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STAGE-WISE EXPANSION PROGRAMME OF A STEEL STRIP MILL[1]

by

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SUMMARY

In this paper, the expansion of a steel strip mill in successive stages is described.

As the facilities for a steel strip mill plant require a very large capital investment, it is very important that thought should be given in the planning stage to the preparation of a layout that will permit incremental expansion to take account of future market demands.

Several methods for the incremental expansion of cold and hot strip mills have been studied. The principal features of each method have been described.

INTRODUCTION

When planning a new rolling mill, the most important point to consider is to obtain the required production at the lowest capital investment. Especially, great care is required in the planning of strip rolling mill plant having a large capacity, due to the fact that differences in design and layout result in differences in investment.

On the other hand, production demand is very fluid, and so how to interpret future prediction is a great problem for the planner. This has led to consideration of stage-wise expansion; keeping initial capital investment to a minimum and expanding to meet future increase in demand.

This paper is concerned with the incremental expansion of a small-scale hot and cold strip mill plant from the stand-point of mill arrangement, product size, and production capacity.

HOT STRIP MILL

Generally speaking, a hot strip mill has a large production capacity, 1 million to 4 million tons/year, requiring a large plant. Depending upon the layout, there are the following three types of plants: Steckel, Semi-continuous and Fully continuous.

	Tons/Year	PIW Max.
Hot Steckel Mill	300,000 - 500,000	400
Semi-continuous Mill	1,000,000 - 1,500,000	1,000
Fully contiauous Mill	2,000,000 - 4,500,000	2,000

The hot steckel plant is suitable for small production; however, due to the poor quality of products it has not been recently used for the production of mild steel, therefore it will not be considered in this paper.

When planning a hot strip mill, the following points must be considered:

1. Required finished gauge range.
2. Product mix.
3. Production capacity.
4. Product quality, especially with respect to rolling temperatures of the strip.
5. Slab sise (thickness x width x length) or PIW.
6. Sise or weight of coil to be handled.
7. Reheating furnace and mill arrangement.
8. Mill stand spacing and coiler locations.

9. Bar thicknesses at entry of finishing stand.

10. Mill speed, driving motor capacity, and motor RPM.

Regarding determination of the mill layout required to produce the required types and quantities of products, controlling factors such as rolling temperature and coiling temperature must also be considered. As an example, even in the case of small production, due to rolling temperature conditions it is not possible to reduce the mill speed, threrfore it is difficult to construct a hot strip mill of small capacity.

A summary of existing hot strip mills is as follows:

	Semi-continuous type	Fully continuous type
No. of roughing stands	1-2	4-6
No. of finishing stands	4-6	6-8
No. of down-coilers	2-3	3-5
PIW (Max.)	1,000	2,000
Coil weight (Max.)	27 tons	45 tons
Bar thickness at entry of finishing stand	19-25 mm	22-45 mm

The simplest hot strip mill layout consists of one roughing stand and four(4) finishing stands with two(2) down-coilers. Compared with the foregoing, a fully continuous mill plant produces twice as much and the slab PIW is also doubled. However, production is increased not merely by increasing the number of stands but also by increasing slab PIW; in other words coil weight, proportionate to the increase in the number of stands, and necessary consideration to temperature conditions during rolling.

The hot strip mill plant consists of the following three(3) main components.

1. Reheating furnace and its auxiliary equipment.
2. Roughing mill equipment.
3. Finishing mill train and coiler equipment.

These components usually have differing production capacities; however, they have common factors such as material to be rolled, slab weight, thickness, length, products, and rolling temperature. It is therefore necessary to consider balance of above factors in contemplating an overall incremental expansion plan.

Needless to say, the number of passes in roughing and finishing rolling is determined by the ratio of entry and delivery thicknesses. In general, five(5) - six(6) roughing passes and four(4) - seven(7) finishing passes are considered as reasonable.

The following is the relationship between elongation and the number of stands:

No. of finishing stands	Max elongation	Max reduction %
4	12	91.7
5	16	93.8
6	27	95.9
7	32	96.9

To increase production there has been a yearly increase in PIW (slab weight per inch width, which determines relation between slab thickness and length). In Japan a plant using a maximum slab of 2,000 PIW has been constructed. Rolling speed on finishing train has also increased to diminish the thermal rundown of large slab. Figure-1 shows the yearly increase in slab PIW and maximum rolling speed of finishing train in Japan.

As a method of accomplishing incremental expansion of a hot strip mill, considering above factors, the following can be offered:

A. Install additional roughing stands.

B. Install additional finishing stands.

C. Speed up the finishing train.

D. Increase slab weight (PIW).

E. Install closed coilers.

F. Shorten maintenance time.

In addition to the above, raising of furnace yield and slab yard expansion are important factors but this paper will be limited to consideration of the rolling mill.

A. Install Additional Roughing Train.

As the arrangement of roughing mill train, three quarter type which is intermediate to the semi-continuous type and fully continuous type mentioned previously, can be considered.

Table 1 shows several representative types of roughing train layouts that have been studied and typical production level of each. As shown by this table the increase in number of stands and the decrease in number of reverse or back passes raise production considerably. However, reverse or back passes conducted while the slab is thick and short, does not materially reduce production.

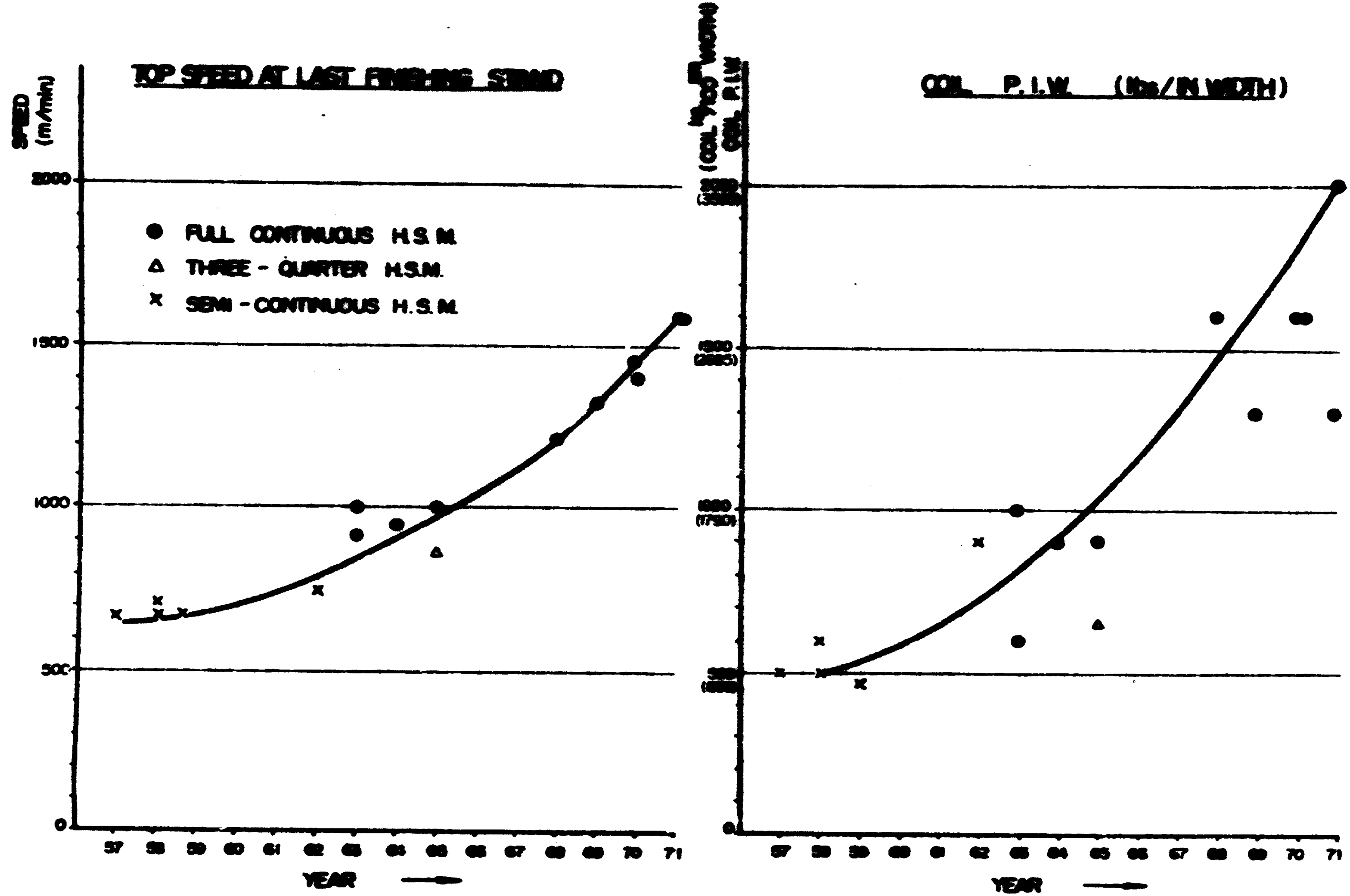

TOP SPEED AT LAST FINISHING STAND
SPEED (m/min)
2000
1500
1000
500
0
FULL CONTINUOUS H.S.M.
THREE - QUARTER H.S.M.
SEMI - CONTINUOUS H.S.M.
57 58 59 60 61 62 63 64 65 66 67 68 69 70 71
YEAR
COIL P.I.W. (lbs/IN WIDTH)
0
57 58 59 60 61 62 63 64 65 66 67 68 69 70 71
YEAR

FIG. 1

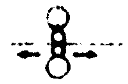
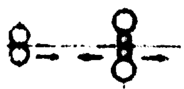
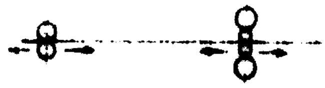
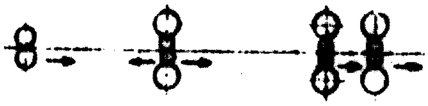
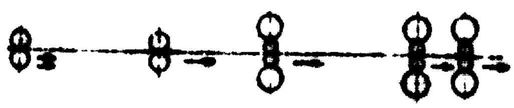
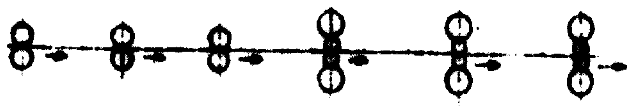
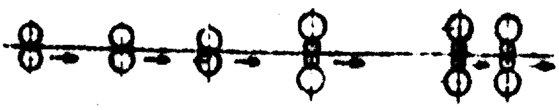
TYPE		LAY OUT	[illegible]
SEMI-CONTINUOUS MILL	A-1		TON/YEAR [illegible] 000
	A-2		[illegible] 000
THREE QUARTERS MILL	B-1		436,000
	B-2		36[illegible] 000
	B-3		449,000
	B-4		670,000
	B-5		635,000
	B-6		652,000
FULLY CONTINUOUS MILL	C-1		1,140,000
	C-2		1,140,000

Table 1 - Alternative layouts of roughing trains

SLAB SIZE 250 x 1,220 x 11,800 mm
SLAB WEIGHT 28.4 TON (1,300 PIW)
BAR THICKNESS 30 mm
SLAB INTERVAL 10 sec.

Excluding the semi-continuous type layout, in general, the production level in the roughing train is seldom lower than that of the finishing train. Therefore, if comparison is made purely from the stand-point of output, increase in number of roughing stands is not so effective. However, on the other hand, it must be noted that the necessity arises to limit the number of reverse or back passes for reasons stated below. That is, the increase in slab thickness resulting from the use of large slab leads to increase in draft, increase in rolling power, and creates the biting angle problem on roughing stands, necessitating an increase in number of roughing stands. Furthermore, on the reverse or back pass rolling, it is necessary to change roll gap setting in a short time, and when large slab is rolled on reverse or back pass stand, the roll gap setting is required more strictly to avoid the slab to be cambered. This strict gap setting is very difficult in practice. Therefore, installation adding more roughing stand is relative to increase in slab PIW, and necessitates to consider the each stand spacing at same time.

Figure 2 is an example of a plan which was originally semi-continuous planned for future expansion to fully continuous mill having 5 roughing stands. In this example the initial plan is to handle 1,000 PIW 27 ton maximum slab to be increased in the future to 1,300 PIW 45 ton slab. Moreover, additional installation F-7 stand is contemplated. If capital cost of plant to include future arrangement (except the cost of furnace section) is considered to be 100%, initial construction expense can be considered to be 65% and planned production capacity in initial stage is 1,250,000 ton/year and 3,600,000 ton/year in future.

B. Install Additional Finishing Stands.

Two reasons can be given for installing of additional finishing stands:

1. Increase in slab PIW.
2. Production of thin finished strip.
   (widen range of finished gauge)

Since increase in PIW naturally leads to increase in bar thickness, in order to attain the same finished gauge, increase in the number of finish passes is unavoidable. Therefore, in this case, the production capacity that can be expected will be proportional to the increase in PIW. However, it will be necessary to increase the capacity of flying crop shear also.

Moreover, the increase in the number of finishing stands makes possible production of thinner strip without decreasing the bar thickness. Additionally, in comparison to obtaining thin strips by reducing entry bar gauge, installation of additional finishing stands means a proportional increase in speed and yield of thin material.

When considering a plant having four(4) finishing stands originally, from the standpoint of not reducing output greatly compared with final installation, F-2 to F-5 are initially installed and F-1 stand is added in future, and there are many instancesin which F-6 stand has been added in same stage.

Figure-3 shows the relation ship between bar thickness and production figures of 4, 5, 6 and 7 stands finisher to produce strip of same thickness. The production shown in this figure was based on the following provisos:

1. Relationship between speed and PIW is as indicated in Figure-8 regarding strip temperature difference from top to tail to be small at delivery side of finishing mill.

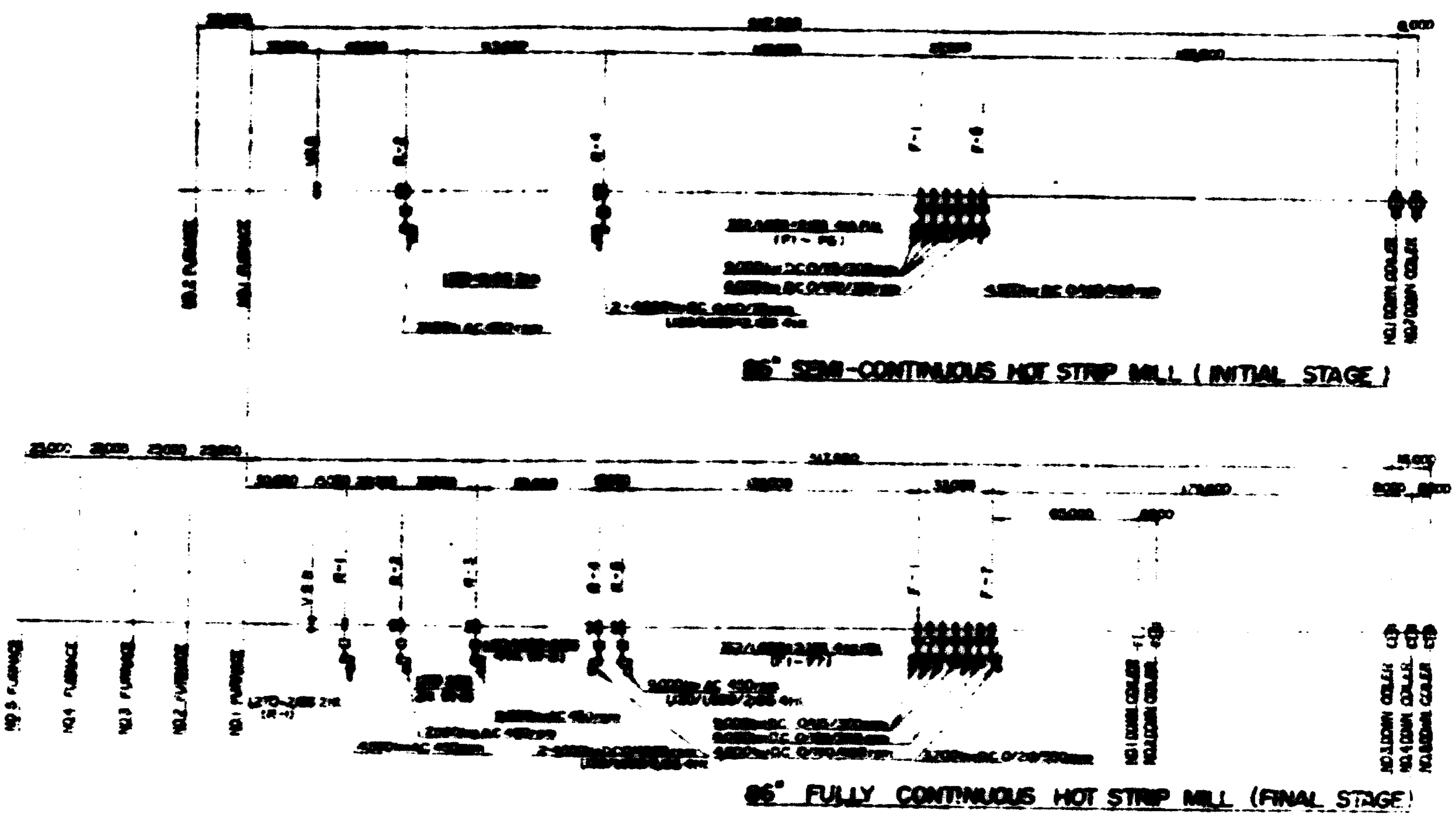
2. Relationship between bar thickness and slab PIW is as indicated in this figure.

C. Speed Up The Finishing Train.

As stated in the portion of this report concerning roughing stands, in a three-quarter or fully continuous type of roughing train, production of roughing train exceeds that of the finishing train.

In such instances raising the speed on the finishing train is a very effective method of raising production levels. Table 2 is an example of such a system in Japan.

Fig. 2 – Conversion plan from semi-continuous to fully continuous mill layout



	SEMI-CONTINUOUS MILL	FULLY CONTINUOUS MILL
SLAB THICKNESS	130 ~ 200 mm	130 ~ 300 mm
WIDTH	600 ~ 2,200 mm	600 ~ 2,200 mm
LENGTH	4,000 ~ 14,000 mm	4,000 ~ 14,000 mm
MAX. SLAB WEIGHT	27 TON	45 TON
	1,000 PIW	1,300 PIW
STRIP THICKNESS	1.2 ~ 16 mm	1.0 ~ 16 mm
FINISHING STANDS	6 STD	7 STD
MAX ROLLING SPEED	1,185 MPM	1,317 MPM

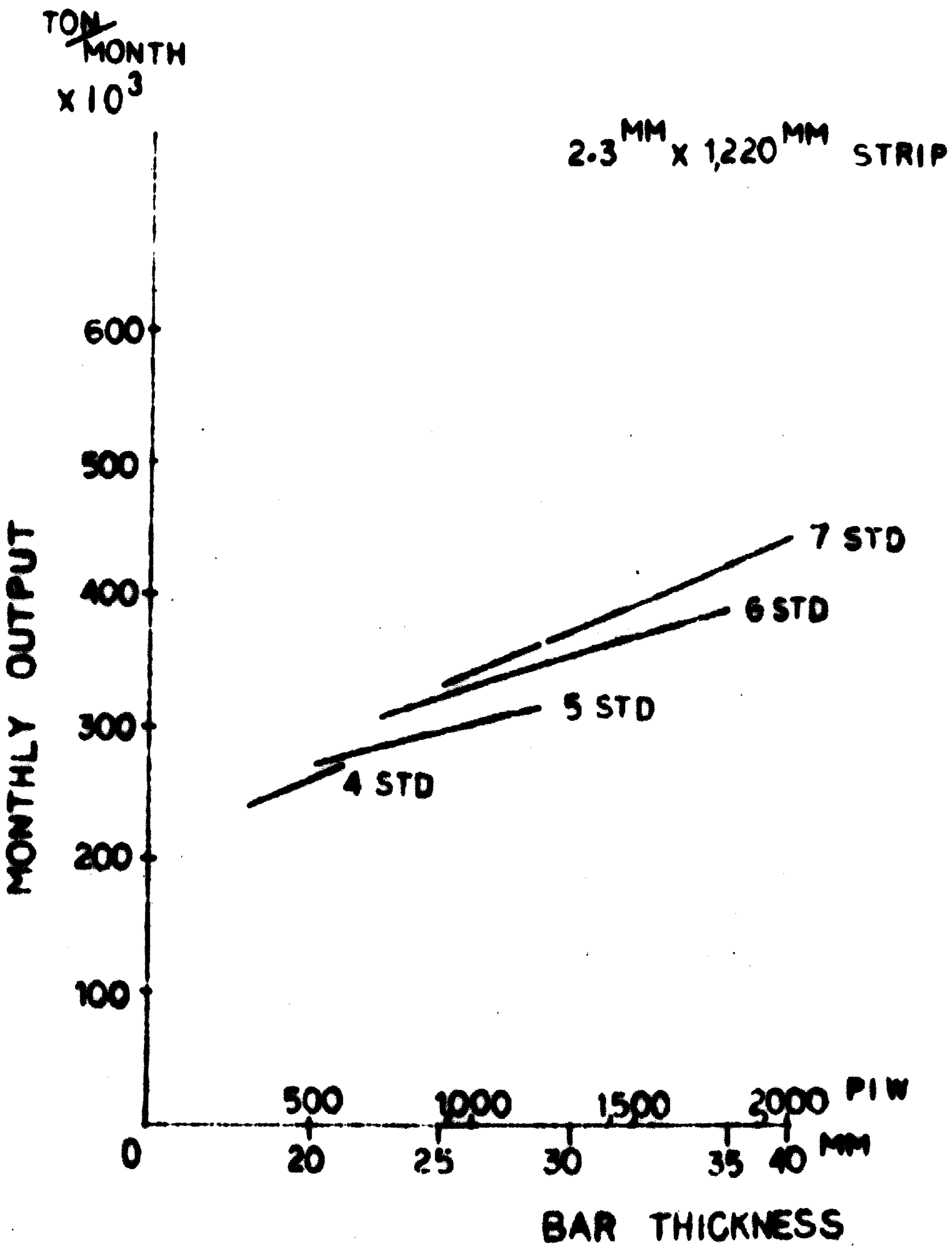


Fig. 3 - Relationship of finishing mill production to slab PIW

Table 2

		INITIAL	FUTURE
	R-1	4500kw AC 450 rpm	4500kw AC 450 rpm
	R-2	7500kw AC 450 rpm	7500kw AC 450 rpm
Driving	R-3	9000kw AC 450 rpm	9000kw AC 450 rpm
Power	R-4	-	9000kw DC 138/230 rpm
	R-5	9000kw AC 450 rpm	9000kw AC 450 rpm
	F-1	7500kw DC 115/300 rpm	11250kw DC 115/300 rpm
	F-2	7500kw DC 150/390 rpm	11250kw DC 150/390 rpm
	F-3	7500kw DC 150/390 rpm	11250kw DC 150/390 rpm
	F-4	7500kw DC 115/300 rpm	11250kw DC 115/300 rpm
	F-5	5600kw DC 150/390 rpm	8400kw DC 150/390 rpm
	F-6	5600kw DC 175/460 rpm	8400kw DC 175/460 rpm
	F-7	-	8400kw DC 200/530 rpm
SLAB PIW		1200 PIW	1600 PIW
FINISHING SPEED		1270 mpm @ F-6	1450 mpm @ F-7
ANUAL PRODUCTION		3,000,000 tons	4,500,000 tons

In this case, four(4) roughing stands and six(6) finishing stands were provided initially. And delivery speed at F-6 stand is up to 1,270 mpm. Furthermore, total operating power of the finishing train is 75% of the final plan. In the future configuration one(1) roughing stand and one(1) finishing stand will be added, and the power will be increased to achieve high-speed rolling to obtain the same thickness of finishing gauge.

Needless to say, the speed-up of the finishing train will require a speed-up of the runout table and coiler. Therefore they must be considered in initial planning Finishing train speed-up must also be considered when increasing the slab weight. In the foregoing example also, the plan to increase the initial 1200 PIW slab to 1600 PIW slab has been included. As indicated in Figure 4, an increase in PIW means an increase in strip length of material of same thickness. In other words, it means that if strips of differing PIW are rolled at the same speed, rolling time will differ and it will be difficult to keep the finishing temperature in constant range (temperature at delivery side of last finishing stand) from top to tail of the strip.

Generally, to control the finishing temperature within an established range zoom rolling (control of the acceleration of the finish train to keep finishing temperature within range) is utilized.

Figure 5 showes calculated thermal rundown of materials for 3 cases. In these cases, roughing stand spacings and delay table length are decided in compliance with the slab PIW under consideration on executing the calculation.

Figure 6 shows the zooming pattern which the temperatures in Figure 5 are based on. The abscissa indicates the length from strip topend to the point of attention and the ordinate indicates the corresponding finishing speed.

As indicated in Figure 6, temperature difference from top to tail end of finishing gauge caused by increase in slab PIW can be decreased by increasing the speed at the starting point of zooming accelration and final rolling speed on finishing train. On the other hand, as can be seen from the figure, if the speed exceeds a certain limiting figure conversely the finishing temperature will rise excessively. therefore, recently strip coolants have been installed between high speed rolling mill stands. However, it is pointed out that, even if this method is used above a certain speed, control of temperature cannot be achieved by strip coolants.

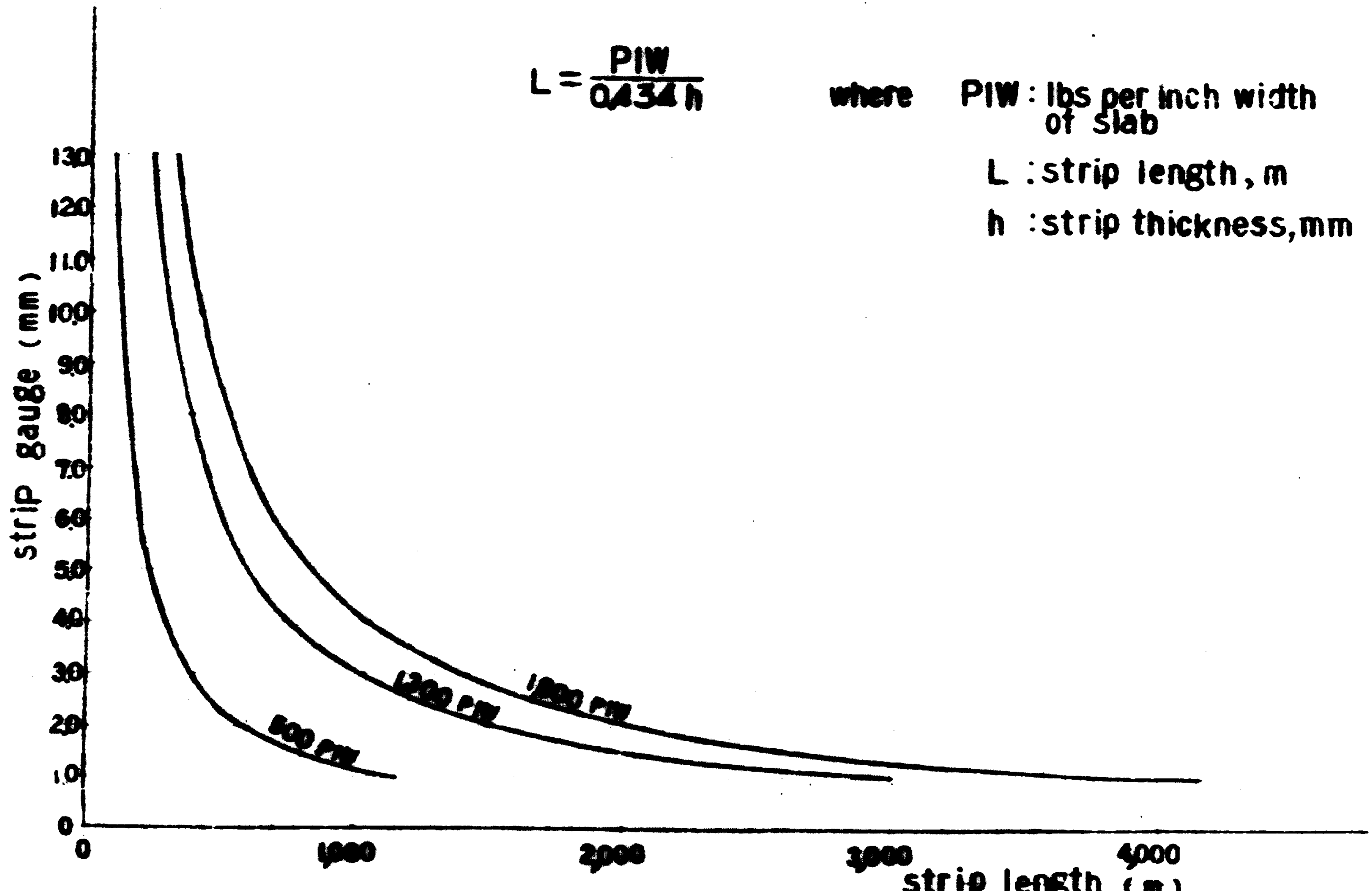


Fig. 4 – Relationship of slab PIW to strip length

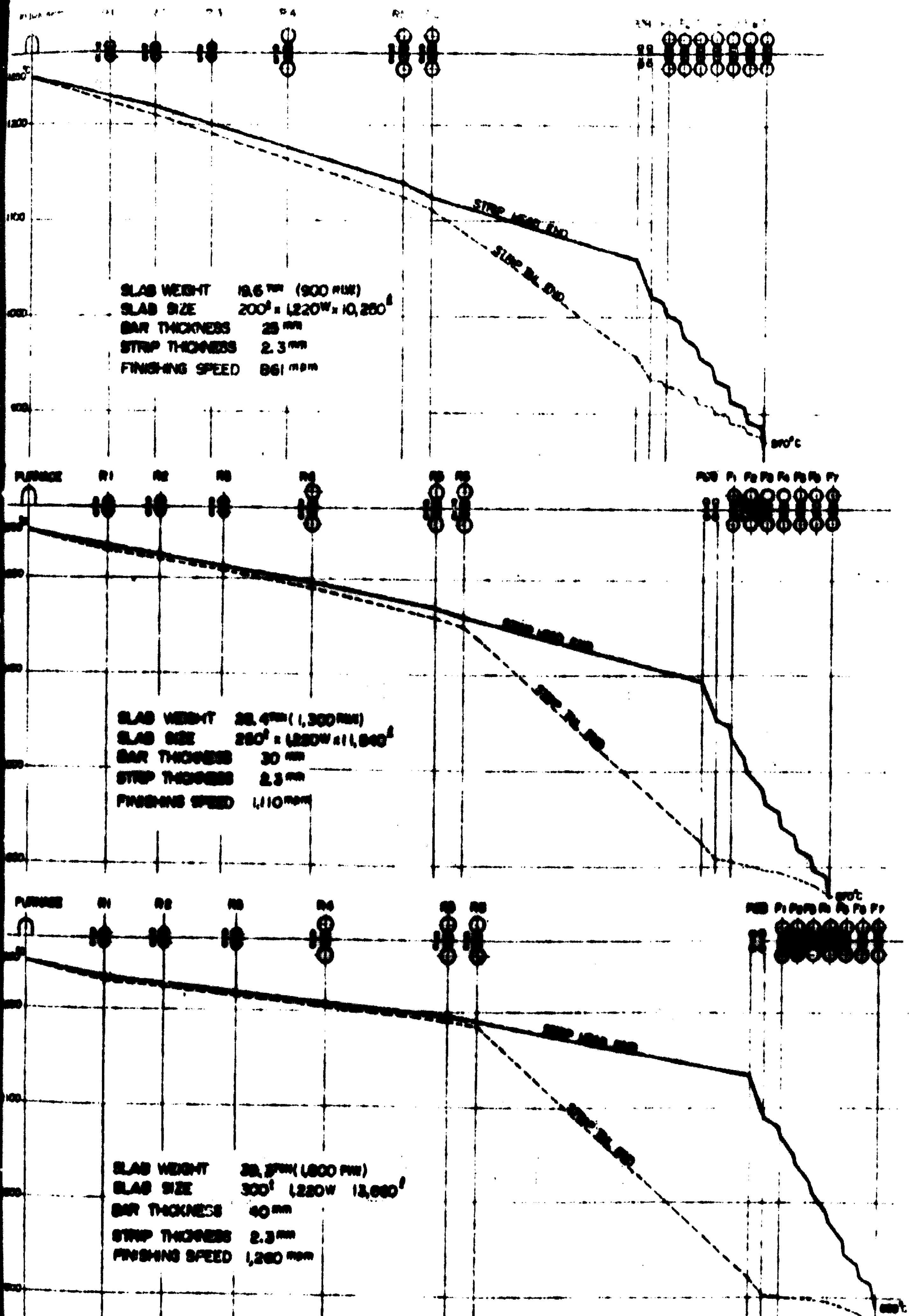


Fig. 5 - Thermal rundown of hot strip mill

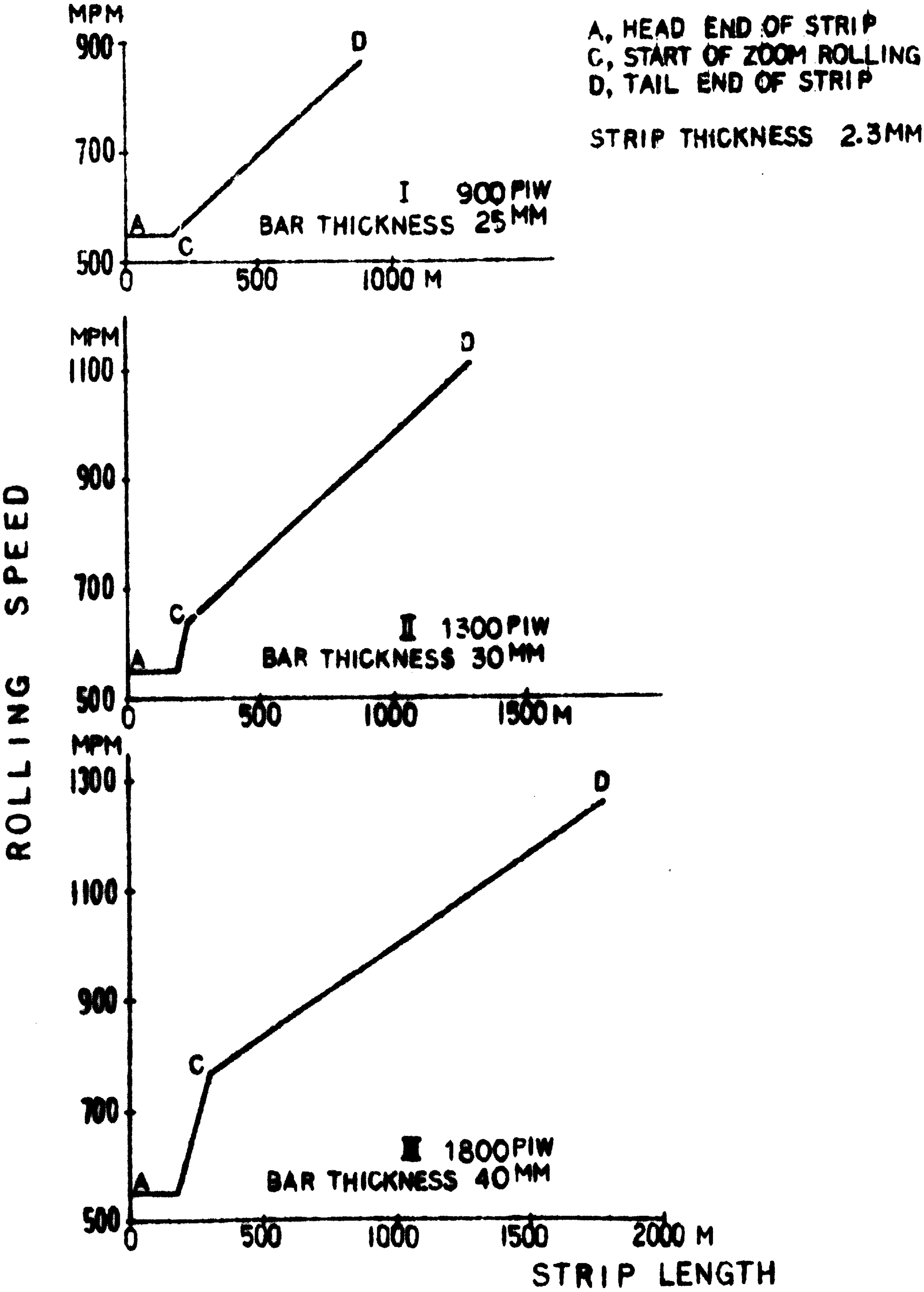


Fig. 6 - Finishing speed pattern in zoom rolling

D. Increase Slab Weight (PIW)

As stated previously, an increase in PIW results in an increase in actual rolling time and creates the necessity of speeding up the finishing train resulting in a great increase in production. Figure 6 indicates the change in production of rougher and finisher due to change in PIW. However, PIW increase does not merely mean increase in driving power, but also affects the mechanical strength of the table roller and down coiler, therefore it is economical to consider the maximum PIW to be handled in the future in making the initial facilities plan.

Figure 7 shows a semi-continuous roughing train production level for slabs up to 2,000 PIW, however, in a semi-continuous roughing train, due to thermal rundown, slab PIW is restricted to less than 1,000.

E. Install Closed Coilers.

In rolling thin strips less than 2.3 mm thick, the length of the cooling zone on the hot run table, which controls the coiling temperature, can be short, and consideration can be given to install down coilers immediately after thortly cooling zone to be exclusively used for thin material. This method offers the following merits:

1. Threading time is short, resulting in rise in production.

2. Because of the distance from the finishing stand to the winding of the strip top onto the down-coiler is short, off-gauge becomes short.

If only the standard coiler is installed, in an existing example, the distance between the last finishing stand and the No. 1 coiler is about 126,000 mm. In an example having a standard coiler and a closed coiler, the distance between the last finishing stand and the No. 1 closed coiler is about 61,000 mm and the distance to the first standard coiler is about 181,000 mm. In these examples, the maximum slab PIW is 1,300 and the maximum finishing speed is 1,500 mpm. If threading speed is 600 mpm, the time required for the top end of the strip to go from the final stand to the acceleration point on the coiler is approximately 13 seconds for the standard coiler and 6 seconds for the closed coiler. Therefore it is possible to conduct high speed rolling for 7 seconds more, resulting in an increase of approximately 69 meter strip in on-gauge production.

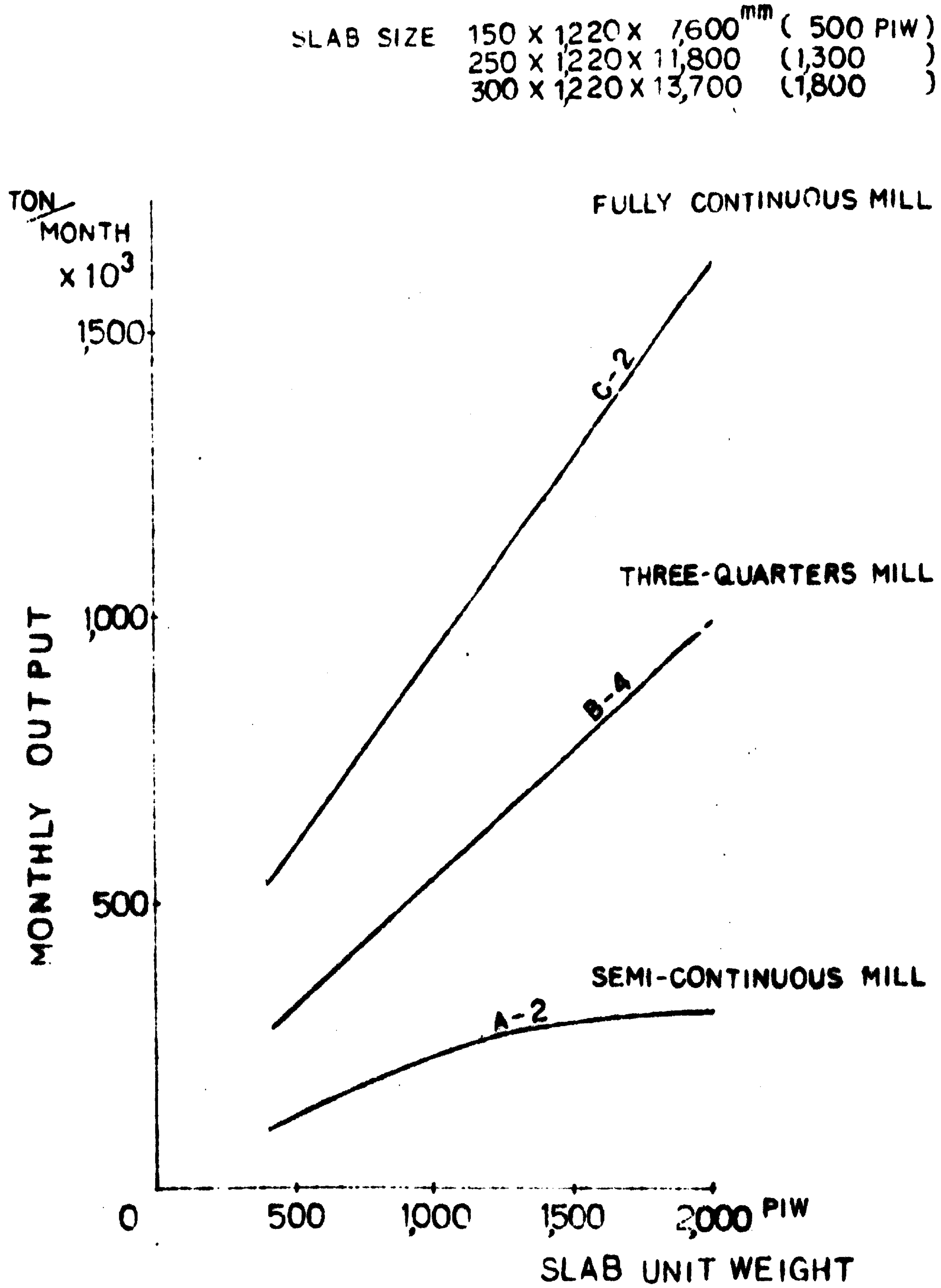


Fig. 7 - Relationship of roughing mill production to slab PIW

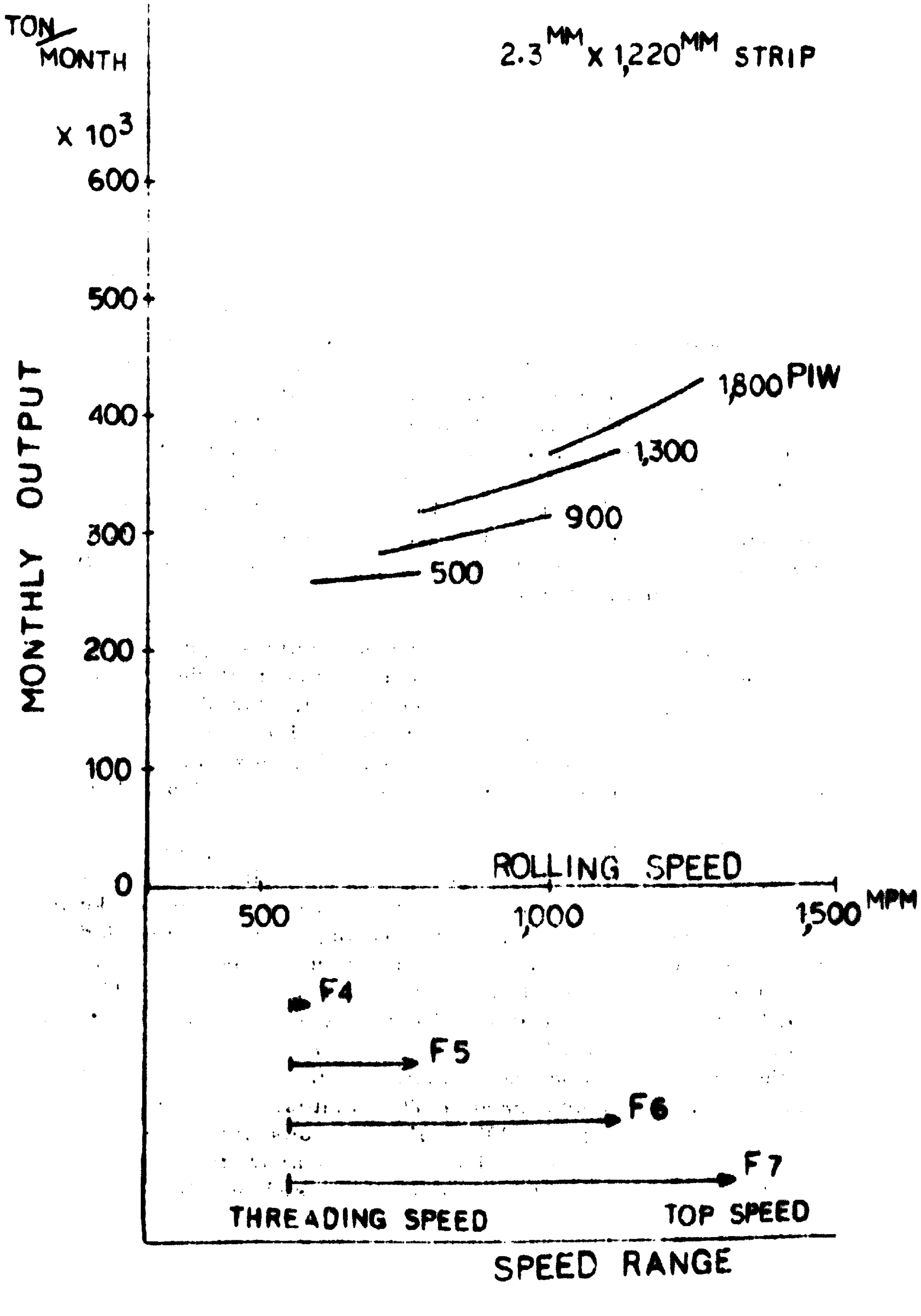


Fig. 8 - Relationship of finishing mill production to finishing mill speed

F. Shorten Maintenance Time.

Two remarkable ideas recently developed are:

1. Quick change of work roll.

2. Quick change of shear knife.

In a hot strip mill, the rolls requiring a high frequency of replacement are the work rolls in the finishing train; approximately 120-125 times per month. In comparison, 20-30 changes per month are required on the roughing train, thereby not presenting much of a problem. Therefore, to raise production by reducing the time required to change rolls, the finishing train is most promising. Of course, quick change of rolls does not merely mean a rise in production but also reduces the number of personnel required and raises the safety standard. For this reason quick change of rolls have been frequently adopted in rougher trains.

Use of porter bars in changing rolls requires approximately 30 minutes. As this operation can be accomplished in 5 minutes by using the quick-change device, this decrease in change time means an increase in operation time of 50-60 hours per month resulting in a 10-12% increase in annual production, assuming an annual operating time of 5,000 hours.

Figure 9 shows the layout of a turn-table type quick roll-changing device. As in the work-roll changing, a relatively high percentage of down-time is required to change the knife blades in the flying crop shear. Changing a straight blade requires about 5 hours; moreover, if one considers that fact that a change of blades is required for each 80,000 to 120,000 tons rolled, a quick-changing systems which permits adjustment of the blades off the line has great merit.
In the quick change method illustrated in figures 10 and 11, change can be accomplished in 20 minutes, meaning that on a line producing 200,000 - 300,000 tons per month, operating time is increased by 14 hours approximately, and that yearly production can be increased by 3%.

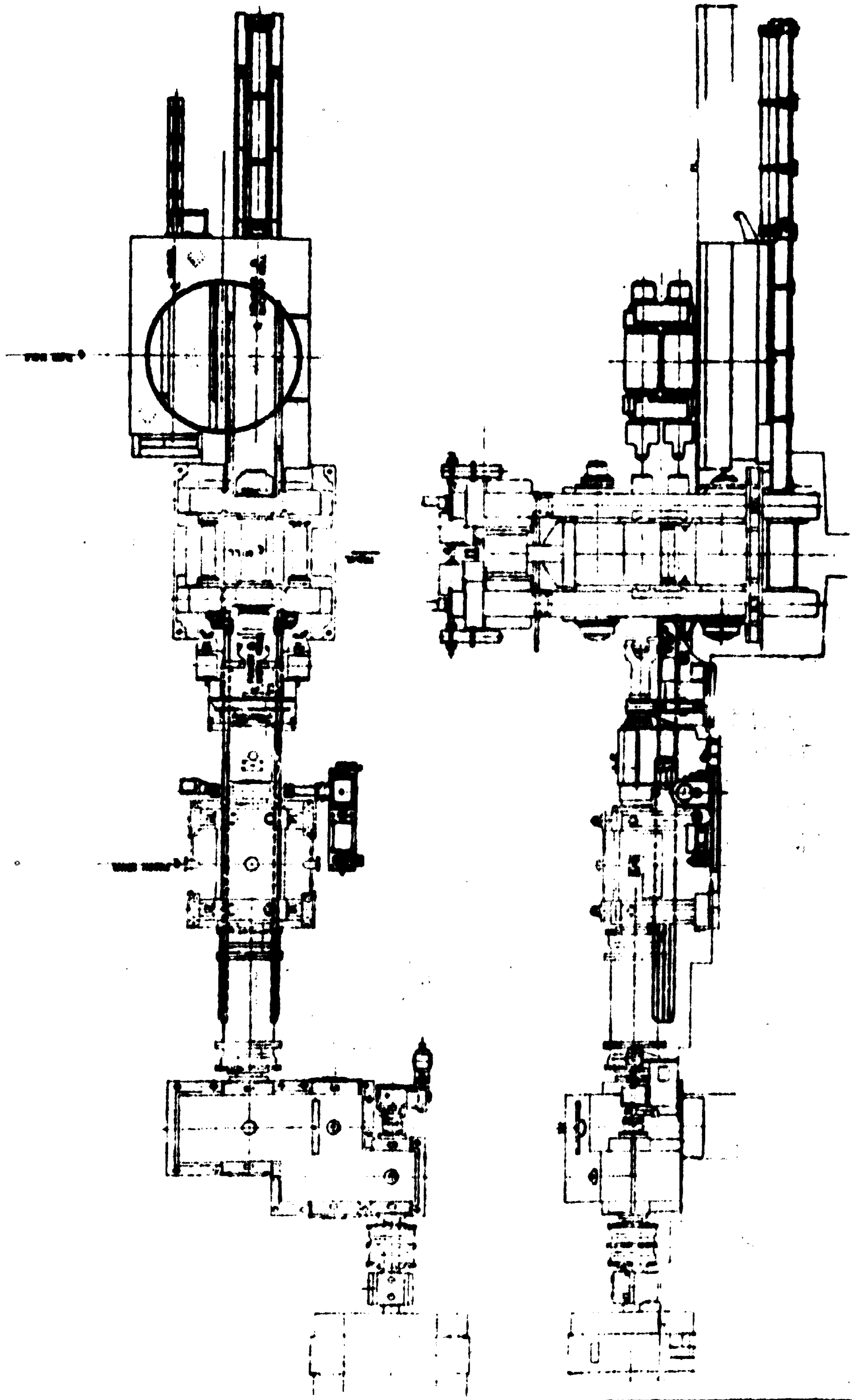


Fig. 9 - Roll changing : general arrangement

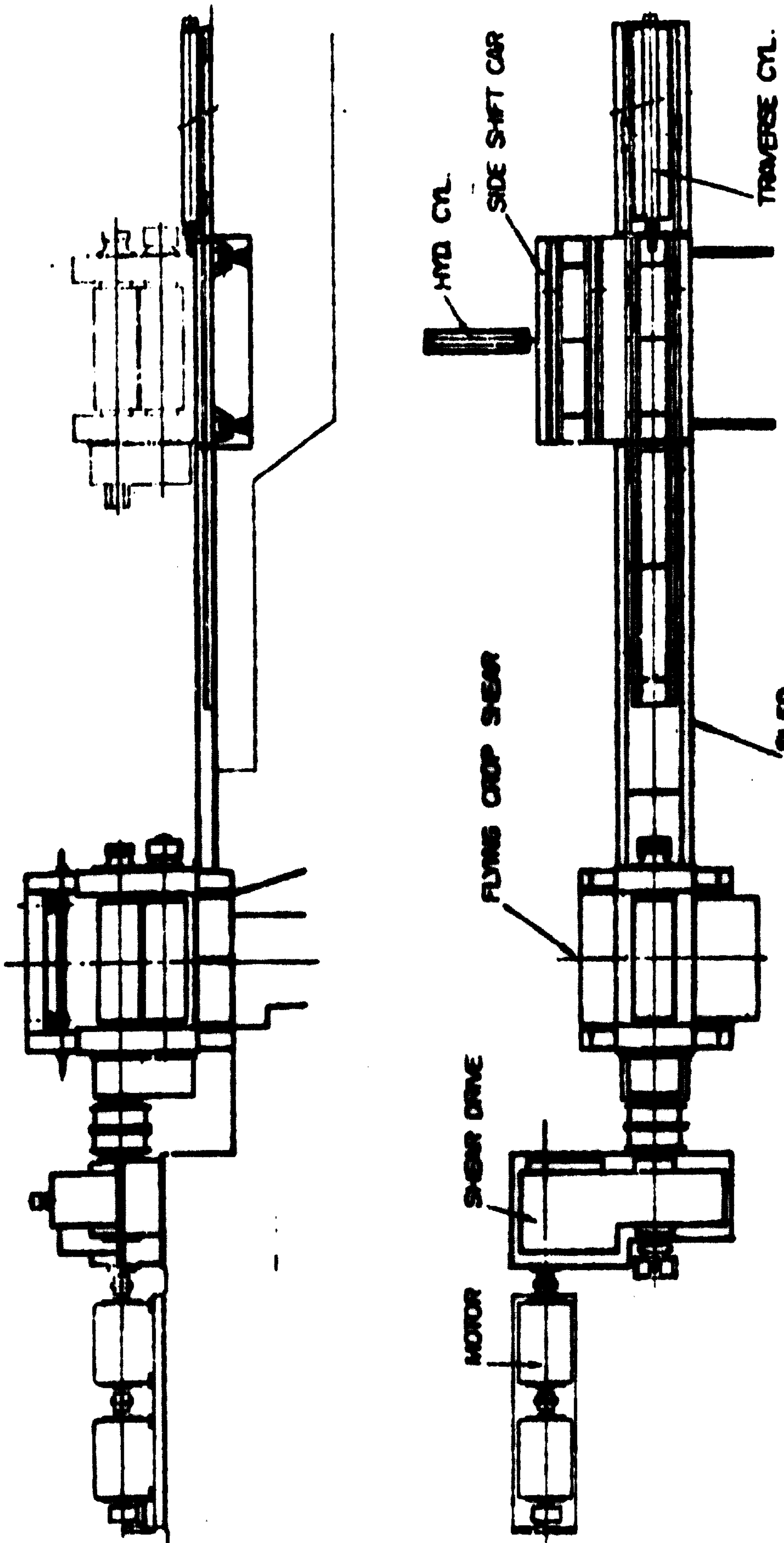


Fig. 10 - Flying crop shear drum changing : general arrangement

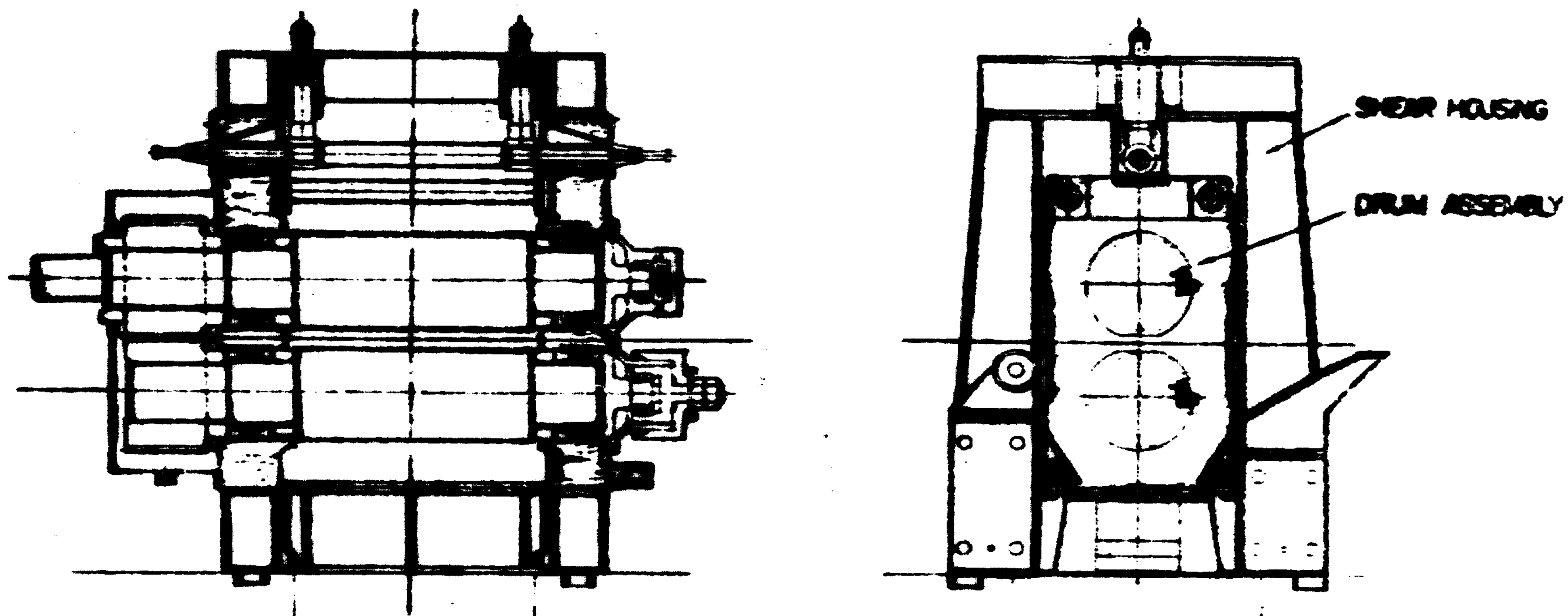


Fig. 11 - Flying crop shear

COLD STRIP MILL.

The general cold strip mill layout is as follows:

1. Single stand reversing cold mill.

2. 3-6 stand tandem cold mill.

As factors that determine capacity there are the followings:

1. Production mix.

2. Initial material thickness

3. Weight of coil to be handled.

4. Mill speed.

5. Production quality.

The number of stands in a tandem cold mill is determined, naturally, by the initial strip thickness and finished strip thickness ratio, or elongation ratio. In general, the relation between the number of stands and elongation ratio is as indicated in the following table:

No. of Stands	Elongation	Reduction (%)
3	1.5 - 5.0	33 - 80
4	1.7 - 7.5	41 - 87
5	2.0 - 11.0	50 - 91
6	2.5 - 18.0	60 - 95

Since there is a limit to the total reduction possible in a tandem cold mill, the entry strip thickness being determined by the desired product thickness, flexible rolling such as in a single stand reverse cold mill cannot be achieved. On the other hand, there is a limit to the thinness of the strip that can be rolled in a hot strip mill. Theoretically it is possible to produce a 1 mm thick hot coil; however the hot strip mill production will be greatly decreased, and there are many problems regarding the shape of the products, and it is not suitable as a cold-rolling material. Therefore, as a cold-rolling material 2.0-2.3mm thick hot coils are most frequently used.

0.8 mm thick gauge can be rolled from 2.3mm thickness hot coil on a 3-stand tandem cold mill; however, 5-6 stands are required to roll strips less than 0.23 mm thick from the same thickness hot coil. The problem is in how to roll a limited amount of tin-gauge material.

The most commonly adopted method is the single-stand reversing mill. However, in comparison with the tandem cold mill the products rolled by a reverse cold mill are of lower quality, and the yield is poor. The reason that the quality is low is that on each pass rolls having the same crown are used while in a tandem cold mill the crown is changed at each stand; moreover, because of the crown on the strip, as the build-up on the coil increase there will be a diameter difference at the center and the edges, which will cause a difference in tension at the center and the edges. Avoiding this worse cause, there are an idea to reduce the number of passes or number of stands and to be taken heavy reduction on each pass, however, from the practical standpoint it is difficult to roll good quality strips.

As a method of accomplishing incremental expansion of a cold strip mill the following have been frequently adopted:

A. Install additional stands.

B. Increase the speed of the mill, that is, raise the main motor power.

C. Install roll quick-changing devices.

D. Raise weight of coil.

E. Convert to fully continuous mill.

A. Install Additional Stands.

Increasing the number of stands in a TCM is simple if planned in advance. To convert a three-stand mill to four stands or to convert a four-stand mill to 5 stands can be considered as methods to raise production and expand the range of the size of the products. Converting 5-stand tandem cold mill to 6-stand tandem cold mill is very effective in raising tin-plate production capacity. The quality also improves. The most difficult expansion is the single-stand reverse cold mill. To convert a single-stand reverse mill to a 2-stand reverse cold mill has been previously considered; however, it has not been carried out for the following reasons:

1. Electrical control is difficult.

2. Yield is poor (Reverse pass is not possible)

Therefore, it can be stated that the most difficult problem in a plant that has been producing tin-gauge material in a single reverse mill is how to increase production capacity. An answer to this problem has not been found.

To obtain a small amount of tin-gauge material having better quality than that produced by a single-stand reverse mill, a 5-stand tandem cold mill at half rolling speed can be used. A recent successful method is two passes in a 3-stand tandem cold mill.

Figure 12 gives production figures for an example of this type of layout. The values have been calculated on the following bases:

	3-Stand TCM	5-Stand TCM
Total Power	17,300 kw	29,200 kw
Max. Speed (last stand)	1,130 mpm	1,524 mpm
Coil Weight	20 tons	20 tons

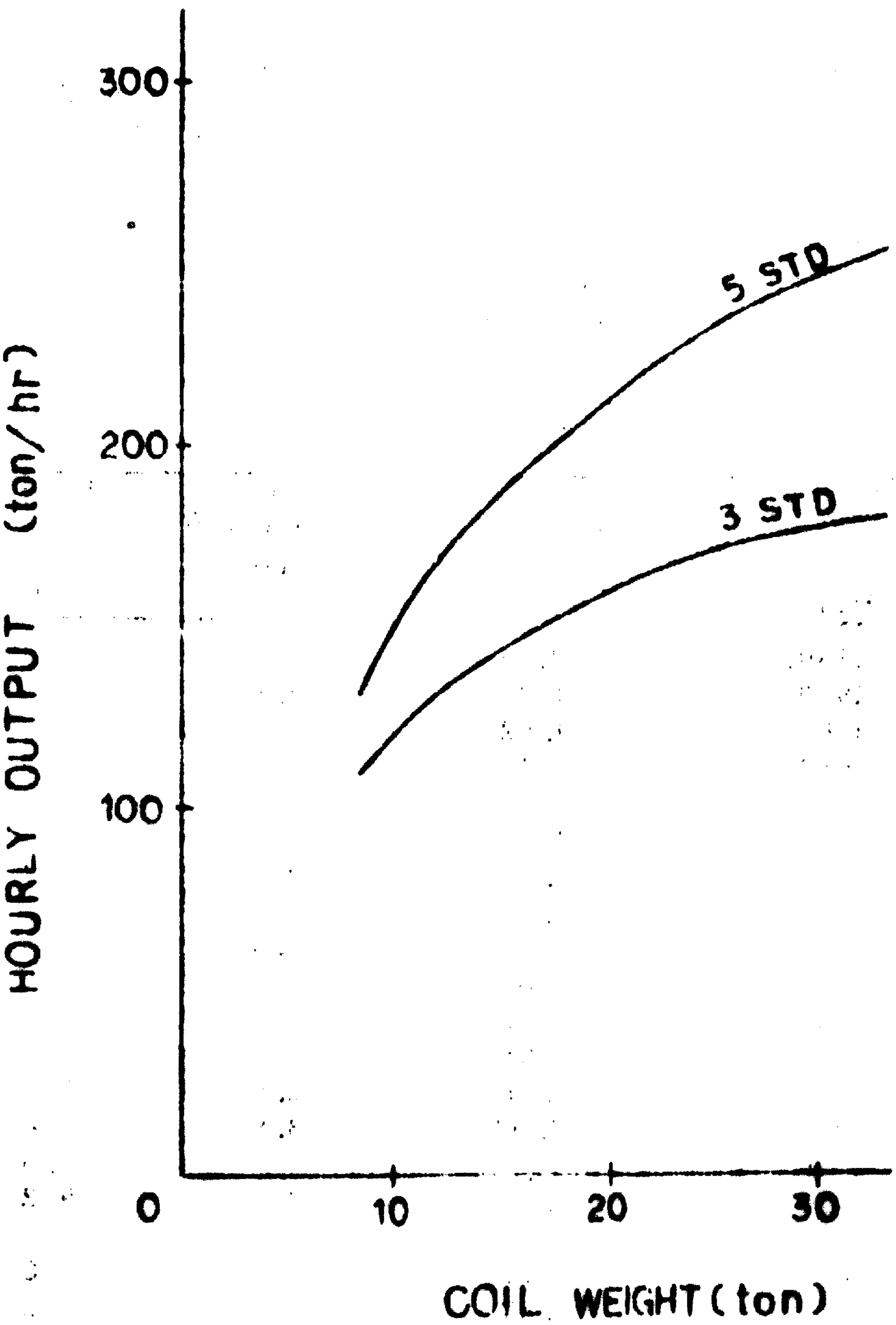


Fig. 12 - Comparison between 3-stand and 5-stand TCM production based on product mix A

Production mix contains 20% that require two passes. Figure 13 are for a production mix, under the same conditions, not requiring second passes. The contents of each production mix are shown on Table 3 and Table 4. In this type of planning the initial capital investment for a 3-stand mill is 60% of a 5-stand mill. However, if a 2-stand increment is made in the future, the total cost will be 5-10% higher than the cost of a mill having 5 stands from the outset. Approximately one month will be required to make the additional installation.

Table 3 - Product mix A

Material width MM	Thickness gauge MM	Initial thickness gauge MM	Percentage of total %
1550.	2.03	3.8	1.0
1550.	1.83	3.8	.1
1550.	1.62	3.5	2.8
1550.	1.42	3.0	.1
1550.	1.22	3.0	3.8
1550.	1.02	3.0	.3
1550.	.91	2.5	4.2
1550.	.78	2.5	5.0
1550.	.71	2.5	3.6
1550.	.61	2.5	.2
1550.	.56	2.5	1.0
1550.	.51	2.0	.1
1550.	.46	2.0	1.6
1020.	2.03	3.8	3.8
1020.	1.83	3.8	.3
1020.	1.62	3.5	9.2
1020.	1.42	3.0	.2
1020.	1.22	3.0	11.8
1020.	1.02	3.0	.2
1020.	.91	2.5	11.8
1020.	.78	2.5	1.6
1020.	.71	2.5	8.6
1020.	.61	2.5	.1
1020.	.56	2.5	3.8
1020.	.51	2.0	.2
1020.	.46	2.0	4.6
870.	.29	2.0	5.0
870.	.26	2.0	5.0
870.	.23	2.0	5.0
870.	.22	2.0	5.0
			100.0 Total

Table 4 - Product mix B

Material width MM	Thickness gauge MM	Initial thickness gauge MM	Percentage of total %
1550.	2.03	5.8	1.43
1550.	1.83	3.8	.2
1550.	1.62	3.5	3.5
1550.	1.42	3.0	.1
1550.	1.22	3.0	4.8
1550.	1.02	3.0	.4
1550.	.91	2.5	5.3
1550.	.78	2.5	6.3
1550.	.71	2.5	4.5
1550.	.61	2.5	.2
1550.	.56	2.5	1.3
1550.	.51	2.0	.1
1550.	.46	2.0	2.0
1020.	2.03	3.8	4.8
1020.	1.83	3.8	.4
1020.	1.62	3.5	11.5
1020.	1.42	3.0	.2
1020.	1.22	3.0	14.7
1020.	1.02	3.0	.3
1020.	.91	2.5	14.7
1020.	.78	2.5	2.0
1020.	.71	2.5	10.7
1020.	.61	2.5	.1
1020.	.56	2.5	4.7
1020.	.51	2.0	.2
1020.	.46	2.0	5.7
			100.0 Total

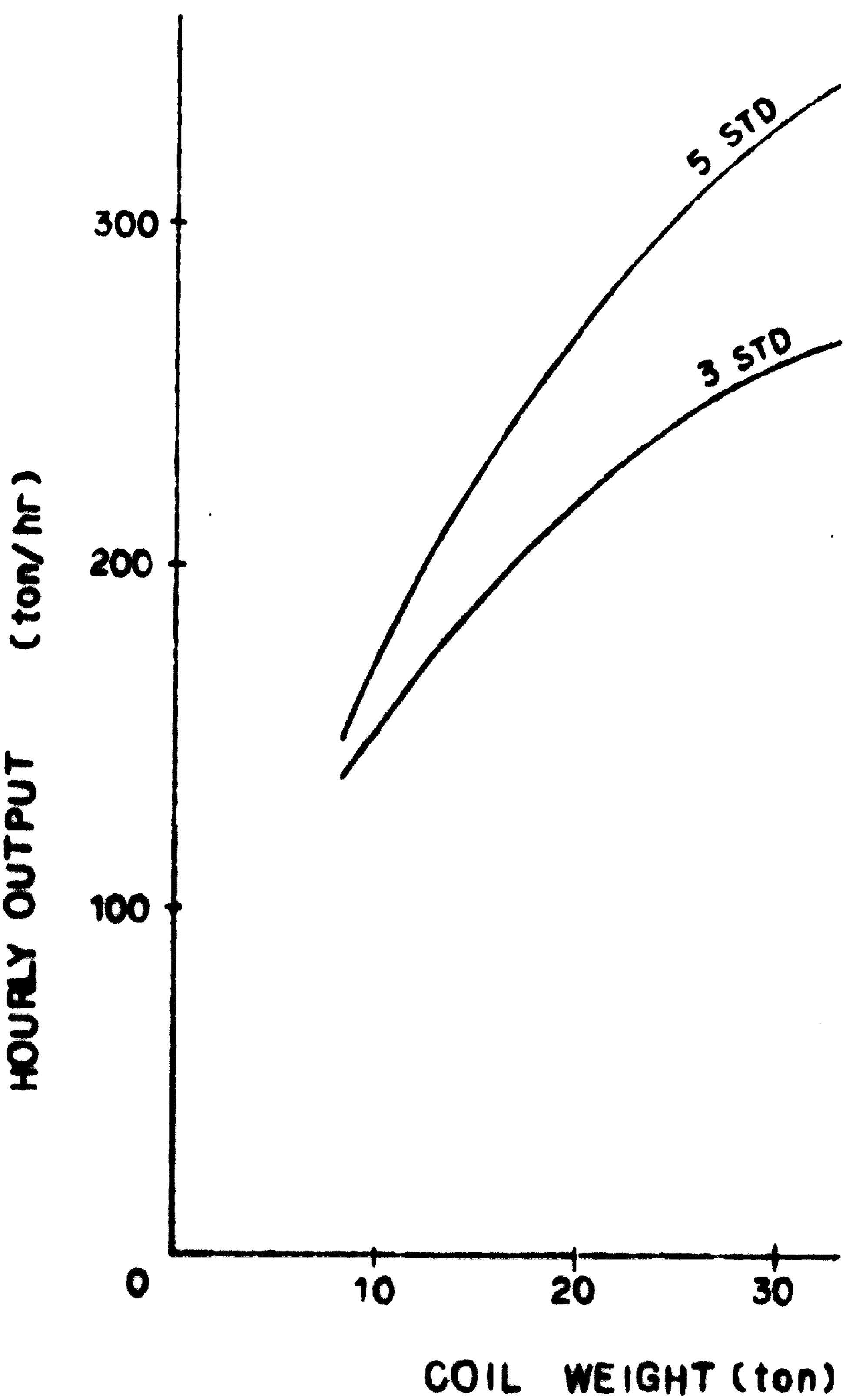


Fig. 13 - Comparison between production of 3-stand and 5-stand TCM based on production mix B

B. Increase The Speed of The Mill.

That the raising of rolling speed is directly related to a rise in production is a natural consideration and can be considered a part of accomplishing expansion of a tandem cold mill. The rise in production resulting from the raising of rolling speed is approximately as shown in figure 14.

For each coil weight there is a speed limit beyond which production will not rise materially. On the other hand, considering production expansion from the economic standpoint, it is not possible to freely select initial and final speeds. In general, as the initial power selected is one half the final power, the rolling speed is also one half. It is possible to keep initial cost at 75% of the capital cost of 5-stand tandem cold mill operating at full speed. The reorganisation time required is two weeks.

When using half power initially, by analysing production mix, it is possible to operate at final speed and to produce full production limited product from the beginning. In other words, by eliminating from the outset thick and wide material that require large power, and producing those products that only require half power this method can be adopted.

C. Install Roll Quick Change Devices.

In the conventional 5-stand tandem cold mill the frequency of change of the work rolls is generally 300-400 sets/month. If a porter bar is used for roll changing, approximately 30 minutes are required to change one set of rolls, therefore, requiring approximately 150-200 hours per month. If the quick change equipment is used it is possible to accomplish the change in 5 minutes, resulting in a monthly actual rolling time increase of 125-167 hours.
Therefore if yearly operating time is 5,000 hours approximately 30-40% increase in production can be expected.
The installation cost of quick changing equipment, in the case of a 5-stand tandem cold mill, is approximately 5% of the total capital investment, therefore, if future installation of quick change devices is considered in the initial planning, at an additional cost of only 5% of the initial investment a 30-40% increase in production can be expected. The change can be made in one week.

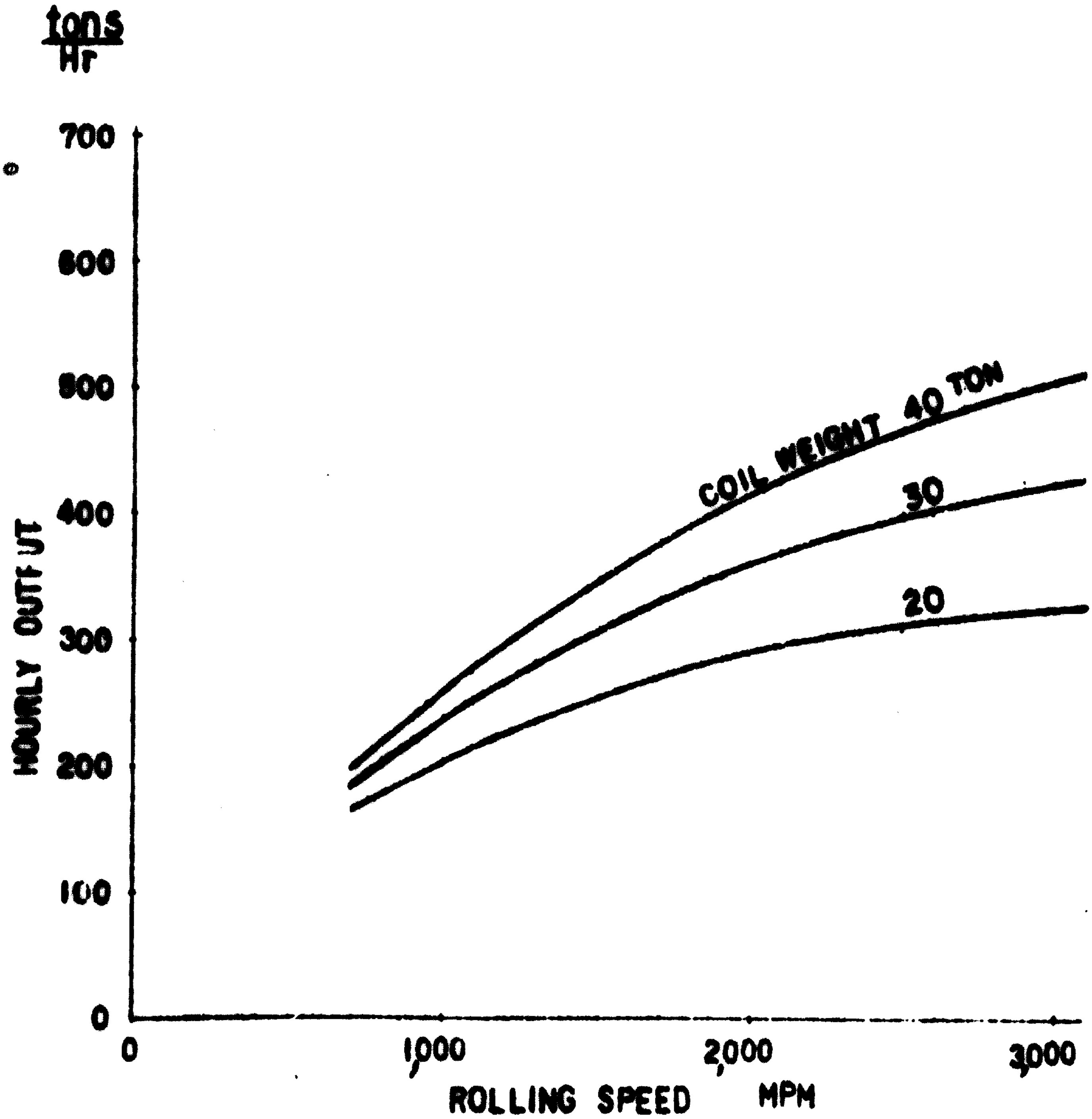


Fig. 14 - Relationship of 5-stand TCM production to maximum rolling speed

D. Raise Weight of Coil.

As stated in item B, increasing the weight of coils handled, which results in an increase in rolling time over preparation time, brings about an increase in production. Figure 15 illustrates an example. Actually since it requires not only changes in entry and delivery facilities but also changes in cleaning and annealing facilities, it does not have much merit as a method of expansion.

E. Convert to Fully Continuous Mill.

Raising production by increasing the weight of the coil and raising the mill speed has been referred to under the discussion of the tandem cold mill. Excluding the production of tin-plate, it is general that the one lot order is small and the average coil weight is 20 tons or less. From the practical standpoint it is difficult to raise the weight of the coil to 40-50 tons. Therefore in a tandem cold mill having variety in its production mix production does not rise. If at the entry side of the mill successive coils can be welded together and if it is possible to change the rolling schedule without stopping mill operations, then no-stop cold rolling is possible. These considerations have led to the invention of the fully continuous tandem cold mill.

The no-stop changing of rolling schedule, that is flying change of mill setting, has been made possible by the progress made in rolling theory, actual mill tests, and the application of the computer. In other words, flying mill set is now possible even if there is a difference in entry gauge, finishing gauge, or difference in strip width.

This method has the following advantages:

1. Reduction in roll damage owing to elimination of threading and tail-out operations.

2. Reduction in off-gauge material due to elimination of threading operations.

3. Increase in production due to continuous operation.

4. Reduction in personnel.

5. Reduction in production cost.

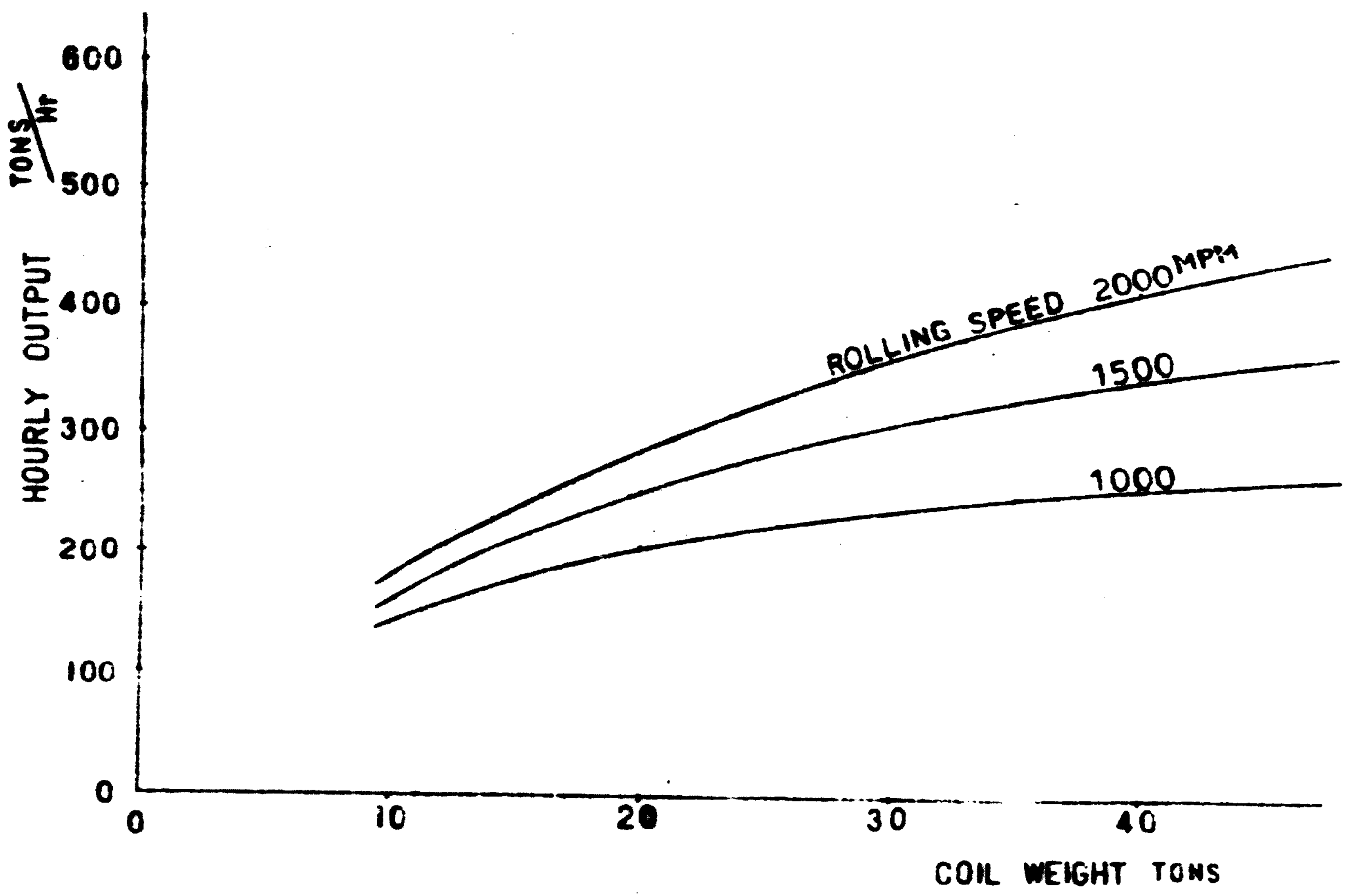


Fig. 15 - Relationship of 5-stand TCM production to coil weight

Generally speaking, if a conventional tandem cold mill is constructed initially and converted to a fully continuous mill, the additional cost will be about 30% of the initial cost. From the standpoint of rise in production and reduction in operating costs this increase in capital investment in worthwhile.

CONCLUSION.

It is very rare that at the outset of operation a strip mill plant achieves maximum production due to the following factors:

1. Development of markets.
2. Troubles and adjustments of mill facilities that arise durly initial operation.
3. Limitation in demand for the initial products.

This leads to consideration of incremental expansion which permits expansion of the plant as the need arises as the most appropriate capital investment method. Needless to say, as a basis for this type of planning it is imperative that the layout planning, from the beginning, be based on the most efficient production of the final required production level.

This paper has discussed incremental expansion of the plant from the standpoint of production, however, needless to say, similar thinking must be applied to the control system, such as: automatic coil handling system, automatic temperature control system and computer control systems.

It is hoped that this paper will be of assistance in the effective planning and design of an incremental expansion plan.

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