

T H E S I S

TEST OF THE TURBINES OF A SMALL HYDRO ELECTRIC PLANT OWNED
AND OPERATED BY SCHLOSSER LEATHER COMPANY, WALLAND, TENN.

For the Degree of

BACHELOR OF SCIENCE IN MECHANICAL ENGINEERING

and

BACHELOR OF SCIENCE IN ELECTRICAL ENGINEERING

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The plant is located on the Little River in the water gap of the Chilhowie Mountains, about 25 miles from Knoxville, Tenn. The principal use of the power developed by the plant is to drive the machines of a tannery operated by this company. The buildings of the tannery and the small town are lighted by the plant also. The company operates a steam plant to carry part of the load, especially at times of low water.

The plant consists of two S.Morgan Smith, inward flow turbines, one 27 in., and one 36 in., geared to a horizontal jack shaft which is belt-connected to a 2300 volt, 115 K.W., 3 phase, 60 cycle, generator. The power, as taken from the generator, is transmitted to the tannery where it is stepped down to the proper voltage for the machines.

The Dam is built of concrete with a concrete apron below, and is set at right angles to the direction of flow of the stream. The head gates are immediately at one end of the dam and perpendicular to it. Water is carried to the power house in an open headrace. The maximum head at the power-house is about 12 ft. An accompanying diagram shows plainly the location of dam,,power house, etc.

In testing the turbines the power developed was absorbed in a Prony brake on driving pulley of jackshaft, except in test of overall efficiency, in which case the power taken from the generator was absorbed in a water rheostat.

The head on the turbines, in each test, was measured by the use of surveyors level. A level rod was set up in the head race with its zero point a known distance above the datum plane, the

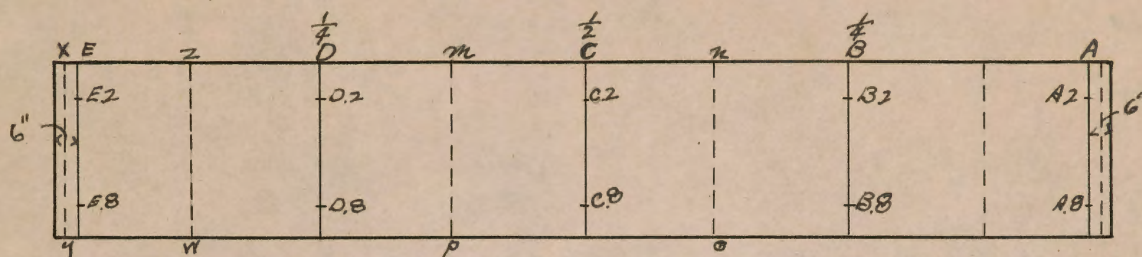
same was done in the tail-race. The total head in each case was the difference between the readings of the level rods, plus the difference in elevation of the zero points of the two rods.

The discharge for each series was measured by means of a current meter in the head-race. The forebay immediately above the power house was approximately rectangular in cross section, which fact made use of current meter simpler. The sides of the head-race at this point being of concrete a temporary bridge was laid across for the operators to stand on.

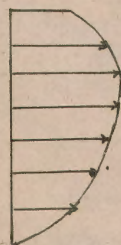
It was decided to take current meter observations at the center of the stream, at one fourth the way across, and at 6 in. from each side. These points were plainly marked on the bridge and established vertical sections. In each vertical section readings were taken at 0.2 and 0.8 the depth except as indicated later in the overall efficiency test. The current meter was fastened to a rod which was marked off into feet and tenths of feet. By means of this rod the current meter could be held at any depth desired. Since it was necessary to lower the instrument to the same depth so many times it was found convenient to mark these points on the rod by nails, so that by lowering the rod until a nail rested on the bridge, the meter would be at a known depth. In this way 0.2 and 0.8 the depth were worked on the rod. On an accompanying sheet is shown a cross section of the head-race with vertical and horizontal sections outlined.

Finding the discharge by means of the current meters

As stated above the cross-section of head-race was laid out in five sections and the sections lettered A, B, C, D & E, thus,



Observations were taken in each vertical section at 0.2 and 0.8 depth. The average of the velocities found at these points was taken as the velocity for that section. For instance the velocity for the area M, N, P, O, was taken as the average of the velocities found at C.-.2 and C.-.8. So, for each sectional area in using current meter three observers were required. Beginning at A, the current meter was lowered to A.2, a reading taken, then A.8, then to B and on across, the observer with stop watch taking at each point, the time required for two ticks or ten revolutions of current meter. Thus finding the number of revolutions per second the velocity was readily found from calibration curve. A cross-section of forebay was drawn to scale and laid off into sections as shown in diagram. The area of each section as M, N, O, P or X, Z, Y, W was determined with planimeter. Knowing the area A, of a section and the velocity V, in that section the discharge was $Q = A V$ in cu. ft. per sec. The total discharge was equal to the sum of the discharge in the different sections.



Th the test for overall efficiency observations were made at 6 points in each vertical section. To find the average velocity in a section; a cross-

A section of head-race was drawn to scale with vertical sections laid out and at points thereon where observations were made velocities to scale were plotted as horizontal lines as shown in diagram and on page . The area of each diagram thus drawn divided by the depth would give the mean abscissa or average velocity in that section. This area was determined with planimeter. The discharge in each section was found as above, being the product of the area of section and velocity therein in feet per sec., and the total discharge the sum of the discharges in the different sections.

The test was made in five runs viz:

No. 1. Friction load 36" turbine

" 2. 27" turbine $1/2$ gate opening

" 3. 27" " $3/4$ " "

" 4. 36" " 1 " "

" 5. Overall efficiency, both turbines operating.

In each run, gate opening, head, load on turbine, and turbine speed were kept constant. Tests were made on 27" turbine, (runs 2 and 3) at $1/2$ and $3/4$ gate opening; on 36" turbines (run 4) at full gate opening. Two runs were made with generator connected; one with generator on open circuit to determine friction load, and one with generator loaded to determine overall efficiency. It was found that the 36" turbine at $1/4$ gate opening brought the generator up to normal speed on open circuit. This corresponds to a test of this turbine at $1/4$ gate. In test of overall efficiency both turbines were running at full gate and the power developed by generator absorbed in a water

theostat. The head on turbine tho was not sufficient to load the generator to its full capacity. The load on generator was about .75 full load. The overall efficiency is the relation between power developed by generator to that delivered by the water expressed as a percent of the latter, and was found to be 55.5%. It was found that it required 46.85 H.P. as delivered by the water to overcome the friction of the gears, belt and bearings of turbines and generator.

In runs number 2, 3 and 4; that is, tests of 27" turbine at $1/2$ and $3/4$ gate and 36" turbine at full gate, the belt to generator was removed and Prony brake put in place.

The load was balanced on a pair of platform scales and kept constant for each run. By adjusting the brake, normal speed of the turbine was maintained and was the same for each run.

In constructing the brake the lever arm was made long so that the product of the speed in revolutions per minute and the load in pounds, at the end of the lever arm, divided by 1000 would give the horse power direct. ?

Observations of load and speed were made every 5 minutes during a run and the average of these taken as the load and speed for that run. So that the delivered horse power during a run was the product of this average load and average speed, divided by 1000. The theoretical horse power of the power in the water was found in this way; the discharge in cu. ft. per second was multiplied by the head in feet and the product by 1134. .1134 is $\frac{62.34}{550}$. Efficiency is

Brake H.P.-----
Theoretical H.P.

Section	Friction load		Run #2.		Run #3.		Run #4.		Overall Efficiency.	
1	Veloc.	Disc.	Veloc.	Disc.	Veloc.	Disc.	Veloc.	Disc.	Veloc.	Discharge
A	.220	2.53	.347	7.34	.295	6.23	.400	8.44	.900	18.99
B	.280	10.75	.300	11.50	.370	14.20	.755	29.00	1.200	45.88
C	.185	7.40	.350	14.00	.507	20.28	.900	36.00	1.200	48.00
D	.260	10.07	.210	8.14	.420	16.25	.755	29.00	1.200	46.44
E	.180	3.98	.355	7.85	.240	5.31	.100	2.21	.80	17.68
=====										
	34.73		48.83		62.27		104.85		177.00	

Run	Turbine	Gate Opening	Discharge	Total Head	Horse Power		Efficiency
					Theoretic	Brake	
Friction Load	36"	1/4	34.73	11.88'	46.85	0,	
#2	27"	1/2	48.83	11.88'	66.88	39.06	58.5%
#3	27"	3/4	62.27	11.74	83.00	53.78	64.7%
#4	36	1	104.85	10.47	124.5	60.47	48.5%
Overall Efficiency Both		1	177.00	10.74	215.94	120.0	55.5%

Calibration of Current Meter.

In the test a Price current meter was used.

In the calibration a still water basis was necessary. The storage reservoir of Brookside Cotton Mills was found convenient for this purpose; the sides being built of concrete and uniform, a straight-away of 100 feet was easily laid out.

In this calibration three operators were necessary, for convenience we will call them A, B & C; while A carried the current meter, walking at a uniform rate thru the 100 feet marked off, B with a stop watch observed the time of A's going that distance, while C, also with a stop watch observed the time for a certain number of clicks of current meter.

The card which supports the current meter was fastened to a long stick, so that the operator by carrying the stick in his hands and walking along the side of reservoir could pull the current meter thru the water.

From the time required to go the 100 feet the velocity in feet per second was calculated, also from the time required for a number of ticks the corresponding current meter revolutions per second was known.

Several observations were made and at different velocities. For instance a run was made thru a range of velocities with A carrying the current meter and B and C the stop watches; then B took the current meter and A and C the stop watches, and so on, thus minimizing the personal error.

This calibration was compared with the table furnished and it

was found that for a given R.P.M. of current meter the velocities in each case ran a little higher.

In calculating the discharges the larger velocities were used. An accompanying sheet shows curves of the two calibrations, plotted between R.P.M. and velocities.

Conclusion.

In a careful consideration of the plant, its location and surroundings, and the results of this test, it becomes evident at once that the low efficiency found in the test must be assigned principally to lack of storage capacity. In the location of the head-race, power house and tail-race the water available is used to best advantage but anything near maximum head cannot be maintained for any length of time simply because the stream will not furnish the water without ample storage. This fact should have been taken into consideration in the design of the plant by building a higher dam and the reason given by the owner for not doing this was the fact that it would flood a ford some distance up stream from the dam. This ford though could have been fixed with a saving in the end to the owner, either by filling in the ford or what would be better still, bridging the stream.

But, since the plant has already been built and conditions as they exist must be dealt with, there are two ways in which the storage capacity of the plant might be increased. One way would be the construction at a suitable place upstream, of a large storage reservoir; another would be the placing of flashboards on the dam itself.

The former would be more successful, tho more expensive, both in construction and operation, for it would require a large expenditure for dam, gates, etc. and would require an operator stationed there all the time to let out the water as needed at the power house. The gates could be operated automatically by electricity but this would mean a larger outlay for equipment, etc.

As to how much this would increase the efficiency of the plant, would depend on the size of the reservoir.

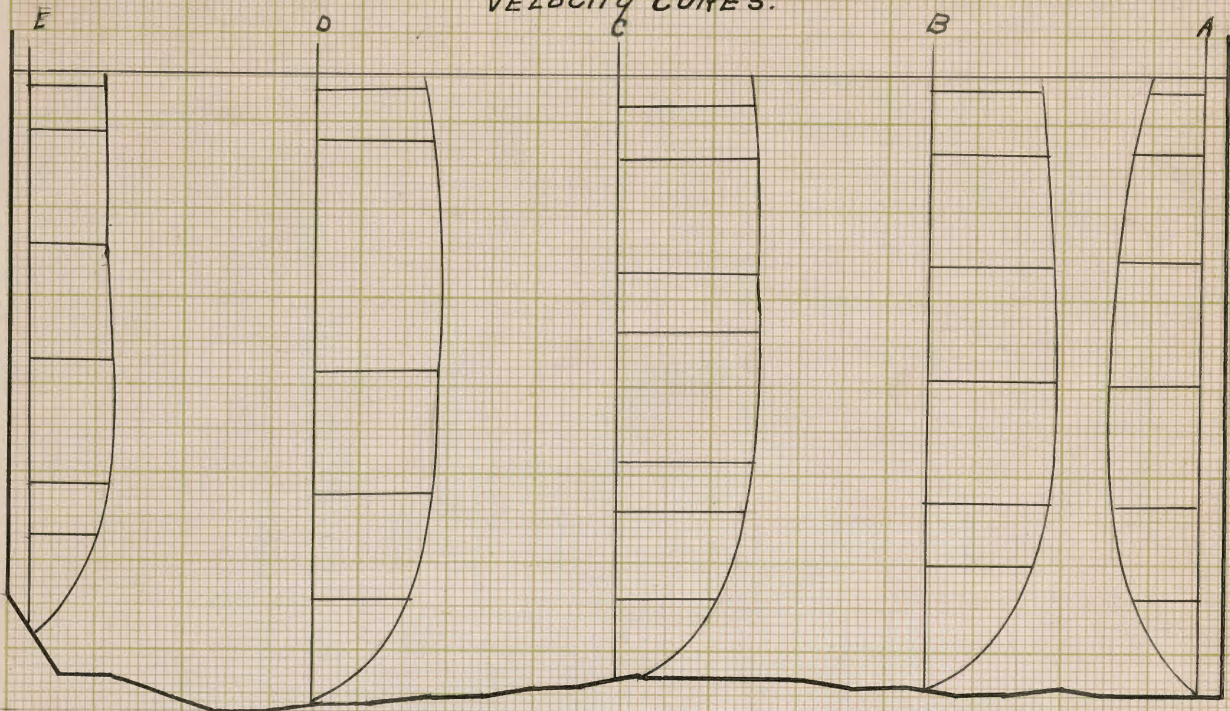
The latter way, the placing of flash-boards on the dam, would be a simple and comparatively inexpensive way to increase the efficiency of the plant very much. Placing flasheboards on the dam would in effect be the same as increasing the height of the dam. They would of course lack the stability of a higher dam and would necessarily have to be let down at times of very high water. This would require a means of letting them down from the shore but this could be easily done. As to how much flash-boards would increase the efficiency of the plant would depend on how high above the dam they could be built and this would depend on the stability with which they could be fastened to the dam, and on the factor of safety used in designing the dam.

From the results of the test of overall efficiency, it will be noticed that an efficiency of only 55.5% was obtained, It will be noticed too, that the generator ran at only about 75% full load. In making the test full load current was maintained but the turbine speed allowed the voltage to drop down to $3/4$ normal full load volt-

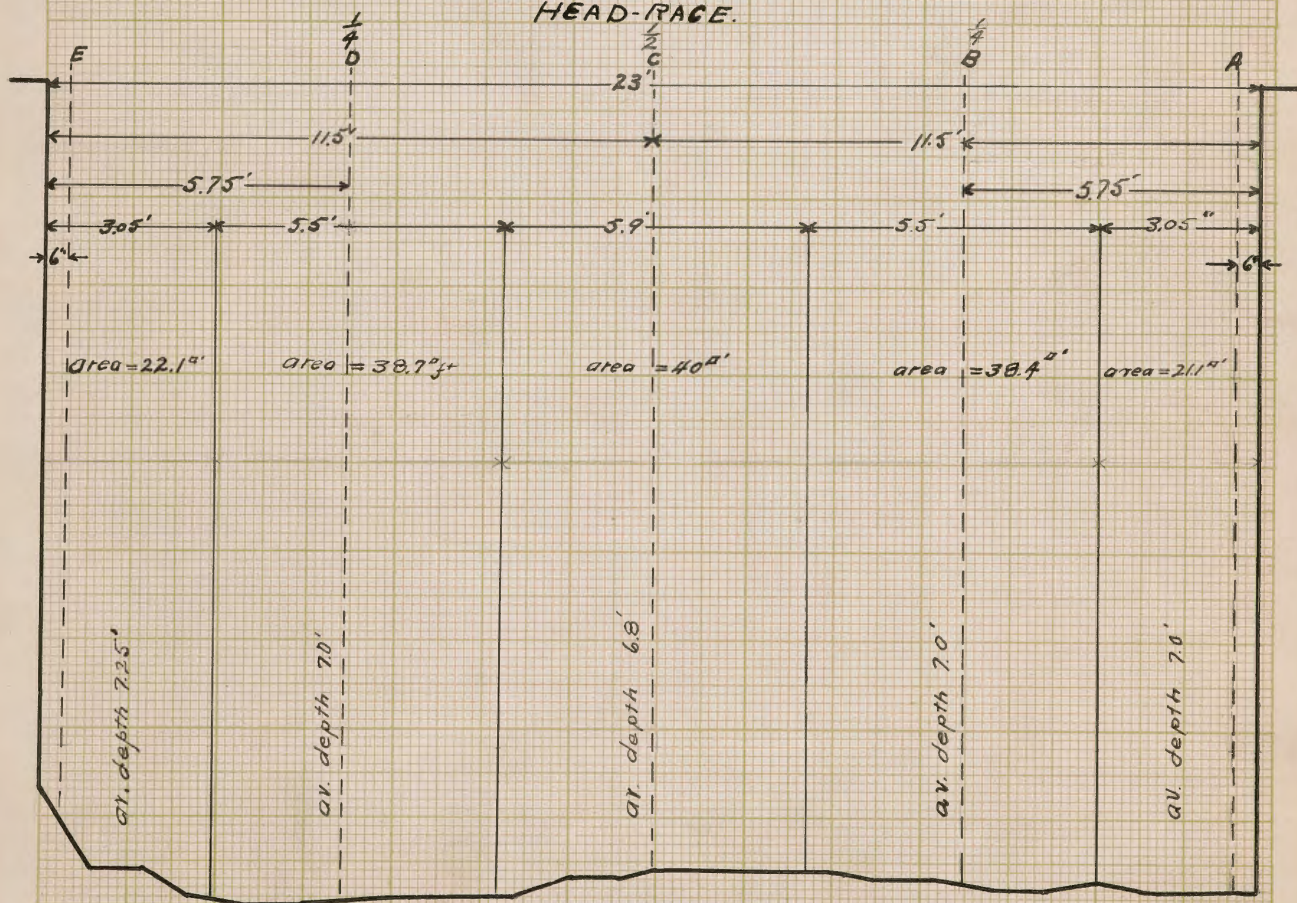
age. Were the maximum obtainable head at the power house kept constant the 36" turbine alone would carry the load and take less water.

Two feet is about the limit to which the head might be increased by putting flash-boards on the dam, but this would increase the capacity of the plant probably 20% and its efficiency from 5 to 10%.

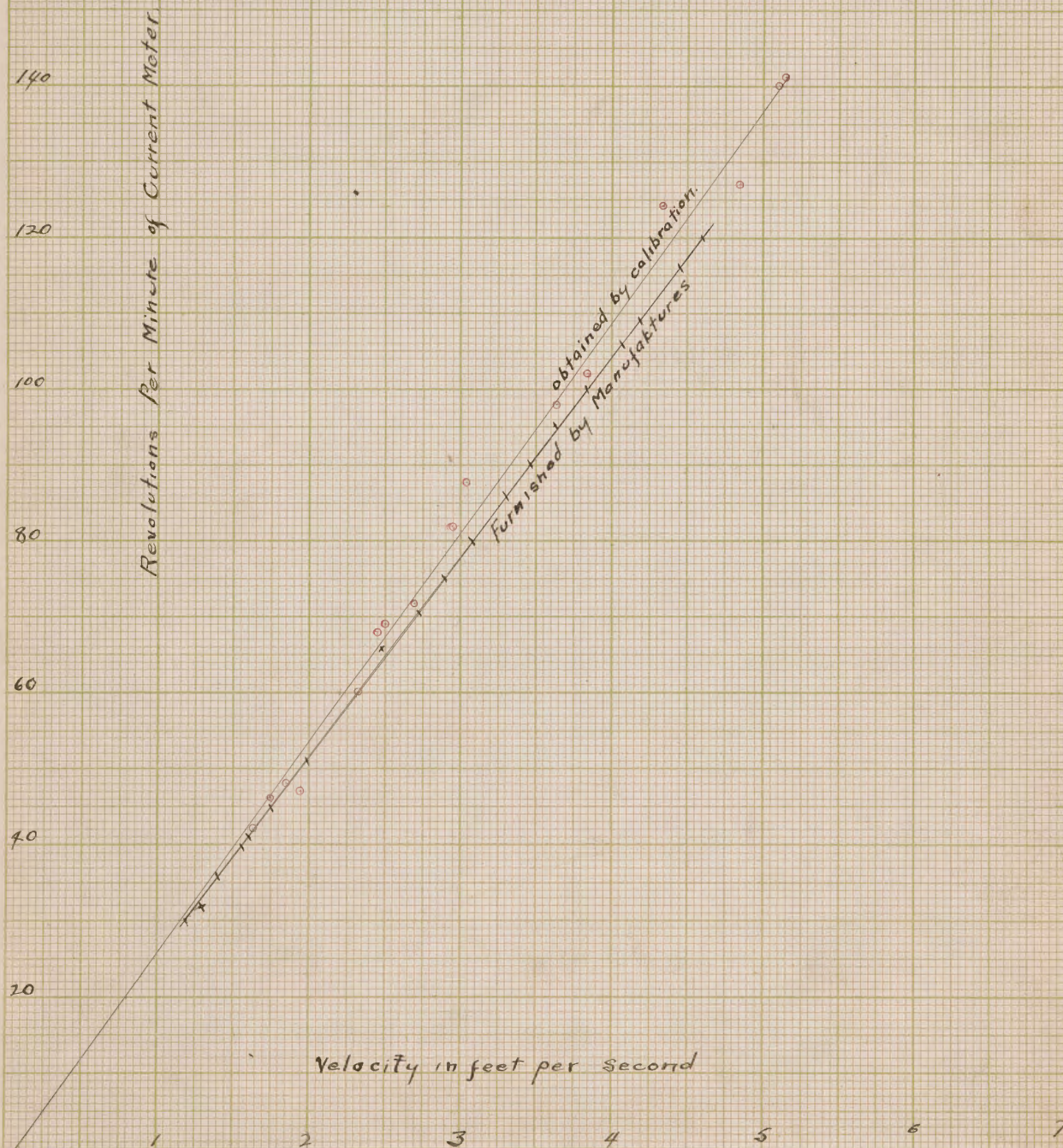
Overall Efficiency VELOCITY CURVES.



CROSS-SECTION OF HEAD-RACE.



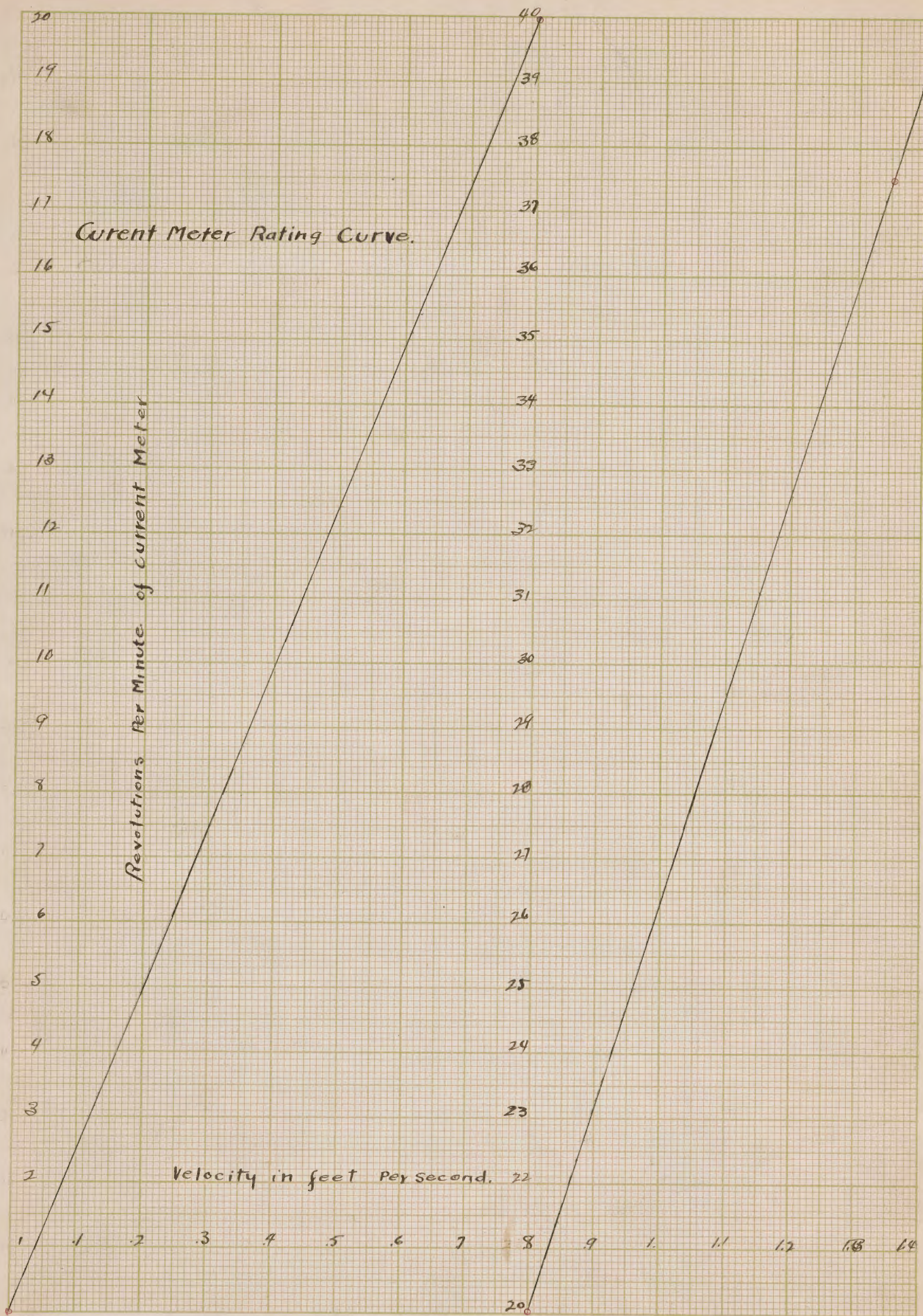
Current Meter Rating Curve.



Current Meter Rating Curve.

Revolutions Per Minute of current Meter

Velocity in feet Per Second.



Scale 1" = 120'

