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Moscow, USSR, 19 September - 9 October 1968

D-6-2

CONTROL OF STRIP TENSION IN ELECTROLYTIC TINNING LINES [1]

by

K.T. Lawson
United Kingdom

D01298

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[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.

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by

Dr. K. T. Lawson
United Kingdom

SUMMARY

1. Introduction

In the last twenty years the operating speed of electrolytic tinning lines has increased from speeds of 800 f.p.m. to present day speeds in the order of 1,750 f.p.m. In the earlier ETL's strip was pulled through the processing sections by means of a bridle at the exit end of the line and often conductor rolls and sink rolls were not driven. As operating speeds increased it became necessary to drive the sink rolls and conductor rolls and at the same time some attention was paid to the manner of load sharing between the various drives in order to reduce scratching and marking of the strip surface and prevent excessively high strip tensions which lead to more frequent strip breakages and consequent down-time on the line.

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

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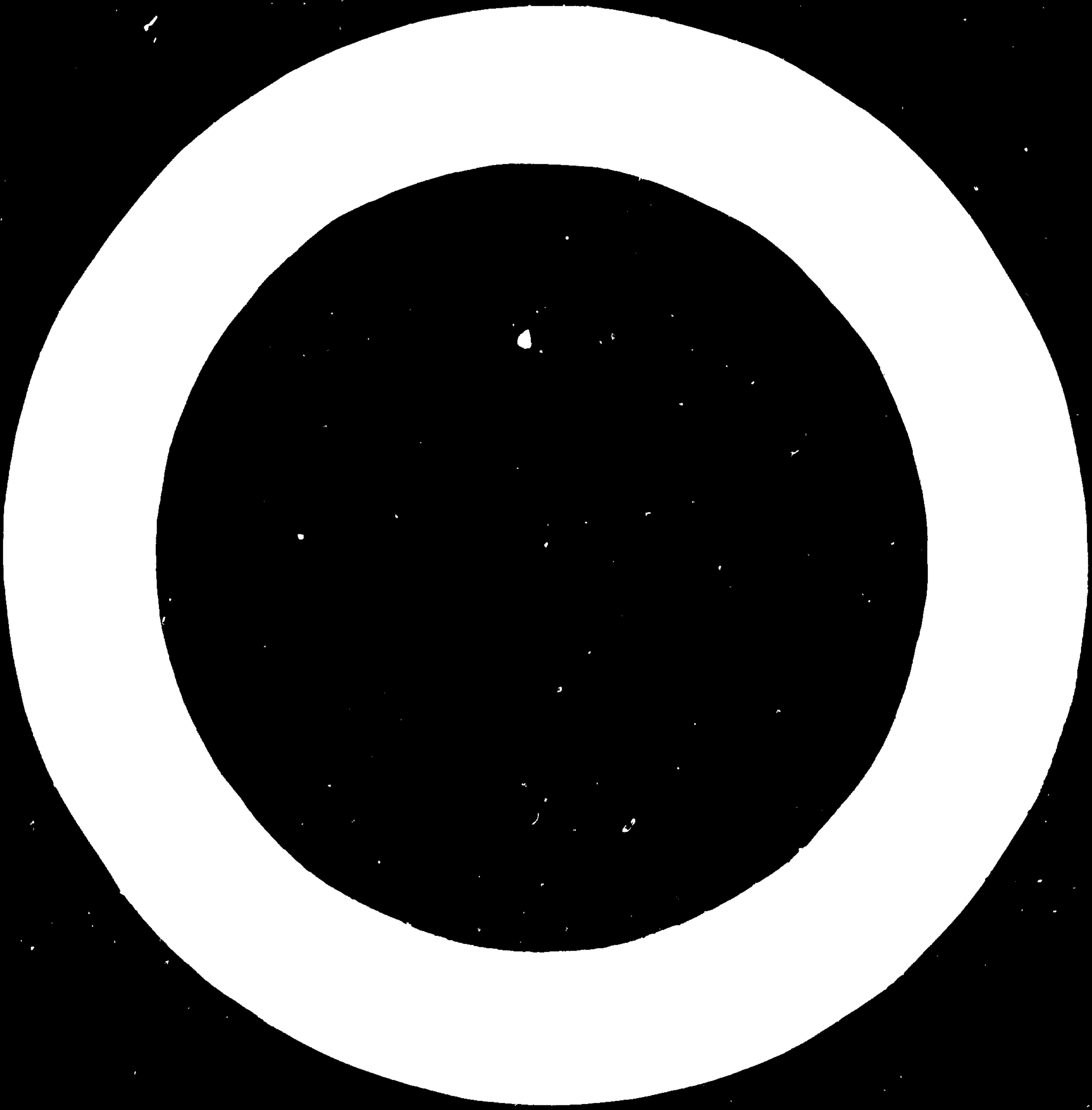

An ETL installed by Head Wrightson in 1961 had drives to sink and conductor rolls of 5 H.P. corresponding to a line speed of 1,500 f.p.m. A later line installed in 1965 had 5 H.P. drives on the sink rolls and 7½ H.P. drives on the conductor rolls, again corresponding to 1,500 f.p.m. line speed. Such drives were consistent with current practice and experience at that time. These lines were not fitted with tensiometers for direct indication of strip tension but during the commissioning period The Head Wrightson Machine Company took the opportunity to record motor horsepowers for various line operating conditions and it was possible to make a fairly accurate analysis from these recorded horsepowers of the strip tensions in different sections of the line. The results showed that strip tensions could occasionally rise to give high values of the order of 5,000 to 6.000 lbs. line tension, whereas desired values of line tension are of the order of 2,000 lbs., this line tension being considered adequate to maintain good tracking of the strip and adequate positioning of the strip between the plating anodes.

Recent lines in the USA have included an intermediate bridle immediately after the plating section and before the reflow section in order to minimise strip tension within the reflow section where a high proportion of breakages occur. These recent lines also include tensiometers which give a direct indication of strip tension and these show that strip tensions do in fact fluctuate considerably during accelerating conditions and that line tensions are still unduly high in certain sections of the line. This paper examines resistance to motion of strip in an ETL, analyses the traction required on conductor rolls, and examines a preferred method of controlling the output torques of the drive motors to Conductor Rolls. The most significant result of this investigation is to show that the current practice of putting 10 H.P. at 1,500 f.p.m. drives onto conductor rolls is not adequate and that 15 H.P. drives are recommended. Use of tensiometers to control strip tension is desirable.

2. Strip Drag in Process Tanks

Viscous drag in tanks consists of:-

(a) Drag at the squeegee or snubber rolls.
(b) Viscous drag on immersed strip.
(c) The squeegee effect of stripping off the boundary layer of water moving on the strip when it contacts the sink roll.

Tests were carried out at Head Wrightson Research and Development Division in order to measure drag on strip. Tests were carried out with tinplate [illegible] wide which was pulled around a sink roll and between squeegee rolls. Liquid level was varied during these tests and also strip speed was varied up to 1,[illegible]00 f.p.m. The difference in strip tension between the entry and the exit to the process tank was recorded by means of tensiometers; the difference in strip tension being equal to the drag on the strip. Measurements taken during these tests were analysed and the results have been used to predict strip drags in a typical ETL, in which maximum strip width is taken as 38" and the immersed length of strip from liquid level to centre line of sink roll is 7 feet. Conductor roll diameters are taken as 24", sink roll diameters are taken as 18" and face widths are taken at 46". Table I gives values for strip drag at various line speeds up to 1,750 f.p.m.

As a check with measured drags, strip drag was calculated theoretically from data given in "Fluid Dynamics and Heat Transfer" (Knudsen-Katz, University of Michigan Press), and theoretical results agree well with the measured values. Measurements were also taken of motor currents on an ETL and the total tractive effort of the drives was equated to strip drag owing to viscosity, friction in bearings, etc., as given in table I; agreement was satisfactory. It is felt therefore that the tractive effort required to pull strip through processing tanks can be assessed quite adequately from the figures given in table I.

3. Helper Drives

Strip is pulled through a processing tank partly by the tractive effort applied by the bridle at the exit end to the processing section and partly by the helper drives on conductor rolls and sink rolls. If there were no helper drives, then the pulling bridle would have to exert the whole of the tractive effort required and strip tension just prior to the pulling bridle would be very high. In order to minimise strip tension it is necessary to apply sufficient tractive tension it is necessary to apply sufficient tractive effort by the helper drives. Operating experience on ETL's has shown that sink rolls have poor contact with the strip, presumably there is a water film between the strip and the roll, and so sink rolls cannot be relied on to apply any significant tractive effort to the strip. The helper drives to the sink rolls are therefore designed to overcome friction in the roll bearings and roll surface drag owing to viscosity only. The tractive effort required to pull strip through a processing tank must therefore be applied by the conductor roll, and in addition to overcoming friction in roll bearings and seals, etc., the drives to conductor rolls must also overcome the effect of viscous drag on the strip. Snubber/squeegee rolls are used to remove liquid from the strip to prevent carry-over and to ensure good electrical contact between the strip and the conductor roll. The resistance to motion of the snubber rolls owing to bearing friction and the squeegee effect of stripping off the boundary layer of water moving with the strip has also to be overcome by the helper drive to the conductor roll.

The total drag due to bearing friction and viscous effects is totalled in table I, in order to determine the tractive effort required from the helper drive to the conductor roll at various line speeds. The required horsepower of the helper drives is also calculated and the recommended size of motor in terms of horsepower is also given allowing an efficiency factor of 85% to take account of loss in gears, etc.

Figure one is a graph showing how the tractive effort from the conductor roll helper drive varies with speed and the strip width. The graph also contains a curve showing the required horsepower for 38" wide strip and also a graph of the rated motor horsepower assuming that a 10 H.P. motor at 1,500 f.p.m. is used and that the motor runs at a constant output torque over the whole speed range.

It will be seen from table I and figure 1 that 12½ H.P. is required for line speeds of 1,500 f.p.m. and allowing an efficiency factor of 0.85 means that a 15 H.P. motor will be required, which is much higher than anything previously used in ETL's.

4. Method of control for helper drives to conductor rolls

In order to prevent build-up of strip tension in different parts of the ETL it is necessary to make the helper drives compensate exactly for the drag on the rolls due to friction and viscosity. It has been common practice to regulate the helper drives to give constant torque throughout the speed range. However table I shows clearly that motor torques on conductor rolls should be made to vary from values equivalent to 87 lbs. drag to 277 lbs. drag over the speed ranges to 1,500 f.p.m. when 38" wide strip is being processed. Strip drag decreases with strip width as shown in figure 1 so that the output from the helper drives should also vary with strip width as well as speed.

In order to minimise the build-up in strip tension when using a control system which gives constant torque throughout the speed range then it is necessary to choose some suitable mean value of strip drag over the speed/width range for the strip, and to design the motor to suit. At present motors are chosen to give full compensation at about 1,000 f.p.m. on full width tinplate. This has the effect that at 1,500 f.p.m. the motors do not apply sufficient torque and viscous drag on the strip and causes a build-up in tension which reaches a maximum at the exit section of the line just before the pulling bridle. Conversely at lower speeds than 1,000 f.p.m. the motor torque is excessive and tension builds up in the line to reach a maximum immediately after the drag bridle. This is indicated in figure 2.

Estimates of the actual strip tensions to be expected with this method of control are derived as follows:-

<u>Line Tension at 1,500 f.p.m.</u>

Assume the line is fully compensated at 1,000 f.p.m.

Assume there are 19 cleaning and plating tanks in the line.

At 1,500 f.p.m., Conductor Roll Drag	277 lbs.
Traction applied by motor (equivalent to Conductor Roll Drag at 1,000 f.p.m.)	180 lbs.
Excess Drag	97 lbs.

Therefore in 19 tanks the excess drag totals

19 x 97 = 1,850 lbs.

If the minimum strip tension for good tracking is 1,500 lbs. in the entry section, the strip tension will build up to a value of

1,500 + 1,850 = 3,350 lbs.

Line Tension at Low Speed

At 0 f.p.m. Conductor Roll Drag	87 lbs.
Traction applied by motor	180 lbs.
Excess Traction	93 lbs.

Over 19 tanks the excess traction provided by the motors totals 1,770 lbs.

If the minimum line tension is 1,500 lbs. and excess traction is 1,770 lbs. then the line tension builds up to a total of 3,270 lbs. in the entry section immediately after the drag bridle.

Figure 1 shows how line tensions vary with speed.

Other factors such as changes in strip width also cause additional variations in strip tension - reductions in width, for instance, cause reductions in strip drag.

5. Conductor roll helper drives regulated by tensiometers

Build-up of strip tension is undesirable because of the risk of breakage especially with double reduced tinplate. The reflow section of the line appears particularly prone to strip breakages. Recent ETL's have included an extra bridle immediately after the plating section and before the reflow section in order to reduce strip tensions within the reflow section. It is possible to reduce fluctuations in strip tension by regulating the helper drives to the conductor rolls so that they balance the effects of strip drag in each processing tank. Tensiometer rolls are always included in modern ETL's in order to indicate strip tensions. These tensiometer rolls can also be used to control the output of the conductor roll helper drives and these helper drives would be regulated in such a way as to minimise line tension fluctuations under all speed/acceleration conditions for the line. Positions of tensiometer rolls numbers T_2, T_3, T_4 and T_5 are indicated in figure 2 which shows a line including an intermediate bridle between the plating and reflow sections.

Method of control is as follows:-

Signal T[illegible] from tensiometer T[illegible] could be used to monitor back tension applied by the No. 2 bridle and thus control and maintain line tension T[illegible] at entry to the cleaning section at some desired value appropriate to the width and gauge of strip being run. Signals T[illegible] and T[illegible] would be compared and the conductor roll helper drives would be monitored as a group by the signal value T[illegible] - T[illegible] so that the helper drives torques would be controlled to give T[illegible] - T[illegible] = 0, i.e. line tension would be kept constant in the clean/pickle/plate section.

Bridle No. 3 is speed controlled.

Tensiometers could be used in much the same way to control tension in the reflow/chemical treatment section. Tensiometer T_4 situated immediately after the intermediate bridle No. 4 would adjust the output of bridle No. 4 to achieve a predetermined line tension value at position T_4. The signal difference T[illegible] - T_4 would be used to monitor the helper drive group in the reflow section to achieve a minimum value for T[illegible] - T_4 and thus limit tension variations within the section between bridle Nos. 3 and 4.

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It is expected that larger drives, of the order of 1[illegible] H.P. at 1,500 f.p.m. will be applied to conductor rolls on future ETL's and that tensiometer control will be introduced. If tensiometer control proves entirely successful, then the intermediate bridle now being included between the plating and reflow section, can be eliminated.

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Method of control is as follows:-

Signal T_2 from tensiometer T_2 could be used to monitor back tension applied by the No. 2 bridle and thus control and maintain line tension T_2 at entry to the cleaning section at some desired value appropriate to the width and gauge of strip being run. Signals T_3 and T_2 would be compared and the conductor roll helper drives would be monitored as a group by the signal value $T_3 - T_2$ so that the helper drives torques would be controlled to give $T_3 - T_2 = 0$, i.e. line tension would be kept constant in the clean/pickle/plate section.

Bridle No. 3 is speed controlled.

Tensiometers could be used in much the same way to control tension in the reflow/chemical treatment section. Tensiometer T_4 situated immediately after the intermediate bridle No. 3 would adjust the output of bridle No. 5 to achieve a predetermined line tension value at position T_4. The signal difference $T_5 - T_4$ would be used to monitor the helper drive group in the reflow section to achieve a minimum value for $T_5 - T_4$ and thus limit tension variations within the section between bridle Nos. 3 and 4.

The advantages of tensiometer control are:-

(a) They automatically compensate for changes in strip drag owing to speed variations.

(b) They compensate for changes in strip drag owing to width changes.

It is expected that larger drives, of the order of 15 H.P. at 1,500 f.p.m., will be applied to conductor rolls on future ETL's and that tensiometer control will be introduced. If tensiometer control proves entirely successful, then the intermediate bridle now being included between the plating and reflow section, can be eliminated.

TABLE I

H.P./DRAG FOR CONDUCTOR ROLL

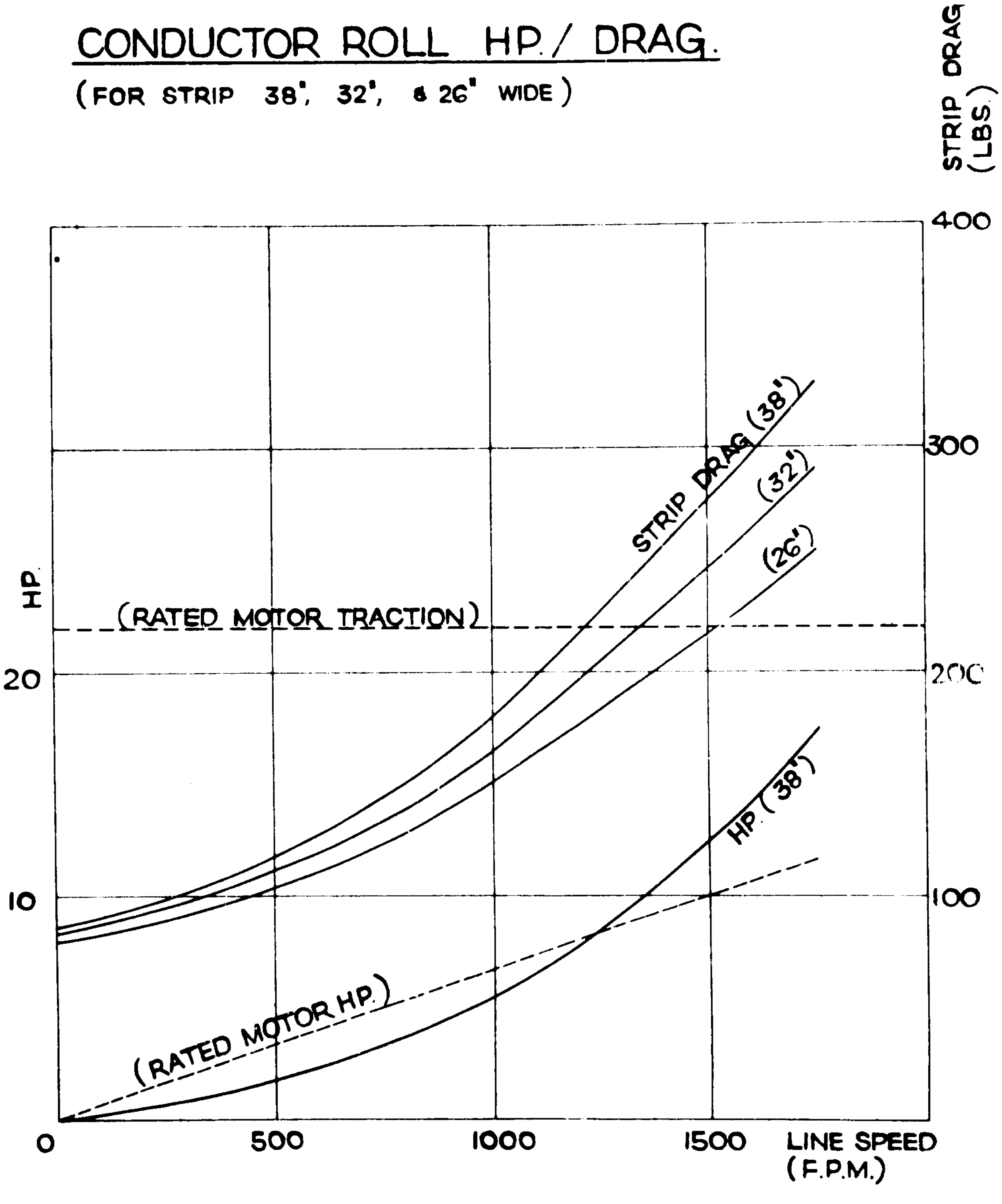
Line Speed	0	500	1,000	1,500	1,750	f.p.m.
a) Strip Drag (14'-0" x 38")	0	15	56	120	156	(lbs.)
b) Sink Roll and Squeegee Drag on Strip	0	15	37	70	86	(lbs.)
c) Conductor Roll Bearing Friction Drag*	40	40	40	40	40	(lbs.)
d) Snubber Roll Bearing Friction Drag**	47	47	47	47	47	(lbs.)
Total Drag	87	117	180	277	329	(lbs.)
HP $\left(\frac{\text{Roll Drag x Line Speed}}{33{,}000}\right)$	0	1.8	5.5	12.6	17.5	H.P.
Motor HP $\left(\frac{\text{Roll Drag x Line Speed}}{33{,}000 \times 0.85}\right)$	0	2.1	6.5	14.8	20.5	H.P.

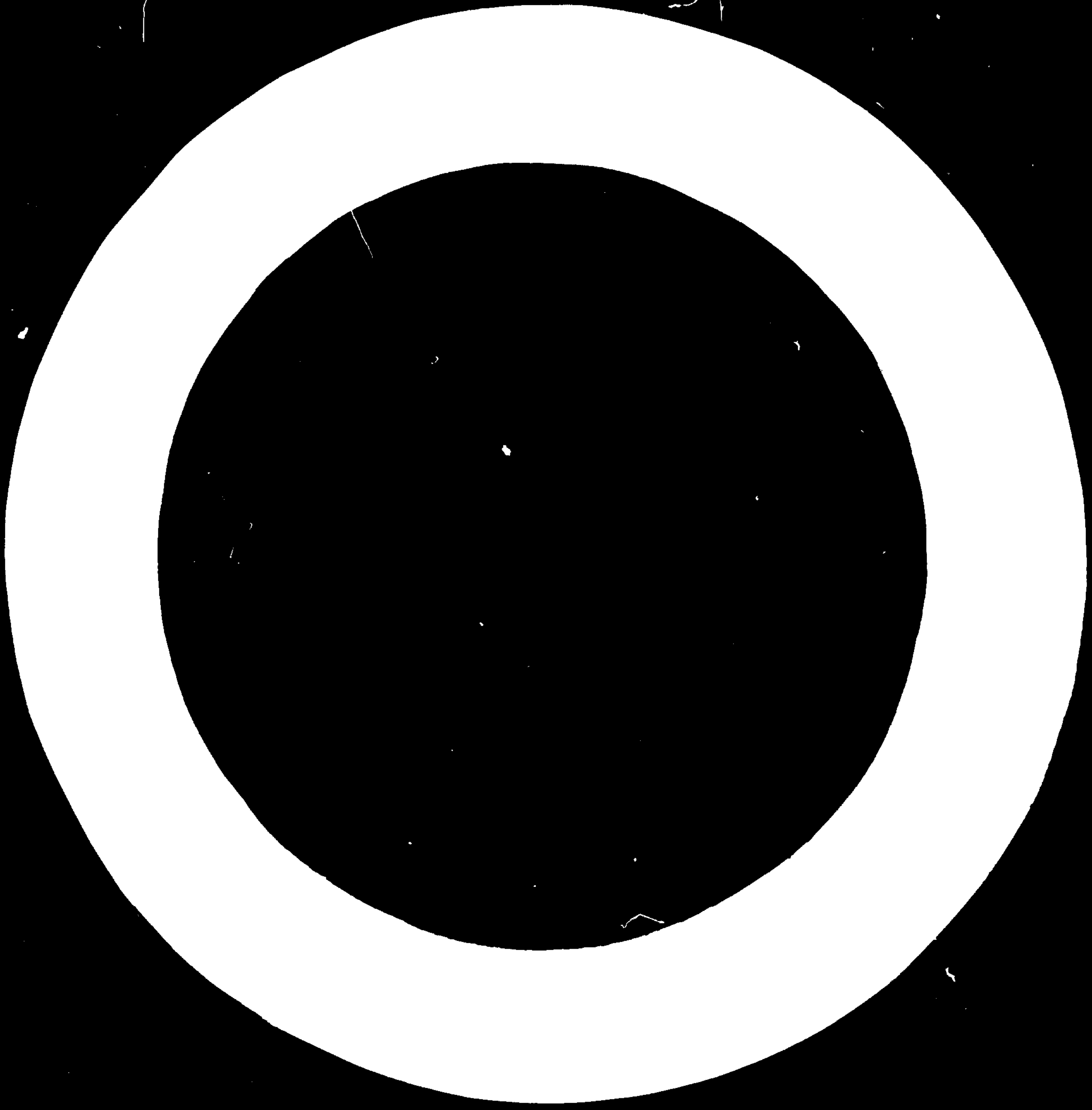
---

* Based on 1,500 lbs. strip tension; weight of roll 3,000 lbs.; bearing friction $\mu = .02$; and bearing diameter = $\frac{1}{3}$ x roll diameter.

** Based on Snubber Roll pressure 75 lb/in and $\mu = .02$

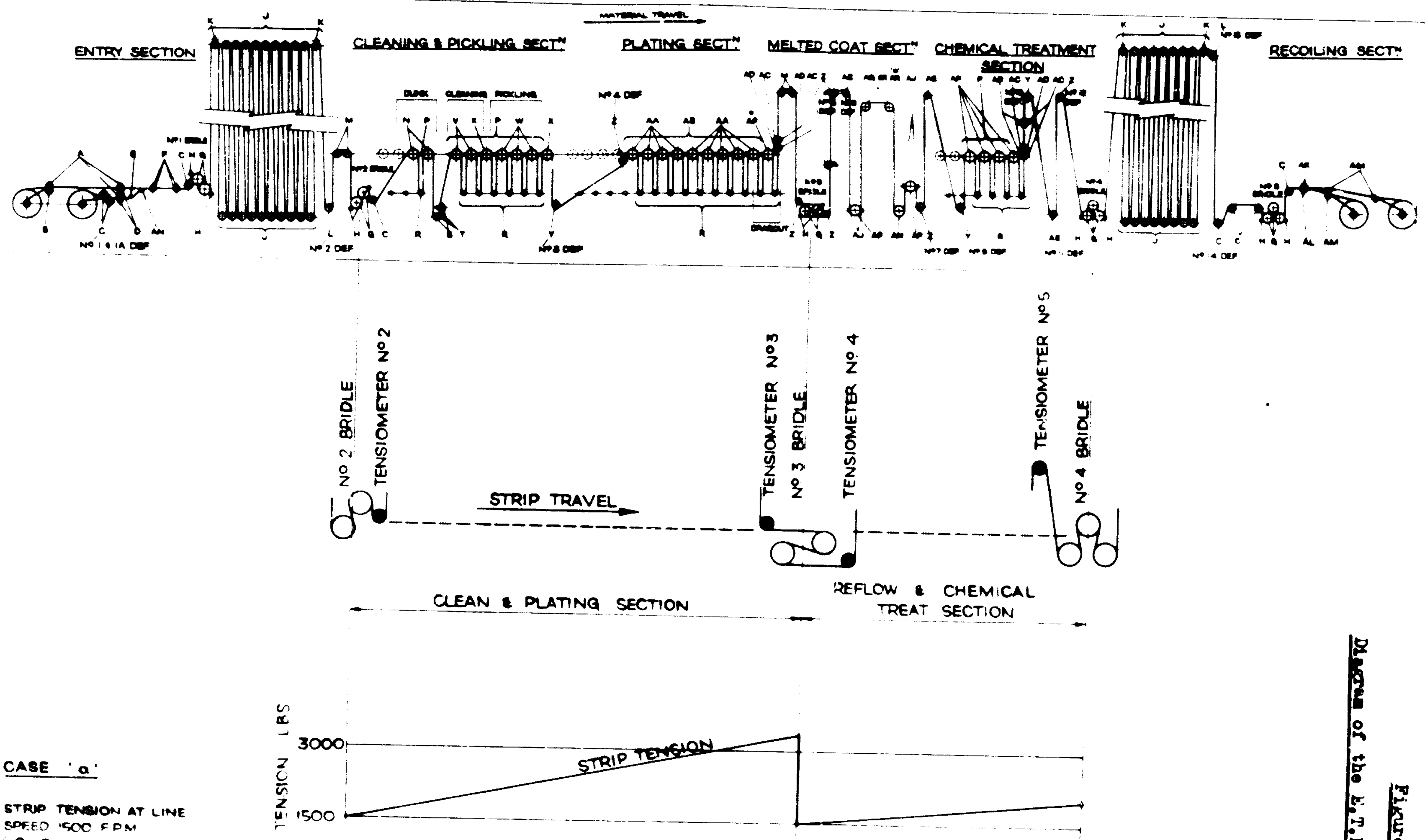
Figure 1


CONDUCTOR ROLL HP./ DRAG.
(FOR STRIP 38", 32", & 26" WIDE)
STRIP DRAG (LBS.)
400
300
200
100
HP.
20
10
0
500
1000
1500
LINE SPEED (F.P.M.)
STRIP DRAG (38")
(32")
(26")
(RATED MOTOR TRACTION)
HP. (38")
(RATED MOTOR HP.)



Figur

Diagram of the E.T.

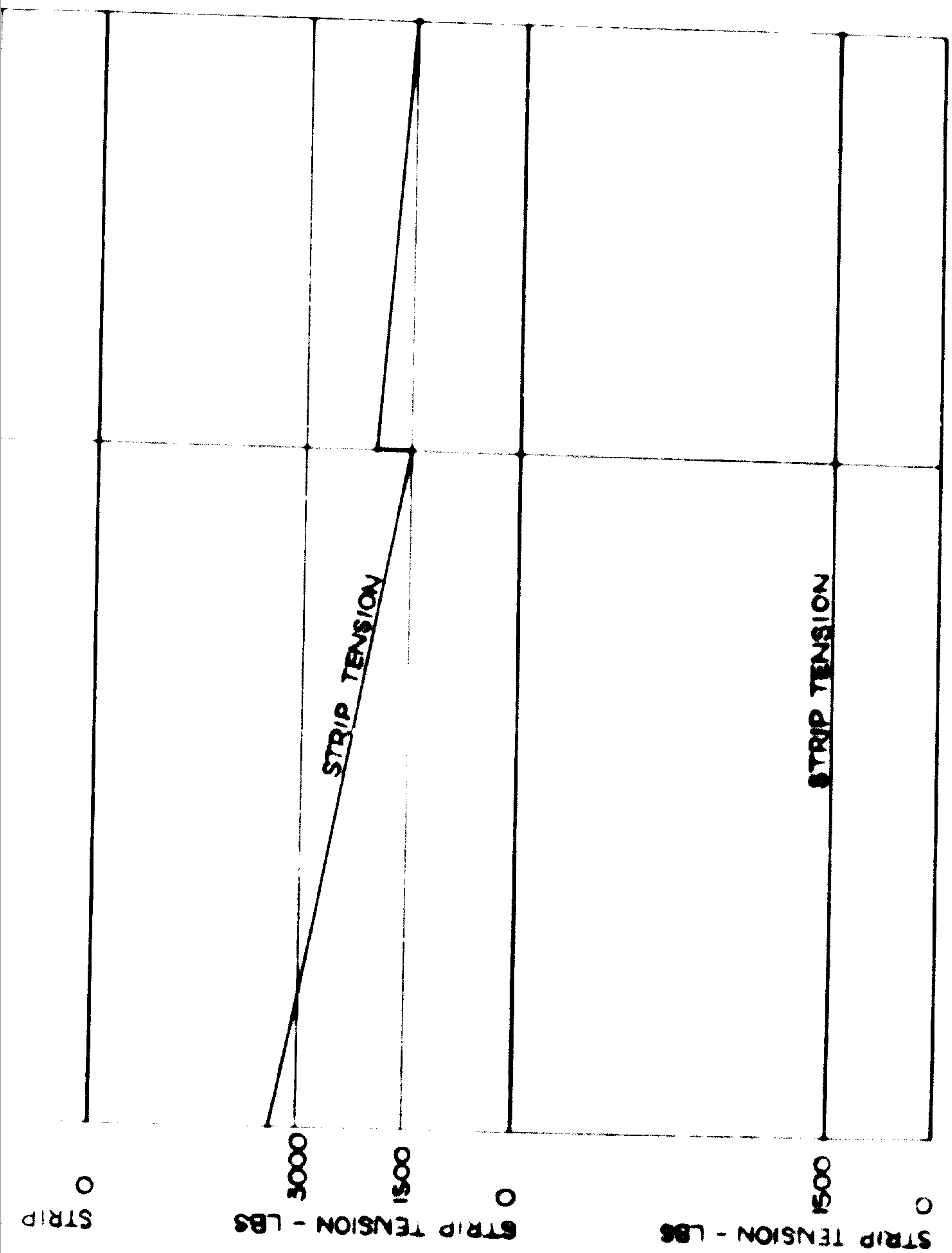


CASE 'a'

STRIP TENSION AT LINE
SPEED 1500 F.P.M

re 2

.L. process sections



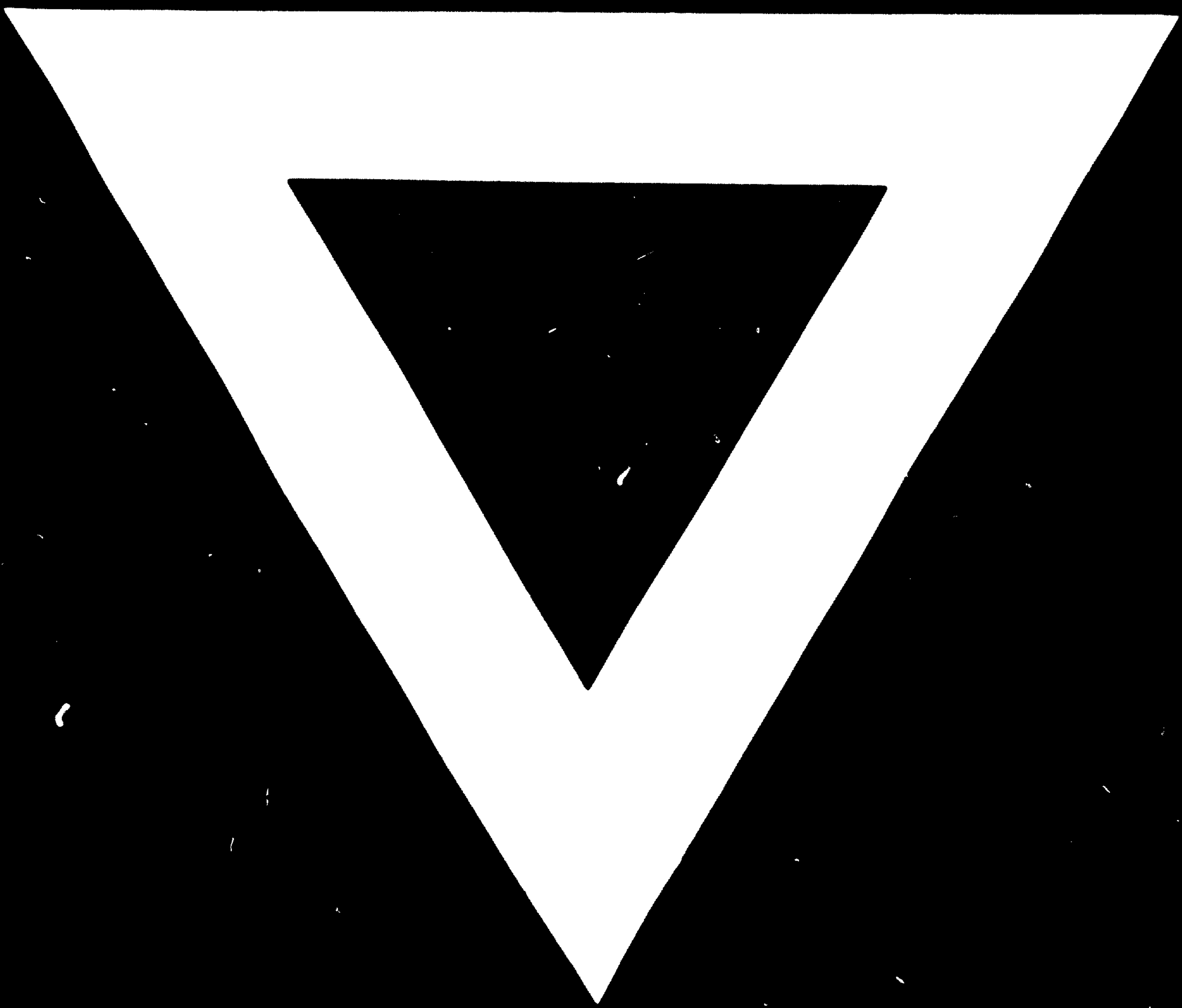
(10 HP @ 1500 FPM MOTOR AND CONSTANT TORQUE CONTROL)

CASE 'b'

STRIP TENSION AT LOW SPEED (10 HP @ 1500 FPM MOTOR AND CONSTANT TORQUE CONTROL)

CASE 'c'

STRIP TENSION CONSTANT AT PRESET VALVE - ALL SPEEDS (15 HP MOTOR AND TENSIOMETER CONTROL)



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