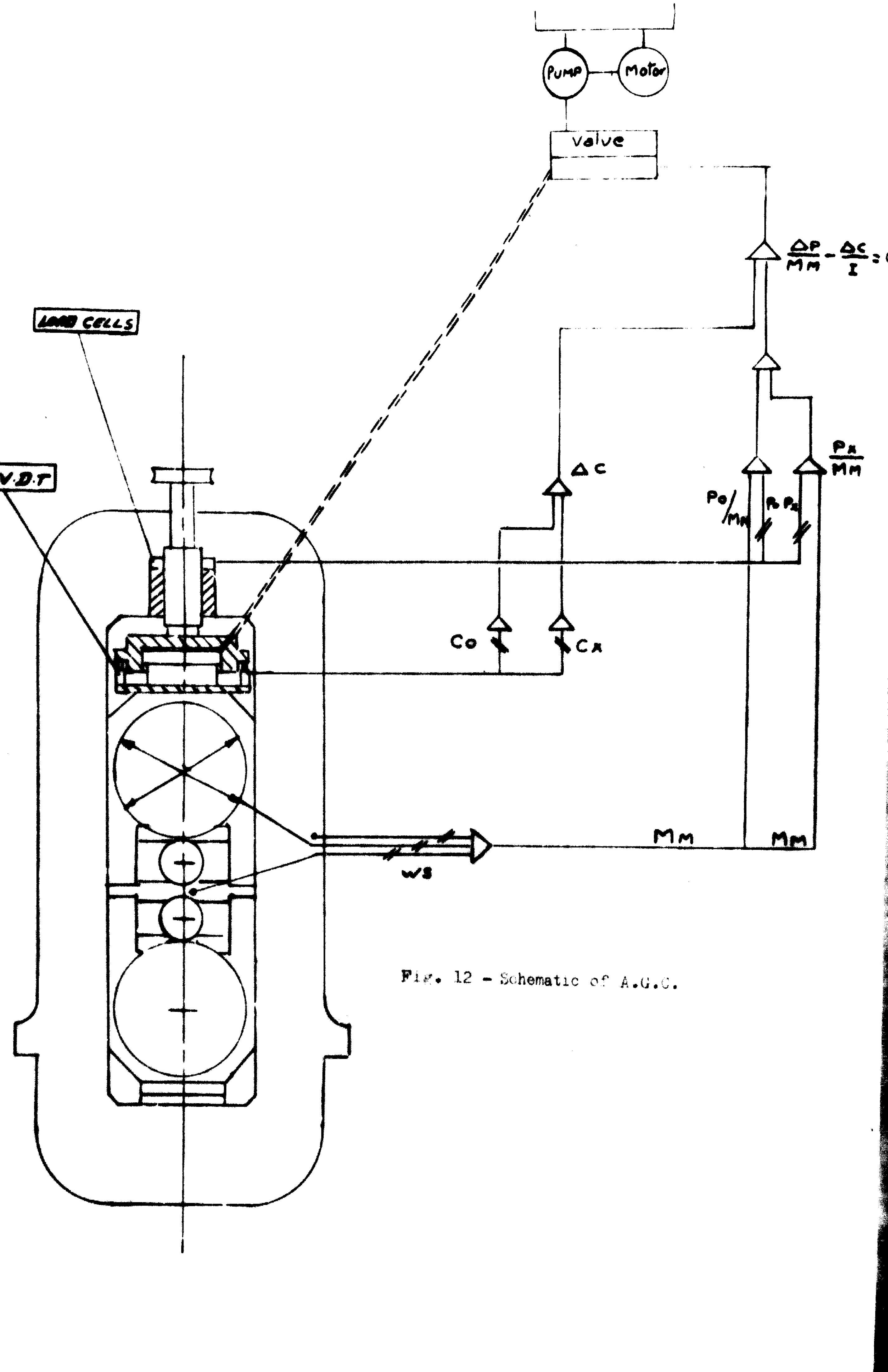


Fig. 12 - Schematic of A.G.C.

- -

3.2 Description of back-up roll bending equipment

On 4-high mills used for medium-size strip, in which the ratio between back-up roll diameter and width of the material to be rolled is rather high, it is relatively easy to compensate for deflexion of rolls in varying the balance pressure of the work rolls. This pressure variation will change the form of the working rolls, giving the operators a better control of flatness. For the rolling mills which are used for wider products such as hot plate mills, the efficacity of the work-roll bending system becomes quickly very poor. As a matter of fact, the back-up roll modulus of inertia will strongly limit the deflection of the work-rolls and will lead to a bending on the edges of these rolls. Hydraulic cylinders acting directly on the back-up rolls will compensate the deflection with efficiency.

It must be pointed out that secondary effects of the bending of rolls consist of a change in the roll gap on the width of the plate. Any variation in the back-up roll bending involves a change in the roll gap and a change on the thickness of the plate. The A.G.C. previously described must react and compensate this secondary effect.

Back-up roll bending consists of two vertical-force cylinders acting on extensions of back-up roll trunnions. In order to avoid that back-up roll bending forces load the screws of the mill housings, reaction beams both at the top and bottom of the housing windows are used. Fig. 13 shows this type of construction.

As indicated above, the effects of back-up roll bending must be compensated by the hydraulic screw-downs to be compensate the change on gauge. This compensation involves accurate mathematic models and computers.

A complete system has been realized and is in operation on a wide hot plate mill.

3.3 Automatic gauge control on a hot reversing 4-high mill 4300 mm wide

3.3.1 Plate mill characteristics

- Back-up roll diameter	2 150 mm
- Work roll diameter	1 120 mm
- Roll barrel length	4 300 mm
- Maximum rolling pressure	9 000 t
- Maximum bending load on back-up rolls . . .	1 365 t each side
- Maximum entry thickness	1 000 mm
- Minimum delivery thickness	4,5 mm

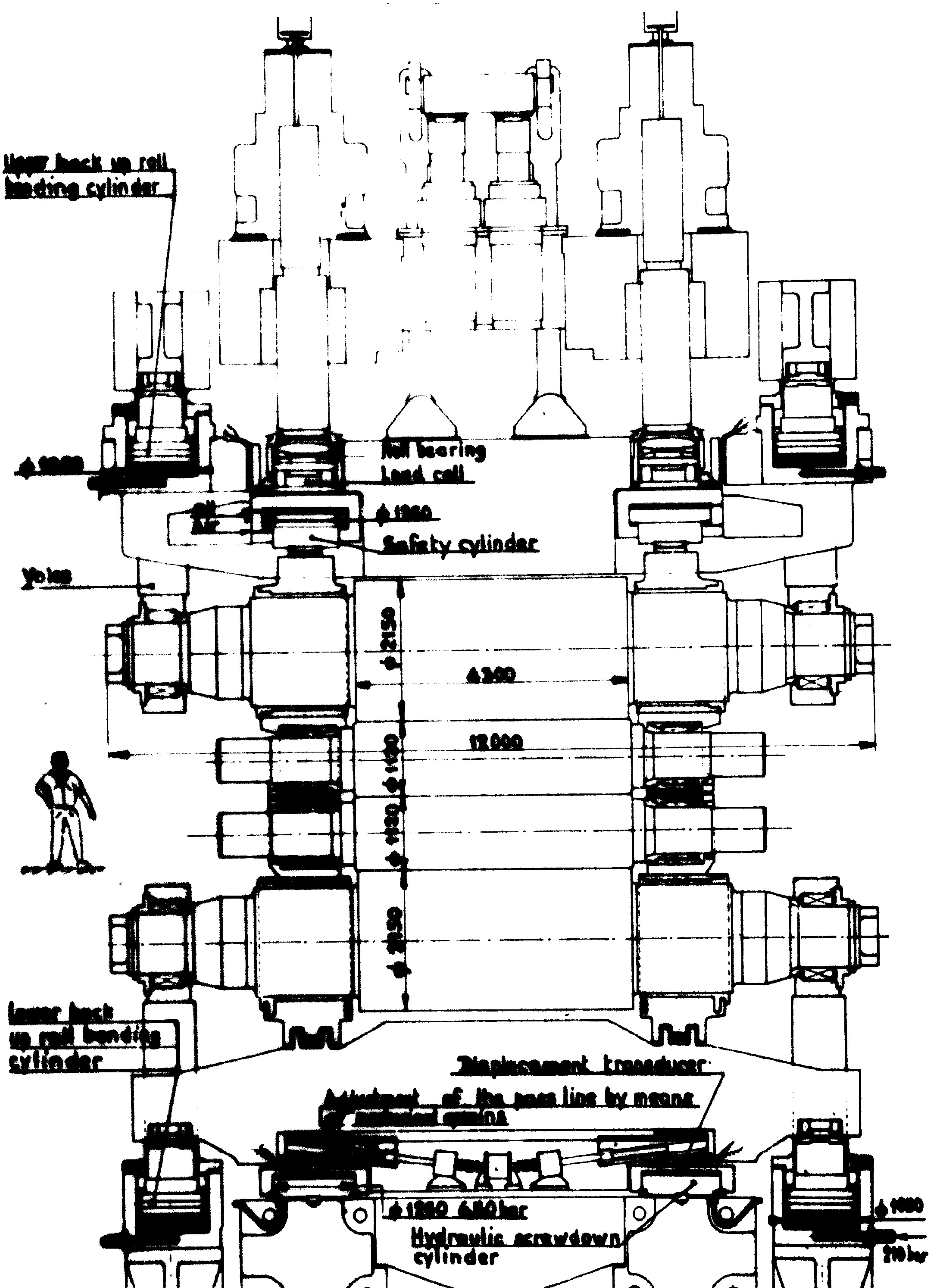


Fig. [illegible] - Cross-sectional arrangement of 4.[illegible] m plate mill

- Minimum plate width . . . . 1 000 mm
- Maximum plate width . . . . 4 000 mm
- Maximum speed . . . . 6 m/sec.

(See Fig. 13)

3.3.2 Corrections realized

1 - COMPENSATION OF DEFLEXIONS WITH 2 POSSIBLE OPERATING MODES.

. Desired thickness : the device compensates the total deflexion according to the actual rolling pressure in order to get a determined thickness.

. Constant thickness : The device compensates the deflexion according to the actual rolling pressure with regard to the pressure which is preset.

The computer gives a position order to the force cylinders equal to the calculated deflexion, taking into consideration deflexion changes due to back-up roll bending and oil film thickness.

2 - VARIATION OF BACK-UP ROLL BENDING (BURB)

The load for necessary bending of rolls is determined according to the rolling pressure and the mechanical crown of the rolls, this bending load being calculated according to 2 principles identical to A.G.C.

. Automatic : The device gives the correct crown allowing the transversal thickness constant.

. Regular : The device gives the regulation of the regulation of the crown according to the shape of the plate at the entry side.

3 - SECURITY ON BEARINGS OVERLOAD

When operating with BURB, if the overload limit is obtained, the computer decreases the bending load up to zero before opening the servo-valves to disengage the circuit (50 mm opening in 1/100 sec.).

3.3.3 Mathematic model

The equations used for deflexion calculations are the classic equations used in materials strength studies. They include :

- One constant coefficient for deflexion of parts according to Hooke's Law (mill stand).

- Equations taking into consideration roll diameters, strip widths for roll deflexions.

The equations give the possibility to control and regulate the thickness on the edges of the plate.

All the equations include 21 coefficients functions of characteristics of the mill which have been determined after commissioning.

This great number of coefficients is due to the size of the rolling mill.

3.3.4 <u>Equipment</u>

1 - POWER UNITS

Total capacity :

- screw-down 3 x 45 kW
- BURB 2 x 90 kW

Each force cylinder is driven through a Triplex servo-valve, with cut off frequency of 25 Hz.

- 2 for screw-down, which are used as position regulation
- 4 for the BURB, which are used in pressure regulation

2 - DATAS EQUIPMENT

- 1 Calculator "DIGITAL-EQUIPMENT" with 4K memory words.
- 1 Convertor numeric-analogue at entry.

ACCURACY AND TIME OF CALCULATION :

. The accuracy of the calculation for position control of force cylinder is 1/100 mm.

. Time for calculation is 5 mls.

. Screw-down signals can be sent with a frequency between 1 and 20 Hz.

3 - INFORMATION SENSORS

- Rolling load given by pressure sensors or load cells.
- Force cylinder position given by L.V.D.T.

Fig. 14 - Hot reversing heavy plate mill

3.3.5 Fig. 13 and picture on Fig. 14 give a good idea of the important technological modifications induced by the hydraulic mechanisms compared to the conventional construction of plate mill stands. It must be noted that the weight of each stand is above 450 t and for that reason type of construction is special. As a matter of fact, each stand consists of 4 parts assembled by pre-stressed bolts. This type of construction was adopted due to the difficulty to obtain so heavy cast-iron pieces and, also, to the difficulty in transportation of such heavy parts.

The picture on Fig. 15 shows the control panel of the plate mill operator.

3.3.6 Results

The guaranteed tolerances on this plate mill is ± 0.1 mm. This result corresponds at approximately half of the tolerances obtained on convention mills.

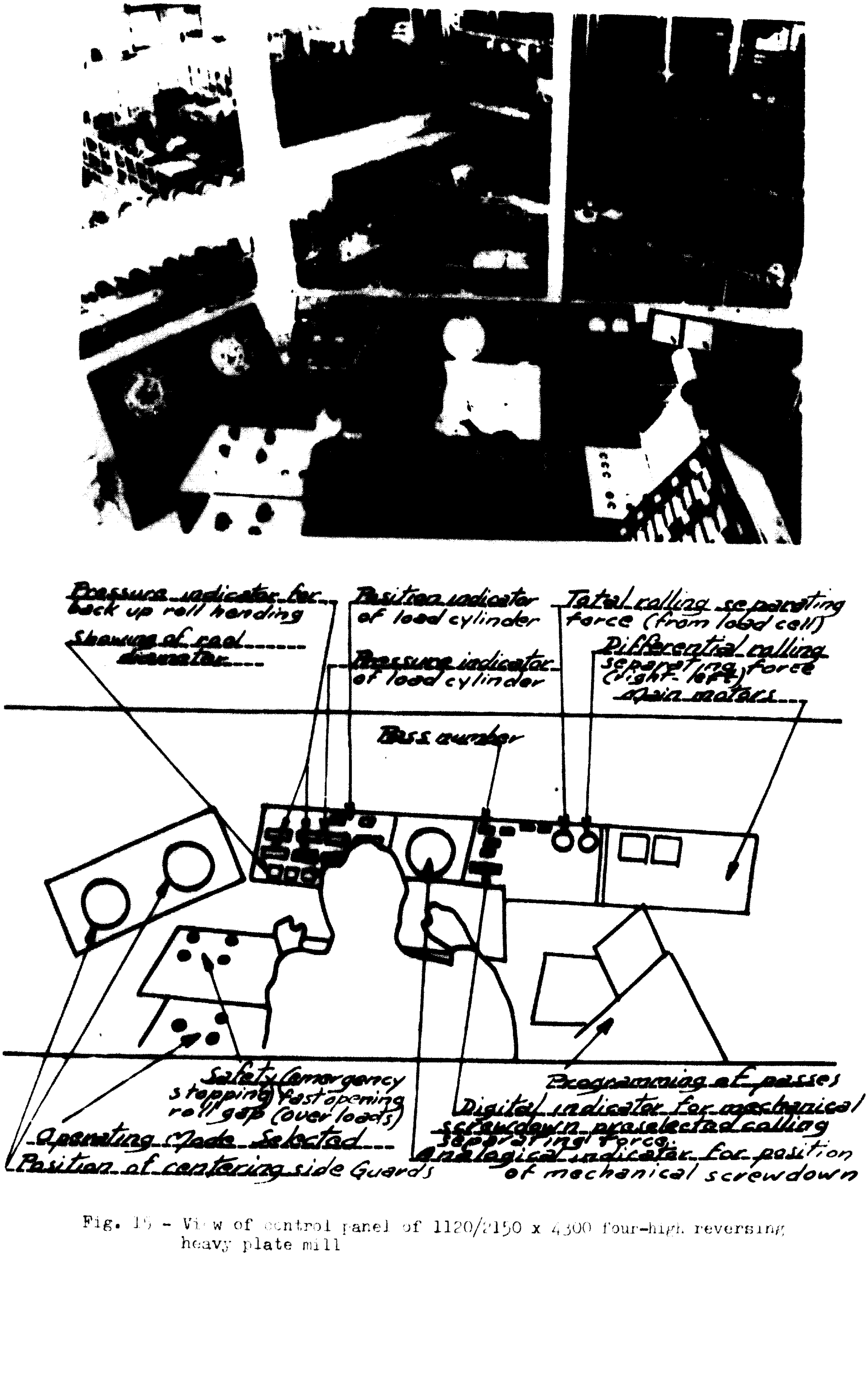


Fig. 15 - View of control panel of 1120/2150 x 4300 four-high reversing heavy plate mill

3.4 Hot strip mill

Same demands in quality on finished products concerning thickness regularity, flatness, and desired thickness corresponding to the lowest part of the tolerances gap combined with the need to obtain high productions have lead to important technological changes in this field of hot strip mills.

The application of hydraulic screwdowns with A.G.C. and BURB installed at the last stand of the finisher allows a possibility to obtain the same advantages as for plate mills with, in addition, the following benefits :

The present techniques of rolling wide strip are limited in speed in the finishing trains by the accurate control of temperature along the strip. As a matter of fact, the speed-up mode of operation allows the possibility to roll longer strip by compensation of the strip cooling before the entry into the first finishing stand but it allows also to maintain uniform temperature throughout the length of the strip. Uniform temperature means uniform pressure in the strip and, therefore, uniform gauge results.

Mill horse-powers are selected on finishing train for maximum width and average gauges. Therefore, the mill has plenty of horsepower to roll narrower width at much higher speeds. However, these speeds are limited by the zoom rolling technique. This possibility of zoom rolling is the factor limiting, in fact, the production of the mill. The finishing mill equipped with hydraulic A.G.C. has much better performances as compared to conventional screw-down and this gives the possibility to make the correction for hot or cold marks plus the correction for temperature variations front to back of the strip resulting from a rolling without speed-up or zoom technique.

3.4.1 The technological improvements have been spectacular in the field of increase in powers and increase in rolling speed of finishing mills, this being due to improvement in the engineering and manufacture of gear drives, pinion stands and spindles. The table here-under shows the importance of diffèrence between two hot strip mills installed in France at 10 years interval.

STANDS	USINOR DUNKERQUE (1963)*		SOLMER (1973)*	
	HP	Rolling speed m/s	HP	Rolling speed m/s
F 1	8000	0,95/2,45	12600	1,21/2,78
F 2	8000	1,6 /4,12	12600	2,08/4,80
F 3	8000	2,45/6,3	12600	3,4 /7,80
F 4	8000	3,7 /10	12600	5,1 /11,7
F 5	8000	4,7 /12,2	12600	8/18,4
F 6	8000	6,4 /17	12600	11,2/25,8
F 7	5300	6,4 /17	1200	13,4/30,8

* Year of installation

The manufacture of large gears has appreciably progressed thanks to welding techniques concerning alloy steel, nickel chromium-molybdenum type at low carbon content having high mechanical properties and with the possibility of gear cutting in good conditions in using modern gear cutters.

The gear-type spindles are made for the active part (gears cut).

3.4.2 The quick work-roll changing systems are now provided for from the beginning of the construction of the modern strip mill and the adaptation of this equipment on existing trains is developing. The hot strip mill built in 1963 of the above table has been transformed in 1972 and equipped with such equipment giving the possibility to decrease the necessary time for roll changing of the complete 7 stands from 35 to 40 mn down to 15 mn in manual operation and to 7 mn in automatic operation.

The equipment consists, for each stand, of :

- one system for quick retracting of thrust roller bearings located under the screws
- one sledge on which the complete set of work rolls and work chucks is located
- one set of removable rails located in each stand
- one system for pushing and pulling the set of rolls

One movable platform, which is made of several cars connected altogether, located in front of the finishing stands parallel to the rolling pass line, on operator's side. This platform will receive the worn set of rolls and the new set and, by transfer, will bring it in the suitable position for changing. A section of such a device is shown on Fig. 16.

3.4.3 It must be noted the constant increase in hot coiler capacity with regard to the maximum thickness (up to 15 mm) and of nature of the strip to be coiled which have higher and higher mechanical characteristics (X63 grade for pipes).

The possibility of rolling thinner and thinner material (1,2 mm, 1 mm or even 0,8 mm) has led to the provision of a set of coilers close to the last stand of the finishing mill in order to avoid the possible difficulties during the transport of the thin strip to the coilers which are normally located at approximately 185 m of the last stand for coiling thicker material. This arrangement allows also to use the zoom rolling technique sooner and, therefore, the possibility to increase the production of thinner materials.

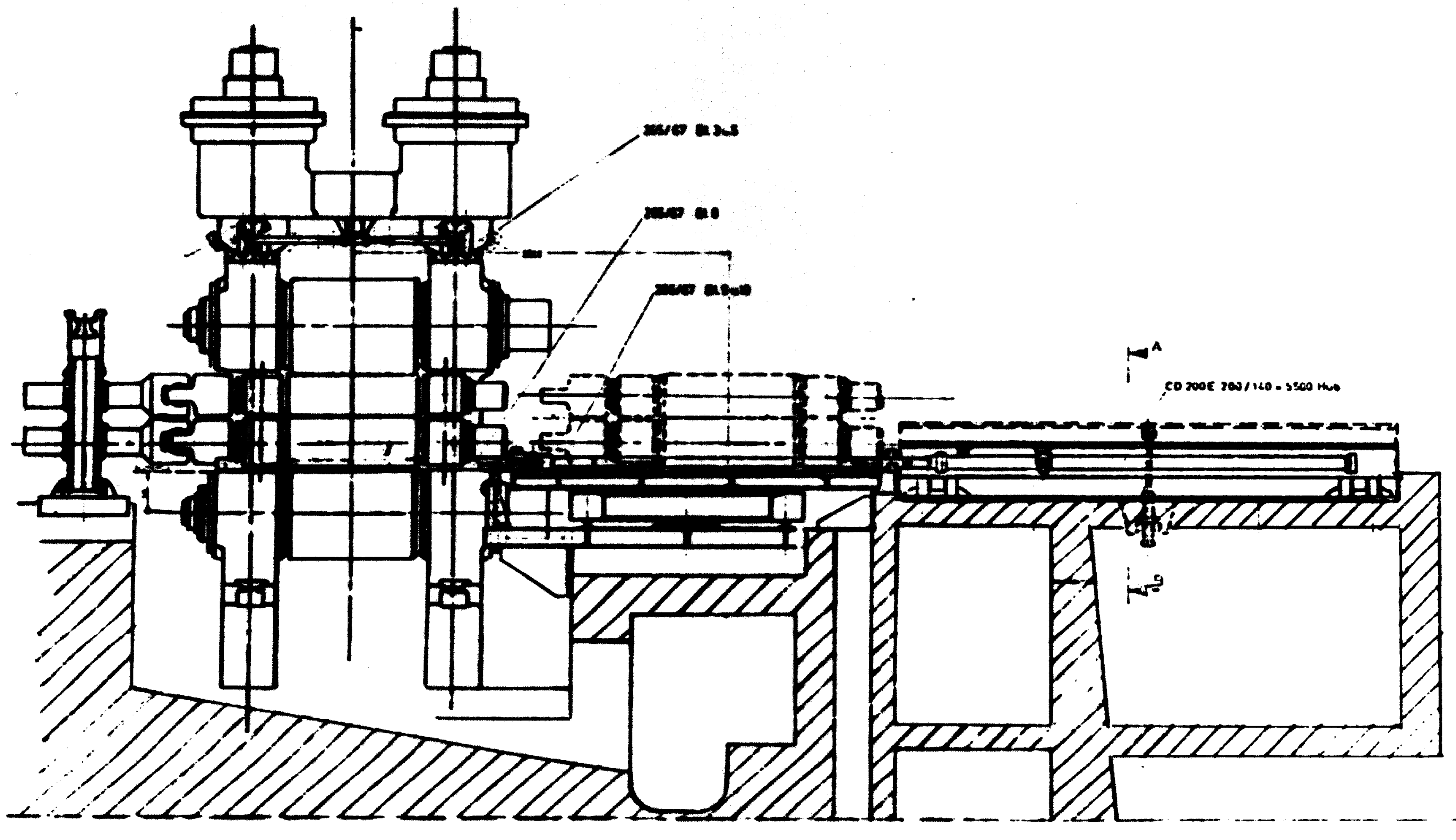


Fig. 16 - Rapid work-roll changing rig

3.5 Cold mills

Two additional quality conditions are requested for cold-rolled strip : cleanness and good surface conditions.

Thickness tolerances are more and more severe on products whose thickness has a tendency to decrease, this tendency applying to cold-rolled sheets and tin-plate stocks.

The technological consequence on tandem cold mills or reversing cold mills are :

- generalisation of hydraulic screw-downs and A.G.C. which has been previously described
- development of work-roll bending systems
- construction of two-stand tandem skin-pass mills for thin tin-plate production, called D.C.R. (Double Cold Reduction)
- the increase in production of cold mills induced an increase in coil weight and and increase in capacity for entry and delivery equipment, an increase in horse-power installed and speeds with, therefore, the corresponding development of cooling and lubrication of strips during rolling.

Finally the automatic changing ring systems for work rolls are practically always installed at the beginning in the new cold mills.

Automation of coil entry, coil preparation and coil delivery is developed in the new cold mills with a great care to avoid any coil slipping which could provoke damage of the surface of the strip.

Flatness conditions and the difficulty to measure it have led to research on flatness measuring devices which are not yet fully developed and used.

Particular mention must be made concerning flatness of the spectacular development of the stretch rolling mill used either in skin-pass or in stretching lines or galvanizing lines.

TECHNOLOGICAL DESCRIPTION

The basic equipment consists of two tension bridles arranged on each side of a temper mill and/or of a tension leveller. These bridles are mechanically connected by means of a kinematic circuitry capable of maintaining a given speed ratio at a constant value in such a way that :

$$\frac{S2 - S1}{S1} = \text{constant} = \text{theoretical elongation}$$

S1 = Entry bridle speed
S2 = Exit bridle speed

It is worthwhile to note that the actual elongation of the material processed is less than the theoretical elongation, particularly due to the elastic properties of the material.

The prototype was equipped with a mechanical connection consisting of a chain transmission, and the speed ratio between the two tension bridles was adjusted by changing the pinions. Afterwards this arrangement was replaced by a gear connection and the speed ratio was adjusted by varying the gear distribution. However, in both these cases, preset elongations were imposed and the machine should be stopped when changing the elongation value.

The machines are now equipped with a kinematic circuitry using the effect of the differential unit or of the planetary gear train.

The elongation value is adjusted by varying the speed of the differential gear or the speed of the planetary sun gear. These latters are driven from the main drive either through a mechanical speed variator or through an hydrostatic system.

Owing to this arrangement, a constant speed ratio can be maintained between the two tension bridles, irrespective of the speed of the machine ; a great stability is ensured to the system during the transient periods of acceleration and deceleration.

Whenever permitted by the torque to be transmitted, the mechanical speed variator is to be preferred to the hydrostatic system as it provides a better stability of adjustment. The adjustment accuracy is, however, very good in both the cases as it is of about 2 % of the value selected ; as an example, a preset elongation of 1.5 % will be maintained at a stable value from 1.53 to 1.47 % and this result is far accurate than what may be expected with conventional levellers.

- . -

Thanks to the devices mentioned, settings can be made while the machine is running and any elongation value can be selected from zero to the design limit of the machine. The tension levellers are generally designed to operate within a range of 0 to 3 % while, in the case of temper mills or combination temper mills and levellers, the elongation value can reach 60 %.

When the machine is operated as a leveller, the tension bridles are driven and, in turn, they drive the strip through the levelling stands. As the rolls of this stand are not driven, they are submitted to less wear and the marks which are generally produced by conventional levellers on the strip surface are eliminated. Likewise, the roll change is very fast (about 1 mn).

When the machine is operated as a temper mill or as a combination stand, the rolls are driven and it is possible to drive a single roll or the two rolls, depending upon the torque to be transmitted. The strip drives the entry tension bridle which, in turn, drives the exit bridle through the kinematic circuitry.

It is to be noted that for some specific applications, the rolls and the tension bridles are simultaneously driven from two different power sources. This arrangement is used when the entire power required cannot be transmitted through the rolls and through the materials or when one desires to control the tension levels at the entry and exit ends of the stand.

Due to the heterogeneous physical nature of the material, variable tension levels must be provided through the tension bridles when submitting the strip to a constant elongation ; of course, this is not the case for the equipments operated under tension control.

It is therefore essential to use a kinematic circuitry designed so as not to be influenced by the tension variations through the bridles.

The solutions using electric or hydraulic drives call for the utilization of an electric or hydraulic speed-regulation system in view of stability and such a regulation system is rather complex and expensive. Moreover, these solutions require a higher installed power as the torque that must be available at each tension bridle correspond to the force developed under steady state and during the acceleration and deceleration periods. Such is not the case for the machines using a mechanical connection as the mechanical parts only must be sized accordingly.

It is to be noted in this connection that savings attainable on the installed power are of about 30 to 40 %, compared with a conventional temper mill ; savings on the investments are still more important due to the suppression of the electric regulation at the tension bridles and at the tension reels and to the utilization of a less expensive type of motor.

PROCESS

The Stretch Rolling Mills offer the possibility of operating, without any risk of strip breakage, with an elongation rate corresponding to stresses situated beyond the yield strength of the metal.

In the case of equipments operated under tension control, it is imperative not to reach the yield strength of the material to avoid any risk of strip breakage, due to the heterogeneous physical nature of the metal. This requirement is eliminated by the Stretch Rolling Mills as, after having reached a maximum value, the tension level decreases due to necking and creeping of the metal ; however, the elongation value is unchanged as it is imposed by the control of the speed ratio between the tension bridles.

For a same tension level, far higher elongation rates can be reached under elongation control than under tension control. This is of particular advantage in the case of levellers where the elongation obtained by flexion of the material is not sufficiently efficient when achieved under a low tension.

The Stretch Rolling Mills are particularly well adapted to temper rolling and levelling of brittle materials such as aluminium and light alloys for which the ultimate strength is very close to the yield point.

All the Stretch Rolling Mills are practically operated according to the same principle, which consists of localizing the plastic strain of the metal in one or several well defined points.

Under pure tension, i.e. at the exit of the tension bridles, the stresses induced in the metal are generally inferior to the yield point ; this zone is only exceeded between the temper mill rolls or over the levelling rolls where the strip is submitted to alternate flexions.

Temper Mills

The Stretch Temper Mills are generally of the hydraulic screwdown type and they are designed to permit rolling force adjustment and to operate at a constant value. The stands are either of the two-high or of the four-high type.

For a given elongation, it is therefore possible to adjust at will and very accurately the amount of plastic deformation resulting on the one hand from the strip necking and, on the other hand, from the reduction between the temper mill rolls or from alternate flexions.

Comparative tests were run to show any metallurgical difference, if any, between a material processed in a conventional stand and a material processed in a Stretch Temper Mill. For comparable settings, the results were rather similar, if not identical. However, the materials processed in a Stretch Temper Mill are more homogeneous in nature : this is essentially due to the greater stability of settings and to the fact that these settings are less subject to variations than in the case of conventional temper mills.

As far as deep-drawing steels are concerned, these tests have shown that the stresses induced in the material must be equal or inferior to 6 to 8 kg/mm2 and that the residual elongation must be included within the range of 0.7 to 1.3 %. Above these values, the hardness and the strength of the material increase while the elongation and the yield point decrease. The Erichsen index is then affected, the resistance to ageing decreases as well as the deep drawability and formability.

These tests have also shown that, for a given elongation, the penetration of the temper effect is more important if the degree of reduction between the temper-mill rolls is decreased while the deformation by tension is increased.

Levellers

The tension levellers are also designed in such a way that it is possible to adjust at will and very accurately the amount of plastic strain resulting on the one hand from strip necking and, on the other hand, from alternate flexions over the levelling and anti-cross bow rolls. Levelling is achieved in a single pass by alternate flexions of the strip over two rolls of small diameter (Ø 20 to 50 mm). The residual bow is corrected by the anti-cross bow unit.

The experiments made in this field, particularly with rimming steels, have shown the necessity of operating with elongation rates as low as possible, generally less than 0.3 %. One may note that deep drawability is rapidly affected by the fast hardness increase. However, if one wishes to eliminate the risk of fluting after a prolonged ageing, it is necessary to operate with elongation rates equal or superior to 2 % as, in these conditions, the return of the yield point is very slow. The products thus processed are not suitable for deep-drawing applications but they are perfectly adapted to the metallic furniture industry, where the flatness requirements are very severe.

The flatness obtained with tension levellers is far better than the one attainable, in the best conditions, with conventional levellers. A sag of 1 mm on a sample of 1m2 is an easily accessible result. Likewise, the surface finish of tension levelled materials is far better : the marks produced by the conventional levellings rolls are eliminated.

The results obtained may easily be reproduced and, like the temper mills, this is one of the outstanding advantages of the tension levellers.

Combination Stands

Many materials must be simultaneously temper-rolled and tension-levelled. These two operations are achieved in a combination stand including a two-high or four-high mill and a tension leveller, with two tension bridles arranged on each side of the stand. The two machines can be either simultaneously or separately operated.

MAIN APPLICATIONS

Temper Mill

- Exit of a Processing or Coating Line (Galvanizing, aluminizing, annealing, etc.)
- Entry of a Finishing Line (Profiling, shearing, paint coating etc.)
- Temper Mill in replacement of a conventional temper mill.

Tension Leveller

- Entry or exit of a Processing or Coating Line (galvanizing, tinning, coating, etc.)
- Entry of a Pickling Line, as a scale breaker
- Installed in Shearing, slitting, Inspection Lines
- Tension leveller only.

COMBINATION STAND

In addition to their indisputable advantages evidenced by the tests that we have just quoted, the Stretch Rolling Mills offer the following advantages over all the other types of equipment : possibility of continuous operation and possibility of instal-lation in processing and finishing lines. The temper rolling and levelling operations are therefore achieved simultaneously with those of the line proper, thus eliminating any intermediate storage and rehandling operation ; the yield is also noticeably improved.

The operation of the Stretch Rolling Mills is very simple compared with the conventional mills and in most cases, the machines installed in finishing lines require no operator.

The operation costs are therefore noticeably decreased inasmuch as the roll consumption is very low compared with conventional mills. The tonnage temper rolled on a two-high mill located at the exit of a galvanizing line can reach 1000 tons and even more between two grinding operations. However, it is worthwhile to note that this result may be expected only if the machine is equipped with an efficient brushing system in order to avoid any zinc deposit on the rolls.

Generally, the investment return time to be considered for a Stretch Rolling Mill is less than three years.

NEW TECHNIQUE

Among the most recent applications of this process, it is worthwhile to quote :

1. Tin-plate double-reduction rolling on a combination stand.

   More than 60 % of reduction can be obtained in a single pass but, in general, such a reduction rate is not necessary as double-reduction tin-plate is generally produced with reduction rates of about 30 to 40 %.

   For a plant of this type, the investment cost is 3 to 4 times less than in the case of a conventional solution (two-stand tandem mill). The production is smaller but this is not an essential point as the tonnages to be produced is one of the outstanding advantages of this material, which competes with the aluminium and plastic packings. The line is designed to be operated as a temper mill or as a leveller when no double reduction is achieved.

2. High-speed temper rolling (800 m/mn) on a combination line equipped to achieve the following operations in a single pass : cropping, weld, temper rolling, levelling, marking, side trimming, inspection, cut, oiling and reconditioning of coils.

3. From the technological standpoint, a significant improvement has been brought to this type of equipment by CREUSOT-LOIRE-ENTREPRISES. The C.L.E.'s machines are now equipped with tension bridles fitted with a single active roll and with an air cushion system used as a tension generator.

   The air pressure in the chamber is of about 1 to 3 bars. The clearance between the strip and the edges of the chamber is of 1/10 to 3/10 mm ; this clearance can be adjusted through an hydraulic cylinder. Owing to this very small clearance, air consumption is very low.

   The noise produced by this air leakage is of some ten decibels only at a distance of one meter from the pad.

This new technique eliminates the problems raised by the synchronisation of the rolls in the case of a multiple-roll tension bridle ; moreover, one side of the strip only is in contact with the active roll and the strip surface is less subject to deterioration. The overall sizes of the machine are reduced and its inertia is smaller, due to the suppression of many gears and rotative parts. It can therefore be easily installed in a processing or finishing line.

4. CONCLUSIONS

The technological improvements in rolling mills being the subject of this report (which, again, makes no claim to be exhaustive) show that automatic drives are more and more used, this fact being due to necessity of production increase or necessity of rolled products quality. A more and more important part is therefore taken in rolling-mill units operation by electronics, hydraulics, electricity etc.

Consequently, there is a clear evolution in the qualification of production personnel, which must now include more and more skilled men in these techniques, this condition applying to production people properly so-called, or maintenance people.

Without minimizing the importance of the traditional mill operators, whose working conditions were particularly difficult and involved a great deal of practical experience (mainly in the long products rolling), it must be emphasized that evolution in rolling techniques and evolution in equipment technology require a deeper general training from the personnel.

One could say that requirements on products quality have been transferred to the men who are in charge of operation of the rolling-mill units .

This conclusion seems important to us mainly for the countries who have no traditional steel industry and who undertake a creation of this basic industry.

In our opinion, problems of engaging and training of the personnel is, on that account, easier to solve, concerning at least the possible field of personnel recruitment.

13.8.74