The Calibration of a Transmission Dynamometer, and Tests with same on Engine Lathe.

by

C. S. Dearborn.

A transmission dynamometer is an instrument by means of which the power in a rotating shaft may be measured during its transmission through a belt or other connection to another shaft, without being absorbed.

The dynamometer in question is of the Brigg's belt type, and was built by the Mechanical Engineering Department of the Kansas State Agricultural College, from drawings made by the author in 1902. Preliminary trials showed a stiffness in the action of the weighing mechanism that precluded reliable results, and changes in the construction were accordingly made for the purpose of doing away with this defect.

Its essential features consist of two pulleys over which runs a belt transmitting the power to be measured, and a weighing mechanism by means of which the difference between the tension in the tight portion of the belt and that in the slack portion may be determined.

The two pulleys A and C, Fig. 1, are keyed on parallel horizontal shafts running in brass boxes, which are supported by standards mounted on the rigid bed. The belt B travels in the direction indicated, C being the driven pulley, and the lower portion of the belt the tight side. Two triangle-shaped castings, one on each side, are pivoted on the ball bearings on the standards at E, and are rigidly connected at F and G by two hardened shafts on which the two guide pulleys rotate. Any movement of this rocking frame is therefore in a vertical plane, and is transmitted through the links H and J to the scale beam. A lever K, fixed to a shaft supported in ball bearings, connects with these links and carries the balance weights L and the dash-pot rod M. The weights may be moved toward or from the fulcrum, and are thus made to balance the weight of the links, guide pulleys, rocking frame and belt. The dash-pot consists of a cylinder containing oil, in which works a loose-fitting piston past which the oil may flow more or less freely. Its purpose is to lessen the amplitude of vibration of the scale beam.

The design is such that when the scale beam is horizontal, the balance lever also is horizontal, the two guide pulleys are equidistant from the center-line of belt pulleys, the one directly above the other, and each of the four portions of belt between pulleys makes an angle of $75^\circ - 31'$ with the perpendicular.

Let the balance weights be so adjusted that when the dynamometer is not running the scale-beam balances, reading zero pounds; then clearly at all points in the belt B the total tension is sensibly the same. But when a belt transmits power by its frictional resistance against the face of a pulley over which it passes, there must necessarily exist a difference in tension in the belt at its two points of tangency, equal to the turning force exerted upon the pulley.

Let the belt run in the direction indicated by the arrow, and exert a turning force P on the driven pulley C. Also let the scale-beam be kept in balance by means of the poise or by hanging known weights on the long arm of the scale-beam.

Let T_1 = total tension in belt at point 1.

and Let T_2 = total tension in belt at point 2.

Then $P = T_2 - T_1$

The two guide pulleys are fitted with case-hardened bushings which run on hardened shafts; also, that component of the belt tension producing pressure between guide pulley and shaft is comparatively small; hence it may be assumed that that the frictional resistance in these two bearings is negligible, from which it follows that every point in the tight side of the belt between the points of tangency with the pulleys A and C has the tension T_2, and every point in the slack side the tension T_1.

In Fig. 2, using the same notation, the vertical component of the belt tension T_2 and the equal resistance T_2, is seen to be

$$R_2 = 2T_2 \cos (75^\circ - 31') = \frac{T_2}{2}$$

$$\text{Likewise, } R_1 = 2T_1 \cos (75^\circ - 31') = \frac{T_1}{2}$$

The resultant of these two components is a force $R_2 - R_1$ acting vertically downward. Since the forces acting on the weighing mechanism are in equilibrium this downward force is opposed by an equal force W acting vertically upward at the knife-edge in the short arm of the scale-beam. The ratio of the arms of the scale-beam being known, W is determined from the known weights on the long arm. The weights used and the graduation of the beam are such that the readings give W direct, in pounds.

$$\text{Then } W = R_2 - R_1 = \frac{T_2 - T_1}{2} = \frac{P}{2}$$

$$P = 2W$$

Then the horsepower delivered by the belt is

$$HP. = \frac{\text{Force (lbs.) x distance (feet per minute)}}{33000}$$

$$= \frac{2W \times \pi D \times \text{R.P.M.(driven pulley)}}{33000}$$

where D is the diameter of driven pulley plus the thickness of belt, on the assumption that the neutral axis of the belt lies midway between the two surfaces.

$$\text{Since } \frac{2\pi D}{33000} \text{ is constant}$$

$$HP. = K \times W \times \text{R.P.M.}$$

In using the dynamometer it is more accurate as well as more convenient to balance the weighing mechanism by means of weights L while the belt is running at constant speed either without external load or with any constant load. Any increase in the load is then shown on the scale-beam, and the necessity of subtracting the power required to overcome the internal friction of the dynamometer itself, as well as the given load is thereby avoided.

Calibration of the Dynamometer.

The purpose of the work of calibration was to find the law according to which the results as calculated from the data given by the dynamometer vary from the truth, and to determine that constant or that factor by which the calculated results must be affected in order to make correction for the error due to such variation.

Because of its simplicity as well as its accuracy, the Prony brake method was adopted as the best by which the power delivered by the belt could be measured. The calibration, then, consists in a comparison of results calculated from dynamometer data with results calculated from brake data.

The apparatus used, (see Figs. 1 and 3) included the dynamometer, a Prony brake, a Fairbank's platform scale reading to quarter-ounces, a brake-pulley cooling device and a Starrett revolution counter.

The Prony brake is of hard maple constructed as shown and fitted to the crowned pulley N, which is keyed to the shaft driven by belt pulley C. The two clamp wheels, with the springs, provide means for adjusting the lower brake shoe so that any desired amount of pressure between brake and pulley may be attained. The knife-edge O resting on the scale platform, has its upper edge placed in a shallow groove cut across a steel plate screwed to the brake, which prevents any change in length of brake arm.

In order to prevent excessive heating of brake, pulley, shaft and bearing, it was found necessary to provide means for cooling the brake pulley. Figure 3 shows the device used. Cold water under a head of a few inches flows through the supply tube into the enclosed space S inside the brake pulley rim, and after taking up more or less of the heat generated by the friction, passes out through the exit tube. The open casing Q, which is stationary, extends over the exit tube a sufficient distance to retain the issuing water, which then flows off through the drain tube. The sleeve which acts as a bearing for the end of the supply tube extends into the casing Q so that in case the supply of water is too great the surplus is emptied inside Q. By adjusting the supply head and fixing the exit at the proper distance from the central opening, any desired quantity of water may be brought in contact with the pulley rim, and a uniform low temperature maintained. This tends to prevent the thinning of the grease on the brake-shoes and its consequent loss, as well as any undesirable increase of friction between pulley and brake after the brake-load has been balanced.

The method of operation was as follows. The dynamometer was belted to an electric motor running at practically constant speed, and leveled. The platform scale was also leveled in position as shown, and balanced at zero pounds with the knife-edge in place on the platform.

After the dynamometer had been running long enough to attain constant working conditions, the brake was placed on the pulley, the rubbing surfaces being well lubricated with machine oil. The lower shoe hanging clear of the pulley the brake was balanced, by means of weights suspended from its short arm, in such a way that its slight contact with the knife-edge O did not materially affect the equilibrium of the brake scale-beam. The dynamometer scale was then balanced at zero pounds by adjusting the weights L, oil being continuously applied to the pulley face while balancing to reduce the friction load to a minimum. While running under these conditions the number of revolutions of the driven shaft during a period of five minutes was taken.

The brake scale was then arranged to indicate one pound weight on the knife-edge O, and the brake clamp wheels were tightened until the scale balanced. While the brake scale was thus balanced the dynamometer scale was brought to balance by means of known weights and the sliding poise. A run of five minutes was then made under these constant conditions and the total revolutions taken as before. In case the brake friction increased, thus throwing both scales out of balance, the clamp wheels were adjusted to maintain the balanced condition.

In a similar manner the readings of both scales, the duration of the run and the total revolutions of the driven shaft during the run were obtained as given in Calibration Log. Two series of readings at different driving speeds were made, the object being to have the scale readings of each series serve as a check on those of the other.

The power absorbed by the brake is obviously equal to that delivered by the belt to the driven shaft, due allowance for the friction at zero load having been made by balancing the dynamometer at that load, it being assumed that any change in this friction under greater loads is so slight as to be negligible in practice.

The formula for the power absorbed by a Prony brake is

$$HP_B = \frac{W_B \times 2\pi L \times R.P.M._B}{33000} = K_B \times W_B \times R.P.M._B$$

where W_B = brake scale reading in pounds,

L = length of brake arm in feet,

$R.P.M._B$ = revolutions per minute, of brake pulley,

K_B = brake constant $= \dfrac{2\pi L}{33000}$.

By this formula the values given in column "Brake horsepower," Calibration Log, were calculated. The corresponding values in column "Dynamometer horsepower" were calculated from the formula previously deduced,

$$HP_D = K_D \times W_D \times R.P.M._D$$

where the subscripts refer to dynamometer.

From a comparison of corresponding values in these two columns, it is seen that in no instance are they equal; but from the accompanying "Calibration Curves" it appears that, within the limits of error in observation, the ratio $\dfrac{W_D}{W_B}$ is constant. Hence

$\dfrac{HP_D}{HP_B}, \left(= \dfrac{K_D \times W_D}{K_B \times W_B}\right)$ is constant, and a factor introduced into the formula for the horsepower will therefore make proper correction for the dynamometer error. This calibration factor is obviously $\frac{HP_B}{HP_D}$. Its value for each reading is shown in Calibration Log, the average for each series being practically the same, i.e. 1.013, with a probable error in the third decimal place.

The formula then for computing the power transmitted by this dynamometer in its present condition is $HP = 1.01 \times K \times W \times R.P.M.$ A point that should be noted is in regard to the sudden increase in belt slip at reading 17, both series. The belt was new, with glued joints and in perfect condition. It had bee n well stretched before being joined and although no means for measuring the exact tension were at hand, it was apparently under a tension usual in practice. The section was 0."18 x 2".75, and at the given speed the belt should have a capacity of five horsepower, whereas it slipped at less than half this amount. A belt dressing was tried, but with no effect, since the belt was new. It is possible that the capacity of the dynamometer could be safely increased to that for which it was designed by shortening the belt. Since shortening the belt will not of itself affect any of the factors in the horsepower formula, and the decrease in thickness due to strain may be neglected, such a procedure will not materially affect the calibration factor for any powers within the limits reached. It is also to be considered probable that this factor will have the same value for the higher powers up to the maximum capacity of the dynamometer.

Tests on Engine Lathe.

A part of the lathe equipment of the College Shops consists of ten engine lathes of 14 inches swing. All are belt driven from countershafts in the ordinary way, these being driven from a line shaft which runs the entire equipment, a ten horsepower motor supplying the power.

The object of the tests was to determine, approximately, the gross power necessary to operate one of these lathes at its maximum capacity under the ordinary conditions of shop practice. The lathe chosen for the test was one of four built at the shops several years before, and although not in first class condition, represented fairly well the others of its size.

The dynamometer was driven in the same direction as when calibrated, by a three inch belt from the line shaft. After having been leveled, its scale-beam was brought to a balance by adjusting the weights L. The countershaft driving belt was then put in place on the small (brake) pulley of the dynamometer. (The diameters of the pulleys were such as to give the countershaft approximately the same speed that it had when belted direct to line shaft).

The lathe spindle and geared feed were then put in operation, with the work on centers. The scale was balanced and the reading noted, together with the revolutions per minute of the dynamometer pulley C, as given in Log of Machine Tool Test. From this data, the dynamometer constant and the calibration factor being known, the power required to drive the lathe running idle was calculated by the formula

$$HP. = 1.01 \times 0.0002556 \times W \times R.P.M.$$

as given in log.

The stock being turned true, its diameter was taken with calipers and scale. A cut was then taken, the tool being fed automatically by the screw-cutting mechanism. During this operation the scale-beam was balanced, and the revolutions per minute of lathe spindle and dynamometer were noted. The final diameter of stock was then found as before. These values, with the scale reading, are entered in their respective columns in the log.

In this manner the data given in the several log sheets was obtained, the different materials, cast iron, wrought iron and machinery steel being used for comparative purposes. The total horsepower is calculated as before, while the horsepower per cubic inch of metal removed per minute, which is the basis of comparison of the power required for different materials, as well as for different areas of cut, is obtained by dividing the computed horsepower for any given run by the cubic inches of metal removed in one minute during that run. The latter was calculated from the area of cut, mean diameter of cut and the revolutions per minute of stock. That is, cubic inches per minute = cut x feed x $\frac{\text{orig. dia.} + \text{final dia.}}{2} \times \pi \times R.P.M.$

The tool used in the tests was of self-hardening (Rex) steel, a diamond-nose with slightly rounded point, ground to angles approved by the shop foreman. For all the materials, the front clear- was about 10 degrees, the cutting edge being level with the centers and at an angle of about 60 degrees with the axis of the work. For the cast iron the cutting angle included between the two plane surfaces intersecting in the cutting edge was approximately 70 degrees. For the wrought iron this angle was reduced to about 65 degrees, and for two runs with the steel was reduced to 60 degrees. Care was taken to keep the tool sharp, and lard oil was applied freely when cutting wrought iron and steel.

The majority of the runs were made at that speed of lathe spindle that the cone pulley belt would maintain without excessive slipping. This belt was slack enough to shift readily by hand, and the speed was found to be considerably lower than has been found possible with self-hardening steels. The highest surface speeds for the different materials used were as follows:

Hard cast iron	-	15 feet per minute.
Soft cast iron	-	38 feet per minute.
Wrought iron	-	27 feet per minute.
Machinery Steel	-	31 " " " .

The number of times the tool required sharpening, even at these comparatively low speeds would seem to indicate that this particular tool was but little better than an ordinary water-hardened tool.

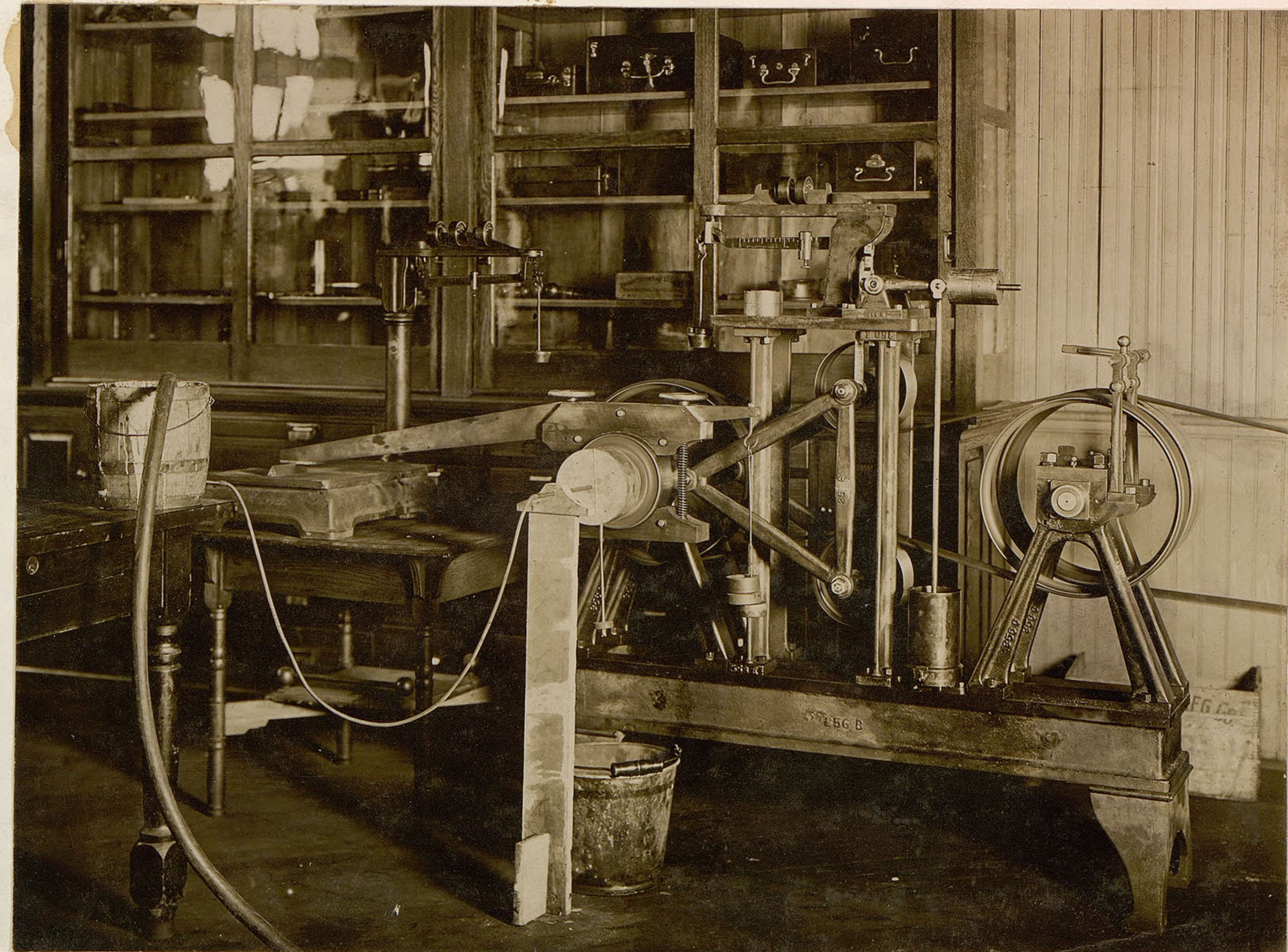
The results of the tests with the different materials, cuts and feeds are plotted as "Power Curves" with horsepower per cubic inch of metal removed per minute as ordinates, and depth of cut as abscissae. The curves are drawn so as to make an approximate allowance for the condition of the cutting edge of the tool. From these it will be seen that the gross power required varies with the material operated upon, the least being required for the soft cast iron, and more for the hard cast iron, wrought iron and machinery steel, in order. It is to be noted that the two heavy cuts in the machinery steel required less power than is indicated by the curve for a similar cut in wrought iron. This is undoubtedly due to the use of a more acute cutting angle of the tool for these two cuts, the effect of which is to lessen the power required, as long as the tool remains sharp.

These results agree substantially with those found by the Bickford Drill and Tool Company from tests (Amer. Mach. Jan. 14-21-1904) of power required in drilling these materials. This was to be expected, since there is no essential difference in the operations of drilling and turning as far as such tests are concerned.

A more important deduction from the results of these tests is that the heavier cuts are the more economical of gross power. This is to be expected, for the waste work is a much larger proportion of the whole work at light than at heavy cuts. Whether this law of greater efficiency at the heavier cuts holds true in regard to the net power, - the power delivered at the tool, - can not be satisfactorily determined from these tests, for the reason that the power lost in belt slip can not be determined from the data obtained.

From a consideration of the comparatively low cutting speeds which the excessive slip of the cone pulley belt made necessary, it is plain that the capacity of the lathe could be increased by the use of a tighter belt, and the efficiency also would be greater because of the reduced loss of power which would result from reduced slip.

It appears, then, from the log that the maximum power used by the lathe is approximately 0.8 HP. This value was reached in the test with wrought iron, surface speed 28 feet per minute, area of cut $\frac{3''}{32} \times \frac{1''}{32}$. It is to be noted that at this point (see Power Curves) the efficiency is the least for this series with the exception of one instance, in which the cut was made without oil, and which is therefore properly excluded from the comparison.



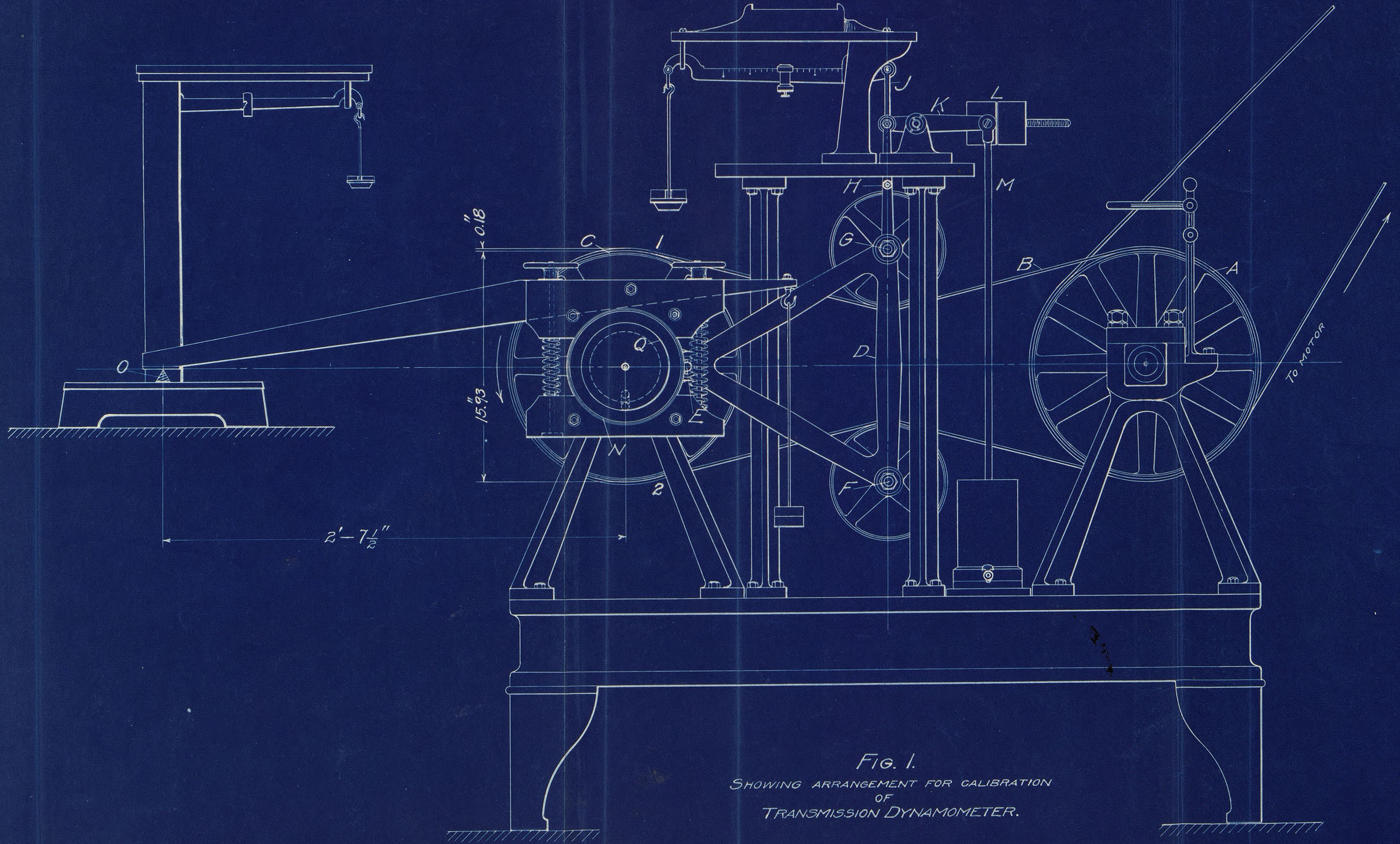


FIG. 1.
SHOWING ARRANGEMENT FOR CALIBRATION
OF
TRANSMISSION DYNAMOMETER.

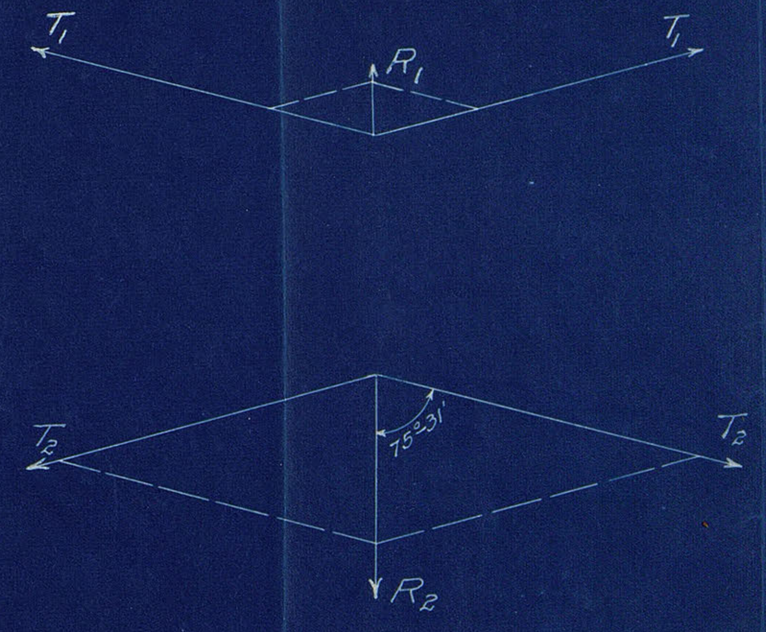


FIG. 2.

C.S.D.

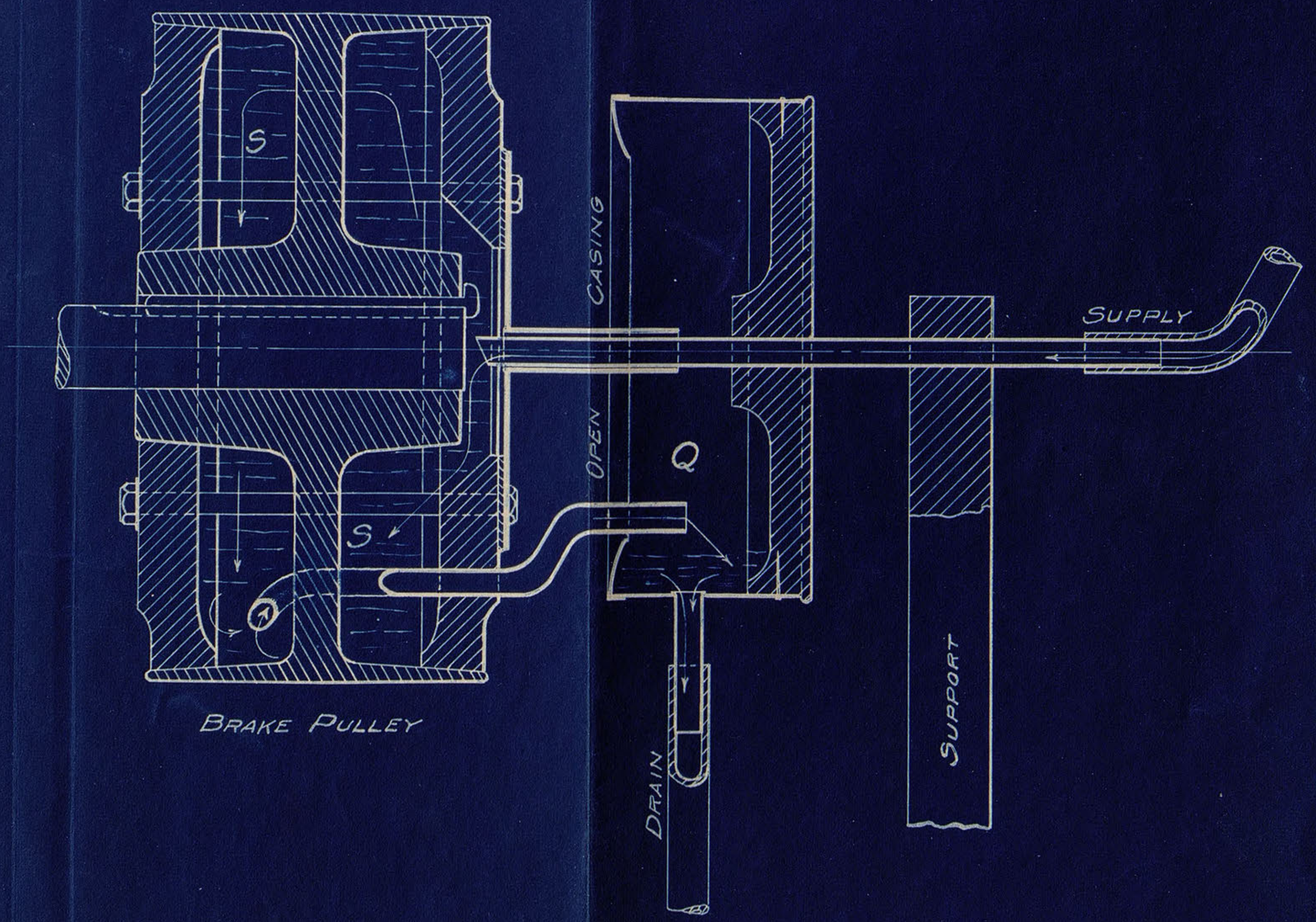


FIG. 3.
VERTICAL SECTION
SHOWING METHOD OF COOLING BRAKE PULLEY.

C.S.D.

DEPARTMENT OF MECHANICAL ENGINEERING, K. S. A. C.

MADE AT Manhattan-Kansas.
Mech. Eng. Laboratory.
ON Transmission Dynamometer.
DATE June 23-24-1904

CALIBRATION LOG

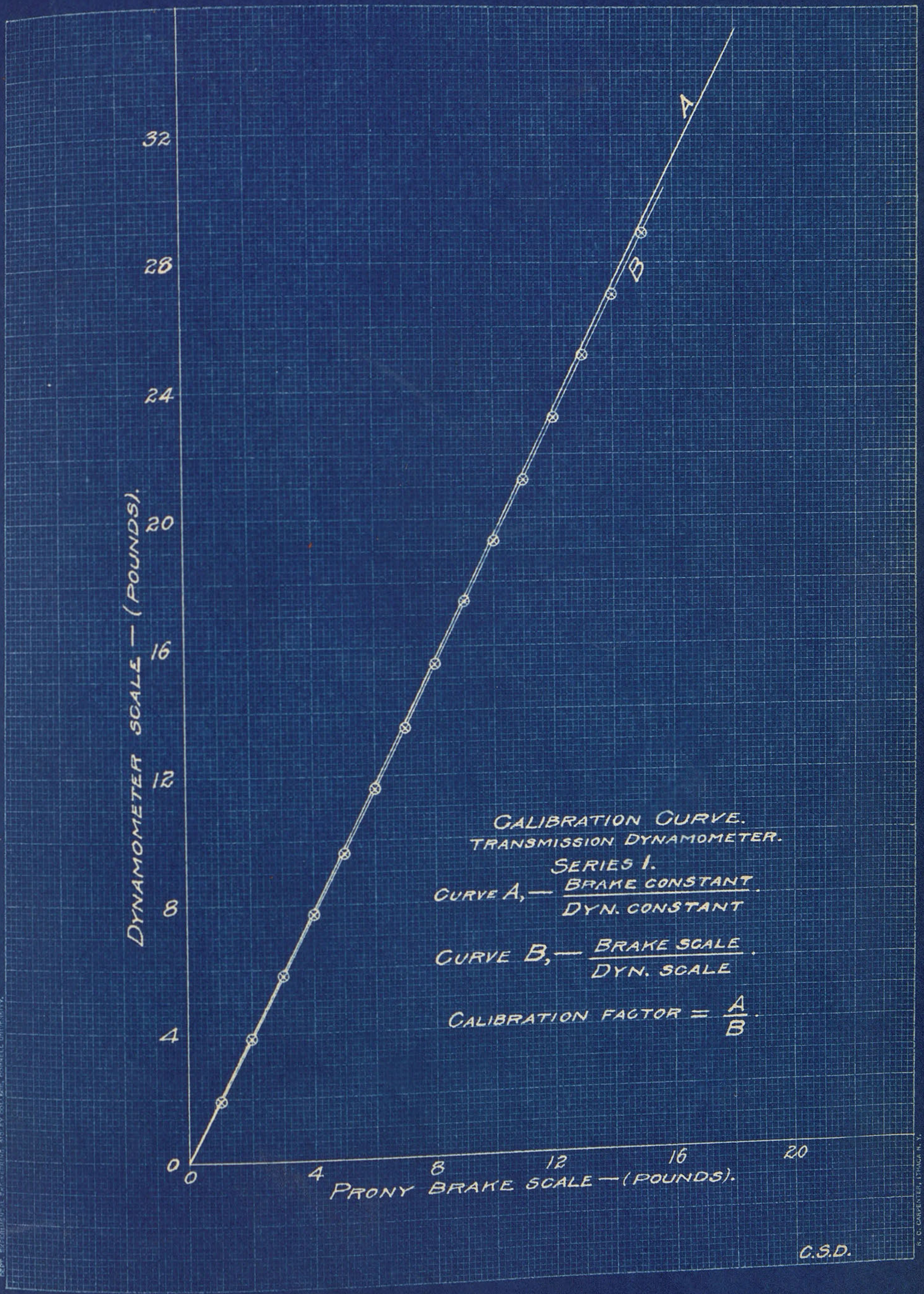
CONSTANTS

Length brake arm, 31.5 in. Diam. driven pulley, 15.93 in.
Brake constant, 0.0004998 Thickness of belt, 0.18 in.
Dynamometer constant, 0.0002556

OBSERVERS

C.S. DEARBORN.

No.	Duration. (Minutes)	Rev. driven pulley. Total	Per min.	Scales (pounds). Brake	Dyn.	Horse-power. Brake	Dyn.	Calibration Factor.	Remarks.
Series 1 – June 23.									
1	5	1800	360	0	0	0	0		
2	5	1795	359	1	1.93	.1794	.1770	1.013	
3	6	2148	358	2	3.85	.3579	.3520	1.016	
4	5	1775	355	3	5.80	.5323	.5265	1.011	In column "Dyn. Scale" there is a probable error in second decimal place, and in columns "Horse-power" and "Calibration Factor" in third decimal place.
5	5	1765	353	4	7.70	.706	.695	1.016	
6	5	1755	351	5	9.60	.877	.862	1.018	
7	5	1742	348.4	6	11.60	1.045	1.033	1.011	
8	5	1740	348	7	13.50	1.217	1.200	1.014	
9	5	1765	353	8	15.45	1.411	1.393	1.012	
10	6	2079	346.5	9	17.40	1.559	1.542	1.011	
11	5	1682	336.4	10	19.30	1.681	1.659	1.013	
12	6	1980	330	11	21.20	1.814	1.788	1.015	
13	5	1610	322	12	23.15	1.931	1.905	1.014	
14	5	1563	312.6	13	25.10	2.031	2.005	1.013	
15	6	1800	300	14	27.00	2.099	2.070	1.014	
16	5	1455	291	15	28.93	2.181	2.152	1.014	
17				16					Belt slip increased to 100 per cent.
	Average for Series 1							1.0136	
Series 2 – June 24.									
1	5	2790	558	0	0	0	0		
2	5	2750	550	1	1.93	.2749	.2713	1.013	
3	4	2180	545	2	3.85	.5448	.5365	1.016	
4	5	2705	541	3	5.80	.8112	.8021	1.011	
5	4	2148	537	4	7.72	1.074	1.060	1.013	
6	4	2140	535	5	9.62	1.337	1.316	1.016	
7	4	2120	530	6	11.55	1.589	1.564	1.016	
8	3	1572	524	7	13.50	1.833	1.808	1.014	
9	4	2060	515	8	15.45	2.059	2.034	1.012	
10	4	1996	499	9	17.40	2.248	2.223	1.011	
11	3	1428	476	10	19.30	2.379	2.348	1.013	
12	3	1335	445	11	21.20	2.447	2.412	1.015	
13	2	830	415	12	23.15	2.489	2.455	1.014	
14	2	756	378	13	25.10	2.456	2.425	1.013	
15	2	662	331	14	27.00	2.316	2.284	1.014	
16	2	366	183	15	28.95	1.372	1.354	1.013	
17				16					Belt slip increased to 100 per cent.
	Average for Series 2							1.0136	


CALIBRATION CURVE.
TRANSMISSION DYNAMOMETER.
SERIES I.
CURVE A,— BRAKE CONSTANT / DYN. CONSTANT.
CURVE B,— BRAKE SCALE / DYN. SCALE.
CALIBRATION FACTOR = A / B.
A
B
DYNAMOMETER SCALE — (POUNDS).
PRONY BRAKE SCALE —(POUNDS).
0
4
8
12
16
20
24
28
32
C.S.D.

DEPARTMENT OF MECHANICAL ENGINEERING, K. S. A. C.

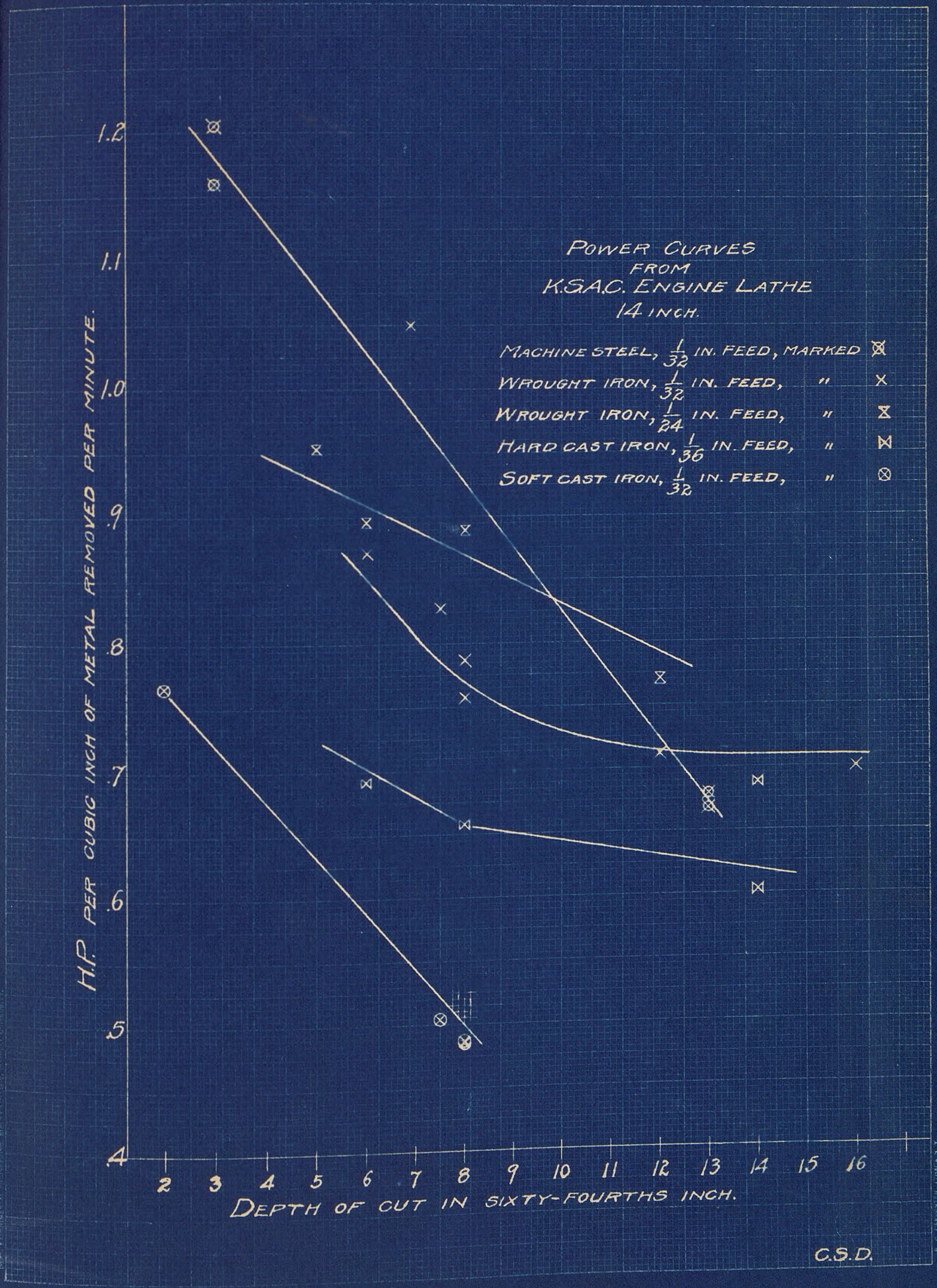
MADE AT MANHATTAN — KANSAS.
K.S.A.C. MECH. ENG. LABORATORY.
ON 14 INCH ENGINE LATHE.
(MACHINE AND SIZE.)
DATE JUNE 27 - 1904.

MACHINE-TOOL TEST.

CAST IRON. — COARSE-GRAINED, HARD.
(KIND AND NATURE OF MATERIAL.)

OBSERVERS:
C.S. DEARBORN.

No.	Dimensions of Stock. (Diameter or thickness.) (inches.)		Cut.	Feed.	R. P. M.			Scale Reading. (lbs.)	H. P.		Remarks.
	Original.	Final.			Dyn.	Counter Shaft.	Spindle.		Total.	Per cubic inch metal removed per minute.	
1					200			.0	.000		DYNAMOMETER BALANCED FREE OF ALL LOAD
2			0	$\frac{1}{36}$	199			2.90	.149		LATHE SPINDLE AND FEED GEAR IN OPERATION.
3	$2\frac{3}{8}$	$2\frac{3}{16}$	$\frac{3}{32}$	$\frac{1}{36}$	200		24	6.00	.310	.692	
4	$2\frac{3}{16}$	$1\frac{15}{16}$	$\frac{1}{8}$	$\frac{1}{36}$	200		22	6.30	.325	.657	
5	$2\frac{3}{8}$	$1\frac{15}{16}$	$\frac{7}{32}$	$\frac{1}{36}$	198		13	7.20	.368	.688	TOOL VERY DULL.
6	$1\frac{59}{64}$	$1\frac{31}{64}$	$\frac{7}{32}$	$\frac{1}{36}$	197		32	12.30	.626	.602	TOOL REGROUND.



POWER CURVES
FROM
K.S.A.C. ENGINE LATHE
14 INCH.
MACHINE STEEL, 1/32 IN. FEED, MARKED
WROUGHT IRON, 1/32 IN. FEED, "
WROUGHT IRON, 1/24 IN. FEED, "
HARD CAST IRON, 1/36 IN. FEED, "
SOFT CAST IRON, 1/32 IN. FEED, "
H.P. PER CUBIC INCH OF METAL REMOVED PER MINUTE.
1.2
1.1
1.0
.9
.8
.7
.6
.5
.4
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
DEPTH OF CUT IN SIXTY-FOURTHS INCH.
C.S.D.

DEPARTMENT OF MECHANICAL ENGINEERING, K. S. A. C.

MADE AT MANHATTAN — KANSAS.
K.S.A.C. MECH. ENG. LABORATORY.
ON 14 INCH ENGINE LATHE
(MACHINE AND SIZE.)
DATE JUNE 28 — 1904.

MACHINE-TOOL TEST.

CAST IRON. FINE-GRAINED, SOFT.
(KIND AND NATURE OF MATERIAL.)

OBSERVERS:
C.S. DEARBORN

No.	Dimensions of Stock. (Diameter or thickness.)		Cut.	Feed.	R. P. M.			Scale Reading. (lbs.)	H. P.		Remarks.
	Original.	Final.			Dyn.	Counter Shaft.	Spindle.		Total.	Per cubic inch metal removed per minute.	
1					200			0.0	.00		
2			0	$\frac{1}{36}$	199			2.10	.108		DYNAMOMETER BALANCED FREE OF ALL LOAD. LATHE SPINDLE AND FEED GEAR IN OPERATION.
3	$4\frac{7}{32}$	$3\frac{31}{32}$	$\frac{1}{8}$	$\frac{1}{36}$	195		20	9.10	.458	.512	
4	$4\frac{7}{32}$	$3\frac{31}{32}$	$\frac{1}{8}$	$\frac{1}{36}$	194		20	9.30	.466	.520	
5	$4\frac{7}{32}$	$3\frac{31}{32}$	$\frac{1}{8}$	$\frac{1}{32}$	195		20	9.70	.489	.487	TOOL REGROUND.
6	$4\frac{7}{32}$	$3\frac{31}{32}$	$\frac{1}{8}$	$\frac{1}{32}$	196		20	9.65	.488	.486	
7	$4\frac{7}{32}$	$3\frac{63}{64}$	$\frac{15}{128}$	$\frac{1}{32}$	196		20	9.40	.476	.504	
8	$3\frac{31}{32}$	$3\frac{29}{32}$	$\frac{1}{32}$	$\frac{1}{32}$	198		36	6.50	.332	.766	

DEPARTMENT OF MECHANICAL ENGINEERING, K. S. A. C.

MADE AT MANHATTAN — KANSAS.
K.S.A.C. MECH. ENG. LABORATORY.
ON 14 INCH ENGINE LATHE.
(MACHINE AND SIZE.)
DATE JUNE 29 — 1904.

MACHINE-TOOL TEST.

WROUGHT IRON.
(KIND AND NATURE OF MATERIAL.)

OBSERVERS:
C.S. DEARBORN.

No.	Dimensions of Stock. (Diameter or thickness.) Original.	Final.	Cut.	Feed.	R. P. M. Dyn.	Counter Shaft.	Spindle.	Scale Reading. (lbs.)	H. P. Total.	Per cubic inch metal removed per minute.	Remarks.
1					205			0	.00		DYNAMOMETER BALANCED FREE OF ALL LOAD.
2			0	1/32	203			2.10	.113		LATHE SPINDLE AND FEED GEAR IN OPERATION.
3	2 5/32	1 29/32	1/8	1/32	201		22	8.00	.415	.757	LARD OIL USED FREELY EXCEPT AS NOTED.
4	2 5/32	1 59/64	15/128	1/32	202		22	8.20	.428	.828	
5	2 5/32	1 15/16	7/64	1/32	200		21	9.40	.486	1.05	TOOL REGROUND: NO OIL USED.
6	2 5/32	1 29/32	1/8	1/32	201		22	8.30	.431	.786	
7	1 29/32	1 23/32	3/32	1/32	190		54	16.00	.785	.871	
8	1 29/32	1 13/32	1/4	1/32	198		12.75	7.10	.363	.700	TOOL REGROUND.
9	1 25/64	1 1/64	3/16	1/32	198		35	10.80	.552	.711	
10	1 29/32	1 17/32	3/16	1/24	196		12	7.70	.390	.770	TOOL REGROUND.
11	1 29/32	1 21/32	1/8	1/24	195		20	10.30	.519	.890	
12	1 29/32	1 23/32	3/32	1/24	193		30	12.00	.598	.896	TOOL REGROUND.
13	1 5/8	1 15/32	5/64	1/24	198		36	10.60	.543	.953	

DEPARTMENT OF MECHANICAL ENGINEERING, K. S. A. C.

MADE AT MANHATTAN — KANSAS
K.S.A.C. MECH. ENG. LABORATORY.
ON 14 INCH ENGINE LATHE
(MACHINE AND SIZE.)
DATE JUNE 30 — 1904.

MACHINE-TOOL TEST.

MACHINE STEEL
(KIND AND NATURE OF MATERIAL.)

OBSERVERS:
C.S. DEARBORN.

No.	Dimensions of Stock. (Diameter or thickness.) Original.	Final.	Cut.	Feed.	R. P. M. Dyn.	Counter Shaft.	Spindle.	Scale Reading. (lbs.)	H. P. Total.	Per cubic inch metal removed per minute.	Remarks.
1					200			0	.00		DYNAMOMETER BALANCED FREE OF ALL LOAD.
2			0	$\frac{1}{32}$	199			3.00	.154		LATHE SPINDLE AND FEED GEAR IN OPERATION.
3	$1\frac{7}{8}$	$1\frac{25}{32}$	$\frac{3}{64}$	$\frac{1}{32}$	185		64	13.60	.650	1.205	LARD OIL USED FREELY ON WORK.
4	$1\frac{7}{8}$	$1\frac{25}{32}$	$\frac{3}{64}$	$\frac{1}{32}$	185		64	13.10	.626	1.16	TOOL REGROUND.
5	$1\frac{47}{64}$	$1\frac{21}{64}$	$\frac{13}{64}$	$\frac{1}{32}$	180		33	14.50	.674	.668	CUTTING ANGLE MADE MORE ACUTE. (60°)
6	$1\frac{3}{4}$	$1\frac{11}{32}$	$\frac{13}{64}$	$\frac{1}{32}$	190		34	14.50	.712	.679	