THE DESIGN
OF A
RECORDING TRACTION DYNAMOMETER.

ADAPTED TO THE TESTING
OF TRACTION ENGINES.
TRACTIVE CAPACITY
FIVE THOUSAND POUNDS.

THESIS.

PRESENTED BY

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1906.

The Design of a Recording Traction Dynamometer.

Dynamometers are instruments used for measuring power and are divided into three classes:- (1) brake or absorption dynamometers, in which the power of a rotating shaft or wheel is absorbed or converted into heat by the friction of a brake; (2) transmission dynamometers, in which the power of a rotating shaft is measured during its transmission through a belt or other connection to another shaft, without being absorbed; and (3) traction dynamometers which are used for determining the power required to pull a car, wagon or other load.

It is one of the latter class, especially adapted to traction engines, with which this thesis deals. We based our calculations regarding the tractive capacity necessary on data taken in 1905 by Messrs. Barnard, Carnahan and Thompson on the tractive power of a twenty two horse power traction engine, in which the greatest pull was 4000 pounds. We thought best to allow for a greater pull than this and so decided that our dynamometer should have a tractive capacity of 5000 pounds.

We first decided on several of the general characteristics of our dynamometer, namely:- that it should have two helical springs through which the pull was to be exerted, these springs to be in compression; that we would mount a frame, holding the springs, below and to the front of an axle connecting two cart wheels; that the frame be made self-adjusting so that there would be a straight pull, at all times, between the draw bar of the engine and the point at which the rear draw bar of the dynamometer is attached to the load; that the deflection of the springs should actuate a pencil having a straight line motion exactly proportional to the deflection of the springs and which would record the said deflection to some convenient scale on a roll of paper winding onto a drum; and that the paper should travel under the pencil at a speed proportional to the distance passed over, to a convenient scale.

Having decided to use two helical springs of round steel stock each having a carrying capacity of 2500 pounds with a deflection of about $2\frac{1}{4}$ inches, we found, from the table of carrying capacities of helical springs, given by Kent, $\frac{5}{8}$ inch round spring steel stock wound in coils having an outside diameter of 3 in. would give a deflection of 2.32 in. for sixteen free coils. We therefore adopted these dimensions.

As the strength of a spring depends to a great extent on the temper, we decided to make the springs and the frame which holds them, then test them in the 100,000 pound Riehlé Testing Machine and get the actual deflection with the maximum load of 5000 pounds before designing the rest of the dynamometer so as to get the desired scale in the pencil motion.

In the making of the springs we used $\frac{5}{8}$ inch round spring steel stock about 13 ft. long. We first bent about 2 in. of the rod at right angles, then heated from 18 to 22 in. of the rod in the coke furnace, took it out and inserted the bent part of the rod in a hole drilled near the end of a handle, about 3 ft. long, which was fixed at right angles to the arbor on which the spring was wound. The arbor was placed in a hole in a heavy plate and the handle turned around, the stock being kept close to the arbor by a swage placed in a hole in the plate close to the arbor hole. Thus as the handle was turned around the stock was wound on the arbor. We continued this process until we had 18 coils, we then opened up 16 coils to the proper distance by heating them and driving a hot cutter between them, leaving a closed coil at each end. We then ground the ends flat to give a good bearing surface.

In tempering the springs we heated them evenly to a bright orange in the coke furnace and hardened them by plunging them into about 10 gallons of lard oil in a can surrounded by water to keep the oil cool. We then tested them in the testing machine to find if they were properly tempered. We compressed them until all the coils touched, then removed the load which was over 3000 pounds. The initial and final lengths being the same we considered that the method of tempering was correct and that the springs were well tempered. We then tested each spring to determine its deflection with a load of 2500 pounds. The load in each case was increased by 100 pound steps and the deflection measured after each increase of load, to determine whether the deflection was constant for a given increase of load up to the maximum of 2500 pounds. As the deflection was found to be constant we concluded that the springs were suitable for our purpose. We found that the total deflections of the two springs for 2500 pound loads were 2.06 and 2.26 in. respectively showing that one was approximately ten percent stronger than the other. In order that the two springs might always have an equal deflection it is evident that the stronger spring should have an arm one tenth shorter than the weaker.

We were now ready to make the remaining parts shown on Plate I. Since the springs were to be 8 in. apart it was necessary to have the draw bars $\frac{3}{8}$ in. nearer the stronger spring than to the weaker. We accordingly completed the work of making and assembling the parts shown on Plate I and proceeded to test the springs as assembled.

In testing the dynamometer at this stage we arranged it in the testing machine and increased the load by 250 pound steps up to its working capacity of 5000 pounds. The deflections were measured by means of micrometers placed between the points of small bars put in near each end of parts A and B, Plate I. This was done to see if the springs had an equal deflection and to determine the average deflection. The readings were taken to thousandths of an inch and were as follows:—

Loads	Deflections: Strong Spring	Deflections: Weak Spring	Remarks
250	.122	.128	
500	.129	.130	
750	.118	.123	
1000	.105	.102	
1250	.107	.109	
1500	.114	.114	
1750	.149	.144	high
2000	.100	.095	low
2250	.112	.110	
2500	.125	.113	
2750	.114	.112	
3000	.110	.104	
3250	.104	.104	
3500	.116	.116	
3750	.109	.105	
4000	.109	.105	
4250	.106	.107	
4500	.107	.106	
4750	.112	.110	
5000	.114	.113	
Total	2.282	2.250	

The average deflection was consequently 2.266 in. for a load of 5000 pounds and the average for each 250 pound increase was .113 in. The first two readings are somewhat high as is also the one corresponding to 1750 pounds but as the next reading is below the average by an equal amount it may be considered that this may be overlooked. Nearly all of the readings are within 10% of the average and the remainder do not exceed this limit seriously. The readings taken may be considered to be accurate within 25 pounds which gives an accuracy of 1% for a load of 2500 pounds. Assuming 2% as a probable maximum error the instrument would be sufficiently accurate for the purpose.

We have designed a recording mechanism to suit the design and action of the parts described above. In this design, the details of which are shown in Plates 2-6 and the assembly view in Plate 7, we have endeavored to fulfill the given conditions.

To secure a direct pull through the draw bar and springs of the instrument, the axle is attached to the dynamometer by the links R which are free to turn on both the axle Q and the drumshaft J. This arrangement allows the wheels to rest on the ground under all conditions, without straining or cramping any of the parts. The relative motion of the axle and dynamometer is limited by the axle loops S which serve to support the machine by the axle when not in use. The range of the dynamometer being about 3 in. above and below 2 ft., the common height of traction engine draw-bars, we believe that all common wagons and engines may be used in tests with this dynamometer.

The pencil motion is derived from the deflection of the springs through the rack M fastened rigidly to the draw-bar and meshing with the pinion K. The arc L on the same spindle with this pinion has fastened at one end of its grooved edge a steel ribbon or piece of annealed watchspring which pulls the pencil slide along the guides N. A spring encased in the tube at one side pulls against the steel ribbon taking up all backlash and moving the pencil away from the arc when the ribbon becomes slack. In order that the record may be read in the conventional manner, ie; with the zero point of the curve at the lower left hand corner of the record, the rack and pinion should be so meshed in assembling as to bring the pencil to the zero line of the record paper near that end of the drum which is nearest the arc, the pencil motion spring being pulled out over the guides to its extreme length with no load on the dynamometer. Then a pull on the draw-bars will move the rack and rotate the pinion and arc in an anti-clockwise direction.

as seen in the perspective view on Plate 7; this will allow the pencil motion spring to pull the pencil toward the end of the drum opposite the arc. The arc is so set that the steel ribbon pulls directly through the center line of the slide, thus eliminating the danger of binding. The pivot bearings are made so as to allow vertical adjustment. The pencil motion spring is made long enough to give an easy uniform action throughout the range. The pinion has a pitch diameter of 2 in. while the arc has a diameter of $8\frac{59}{64}$ in., these dimensions being chosen so that the deflection corresponding to 5000 pounds will move the pencil 10 in. making the scale 500 pounds equal to 1 in.

The motion of the paper proportional to the distance traversed is obtained from the main axle by a train of gears. A bevel gear U on the axle meshes with another bevel gear of equal size on one end of a gear shaft; on the other end is a single thread worm which meshes with a 72 tooth worm gear W on the same shaft with the recording drum. Thus the drum makes 1 revolution to 72 of the main wheels. The diameter of the wheels being 55.8 in. and since we decided to make the record paper travel at the rate of $\frac{1}{64}$ in. for every foot of distance covered, the diameter of the drum must be $5\frac{7}{32}$ in.

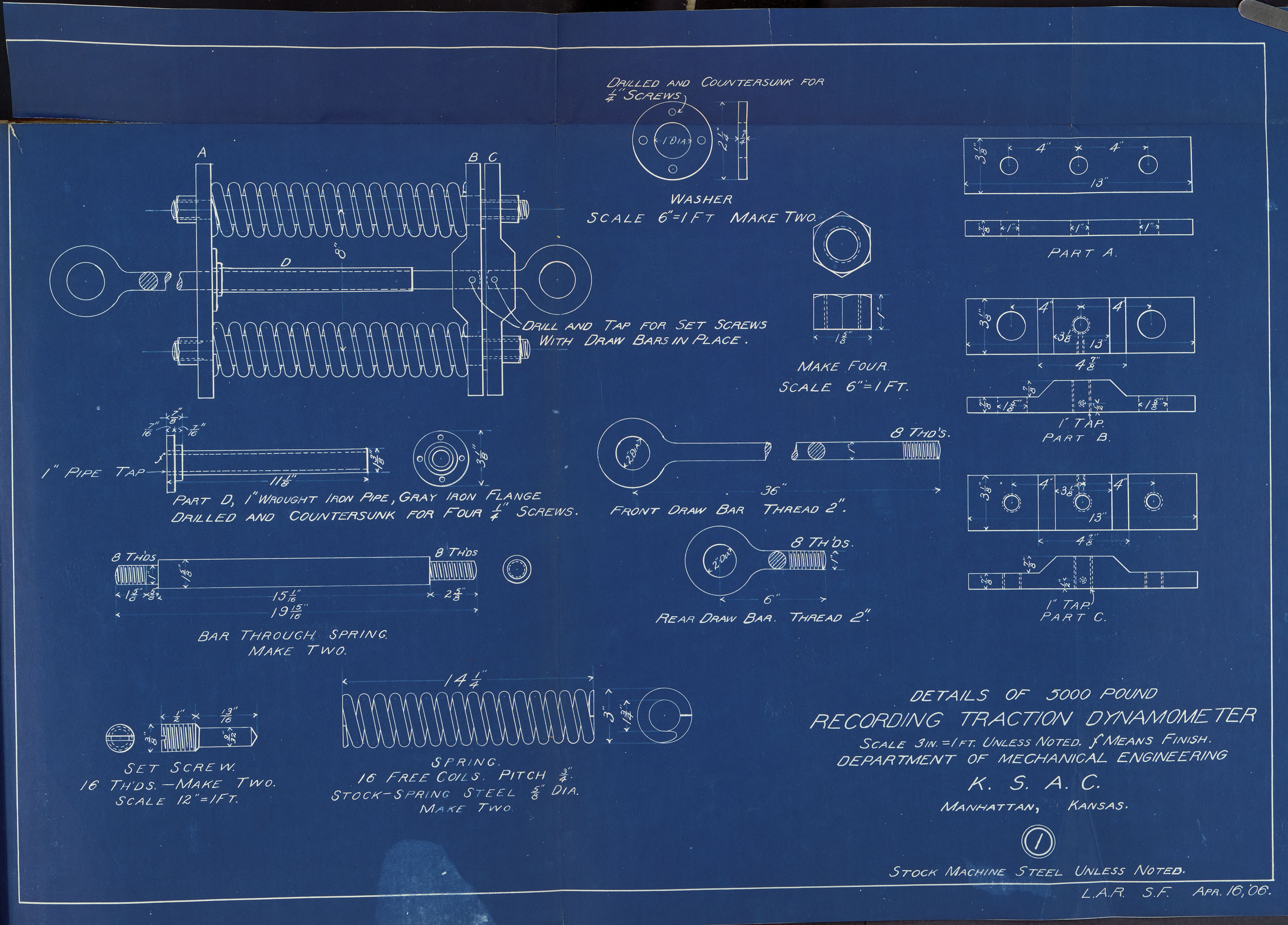
The paper supply for the record is to be a strip eleven inches wide. The record for a mile run will be about 83 in. long. Allowing for waste at the ends, paper about 10 ft. long will be necessary for a half hour test of an ordinary traction engine. The paper used should be as thin as convenient in order that the increase in the diameter of the recording drum should not seriously affect the scale of distances.

Behind the recording drum is a supply drum which has a spring, like the ordinary shade roller spring, to keep the paper in tension. At the beginning of a test the paper should be wound on the supply drum; the thumb screw binding the recording drum to its shaft should be loosened and the ratchet click placed in mesh with the ratchet teeth; the supply drum should then be turned enough to get a slight tension in the spring and the paper fastened to the recording drum. While moving, but not running a test, the thumb screw should remain loose with the ratchet click in place. When a test is to begin, tighten the thumb screw and throw the ratchet click backward so that the paper may run backward or forward with the motion of the engine and load.

The following detail drawings give full details and directions for the construction and assembling of the parts of this dynamometer.

Smith Faris.

Lester A. Ramsey.


DRILLED AND COUNTERSUNK FOR 1/4" SCREWS
WASHER
SCALE 6"=1 FT MAKE TWO.
MAKE FOUR
SCALE 6"=1 FT.
PART A.
1" TAP.
PART B.
1" TAP.
PART C.
DRILL AND TAP FOR SET SCREWS WITH DRAW BARS IN PLACE.
1" PIPE TAP
PART D, 1" WROUGHT IRON PIPE, GRAY IRON FLANGE
DRILLED AND COUNTERSUNK FOR FOUR 1/4" SCREWS.
8 THD'S.
FRONT DRAW BAR THREAD 2".
8 TH'DS.
REAR DRAW BAR. THREAD 2".
8 TH'DS
BAR THROUGH SPRING.
MAKE TWO.
SET SCREW.
16 TH'DS. — MAKE TWO.
SCALE 12"=1 FT.
SPRING.
16 FREE COILS. PITCH 3/4".
STOCK-SPRING STEEL 5/8" DIA.
MAKE TWO.
DETAILS OF 5000 POUND
RECORDING TRACTION DYNAMOMETER
SCALE 3 IN.=1 FT. UNLESS NOTED. f MEANS FINISH.
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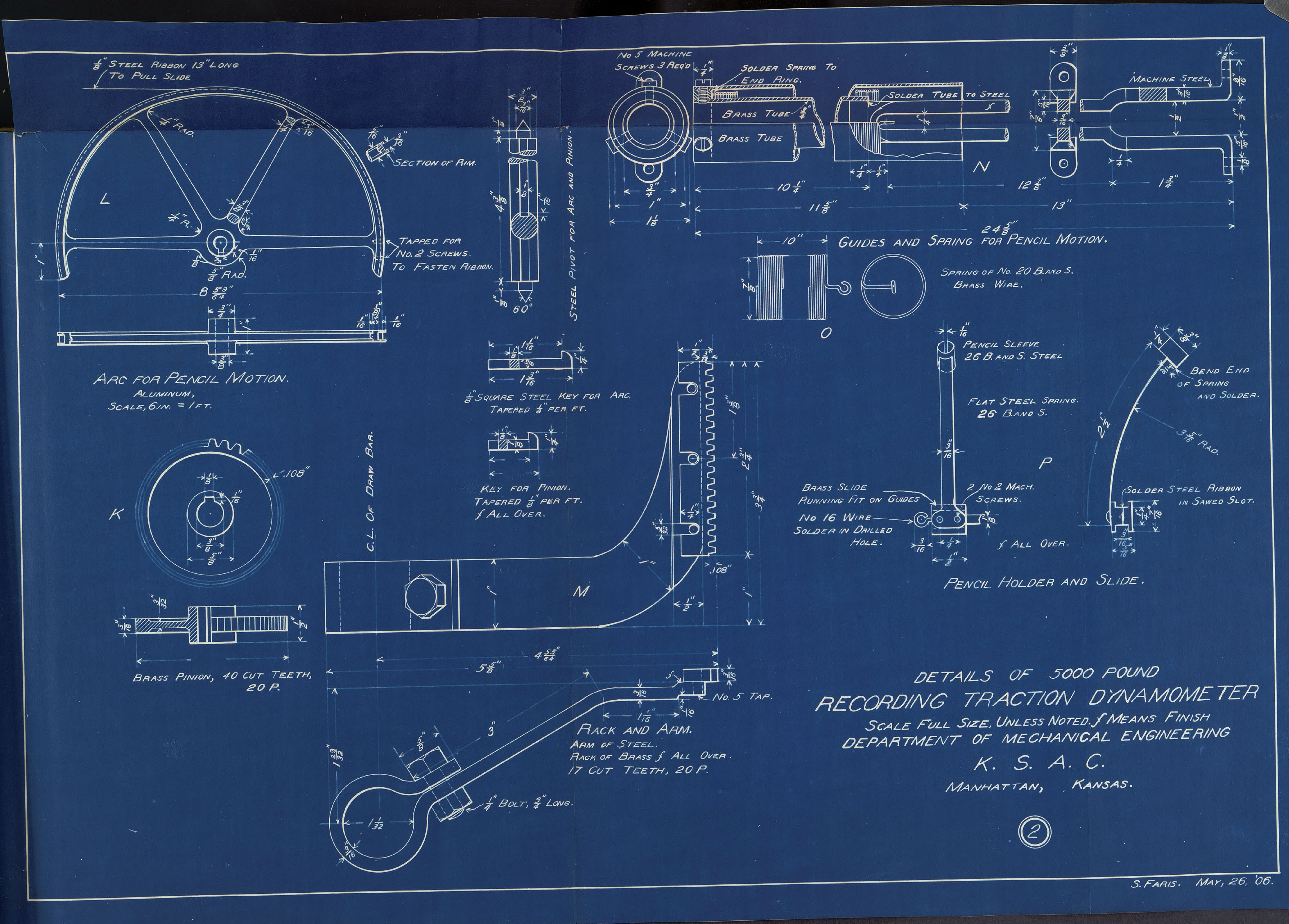
1
STOCK MACHINE STEEL UNLESS NOTED.
L.A.R. S.F. APR. 16, '06.



DETAILS OF 5000 POUND
RECORDING TRACTION DYNAMOMETER
SCALE FULL SIZE, UNLESS NOTED. ƒ MEANS FINISH
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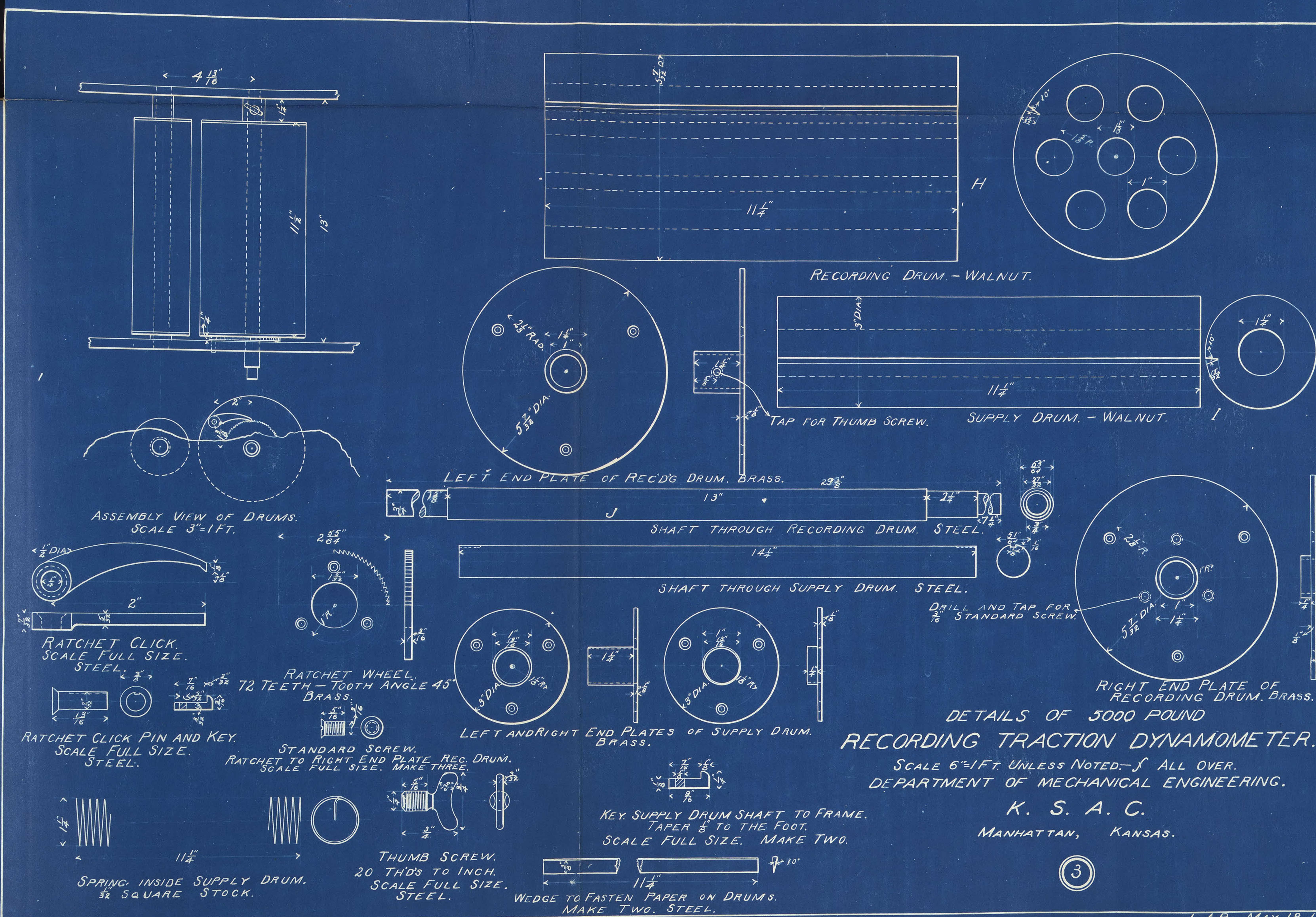
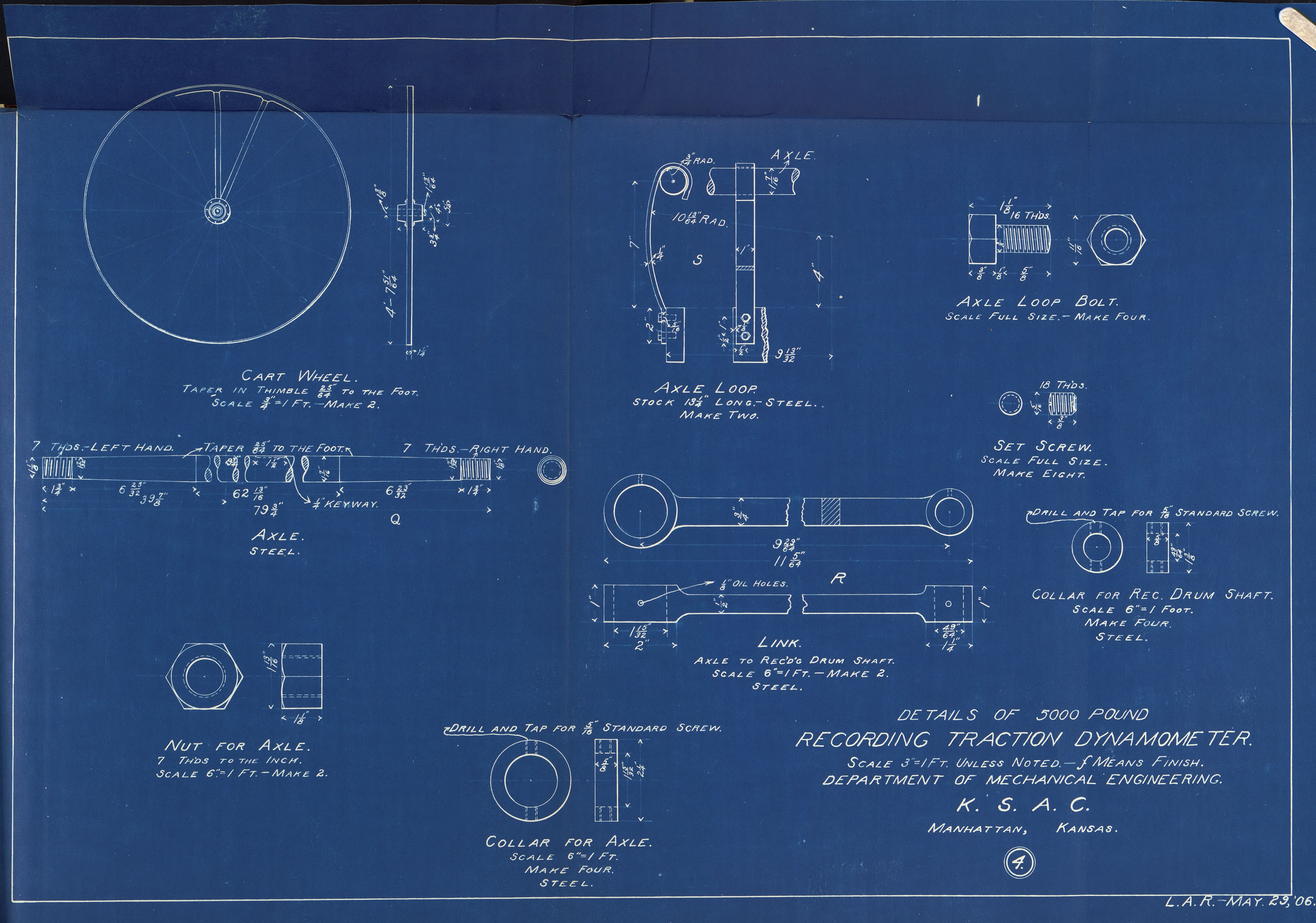
2
S. FARIS. MAY, 26, '06.
1/8" STEEL RIBBON 13" LONG TO PULL SLIDE
SECTION OF RIM.
TAPPED FOR No. 2 SCREWS. TO FASTEN RIBBON.
L
ARC FOR PENCIL MOTION.
ALUMINUM,
SCALE, 6 IN. = 1 FT.
STEEL PIVOT FOR ARC AND PINION.
60°
1/8" SQUARE STEEL KEY FOR ARC.
TAPERED 1/8" PER FT.
KEY FOR PINION.
TAPERED 1/8" PER FT.
ƒ ALL OVER.
K
.108"
BRASS PINION, 40 CUT TEETH,
20 P.
C.L. OF DRAW BAR.
M
RACK AND ARM.
ARM OF STEEL.
RACK OF BRASS ƒ ALL OVER.
17 CUT TEETH, 20 P.
No. 5 TAP.
1/4" BOLT, 3/4" LONG.
No 5 MACHINE SCREWS 3 REQ'D
SOLDER SPRING TO END RING.
BRASS TUBE
SOLDER TUBE TO STEEL
MACHINE STEEL
N
GUIDES AND SPRING FOR PENCIL MOTION.
SPRING OF No. 20 B. AND S. BRASS WIRE.
O
PENCIL SLEEVE 26 B. AND S. STEEL
FLAT STEEL SPRING. 26 B. AND S.
P
BRASS SLIDE RUNNING FIT ON GUIDES
No 16 WIRE SOLDER IN DRILLED HOLE.
2 No 2 MACH. SCREWS.
ƒ ALL OVER.
BEND END OF SPRING AND SOLDER.
SOLDER STEEL RIBBON IN SAWED SLOT.
PENCIL HOLDER AND SLIDE.



L.A.R. MAY. 18, 1906.



CART WHEEL.
TAPER IN THIMBLE 25/64 TO THE FOOT.
SCALE 3/4"=1 FT. — MAKE 2.
AXLE.
3/4" RAD.
10 13/64" RAD.
S
AXLE LOOP.
STOCK 13 1/4" LONG. — STEEL.
MAKE TWO.
16 THDS.
AXLE LOOP BOLT.
SCALE FULL SIZE. — MAKE FOUR.
18 THDS.
SET SCREW.
SCALE FULL SIZE.
MAKE EIGHT.
7 THDS. — LEFT HAND.
TAPER 25/64 TO THE FOOT.
7 THDS. — RIGHT HAND.
1/4" KEYWAY.
Q
AXLE.
STEEL.
R
1/8" OIL HOLES.
LINK.
AXLE TO REC'D'G DRUM SHAFT.
SCALE 6"=1 FT. — MAKE 2.
STEEL.
DRILL AND TAP FOR 5/16" STANDARD SCREW.
COLLAR FOR REC. DRUM SHAFT.
SCALE 6"=1 FOOT.
MAKE FOUR.
STEEL.
NUT FOR AXLE.
7 THDS TO THE INCH.
SCALE 6"=1 FT. — MAKE 2.
DRILL AND TAP FOR 5/16" STANDARD SCREW.
COLLAR FOR AXLE.
SCALE 6"=1 FT.
MAKE FOUR.
STEEL.
DETAILS OF 5000 POUND
RECORDING TRACTION DYNAMOMETER.
SCALE 3"=1 FT. UNLESS NOTED. — f MEANS FINISH.
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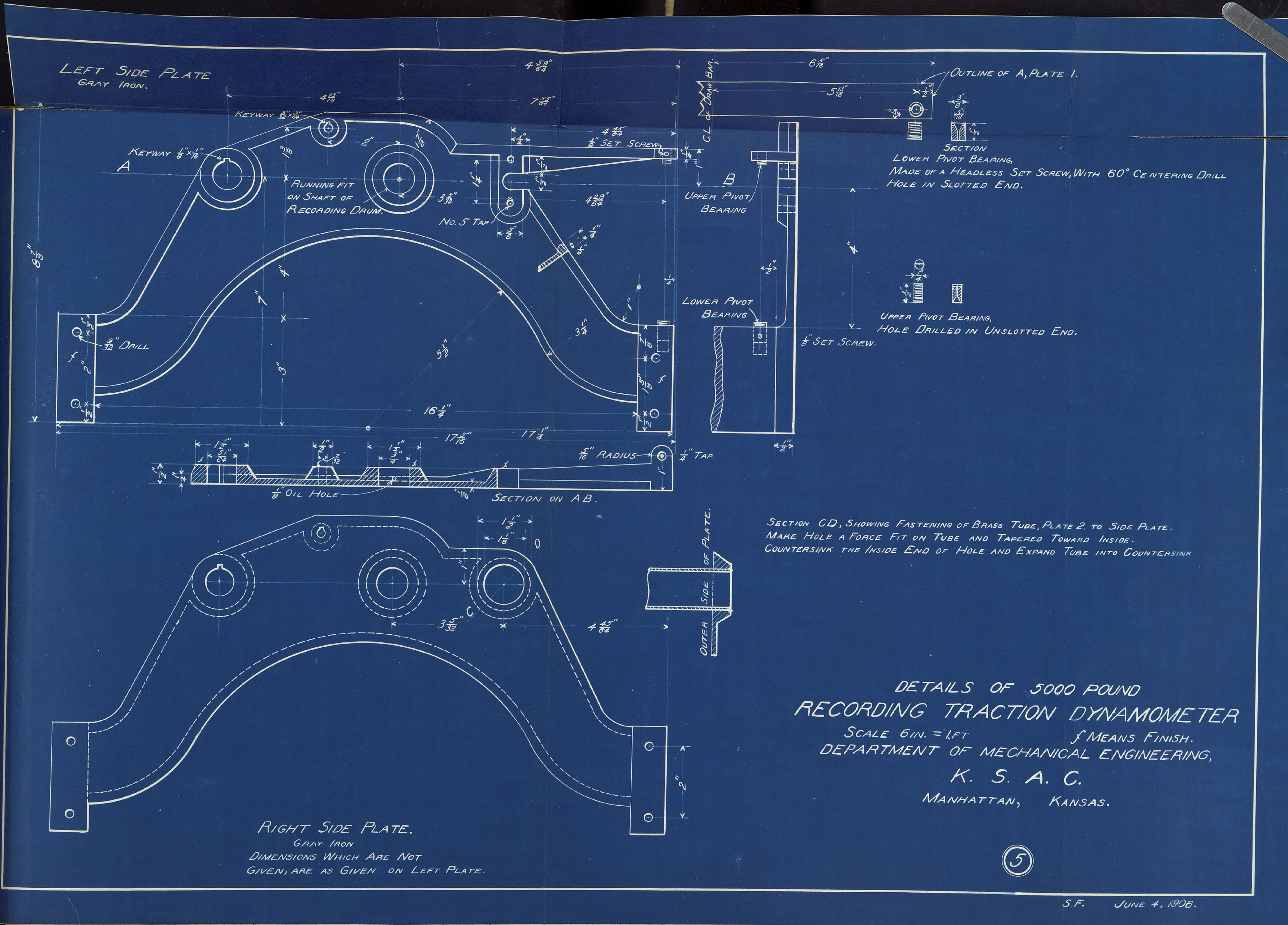
4.
L.A.R. — MAY. 29, '06.



LEFT SIDE PLATE
GRAY IRON.
KEYWAY 1/8" x 1/16"
A
RUNNING FIT ON SHAFT OF RECORDING DRUM.
NO. 5 TAP
1/4" SET SCREW
B
UPPER PIVOT BEARING
C.L. OF DRAW BAR.
OUTLINE OF A, PLATE 1.
SECTION
LOWER PIVOT BEARING,
MADE OF A HEADLESS SET SCREW, WITH 60° CENTERING DRILL HOLE IN SLOTTED END.
LOWER PIVOT BEARING
UPPER PIVOT BEARING,
HOLE DRILLED IN UNSLOTTED END.
1/4" SET SCREW.
9/32" DRILL
5/16" RADIUS
1/4" TAP
1/8" OIL HOLE
SECTION ON AB.
SECTION CD, SHOWING FASTENING OF BRASS TUBE, PLATE 2, TO SIDE PLATE.
MAKE HOLE A FORCE FIT ON TUBE AND TAPERED TOWARD INSIDE.
COUNTERSINK THE INSIDE END OF HOLE AND EXPAND TUBE INTO COUNTERSINK.
OUTER SIDE OF PLATE.
RIGHT SIDE PLATE.
GRAY IRON
DIMENSIONS WHICH ARE NOT GIVEN, ARE AS GIVEN ON LEFT PLATE.
DETAILS OF 5000 POUND
RECORDING TRACTION DYNAMOMETER
SCALE 6IN. = 1 FT
f MEANS FINISH.
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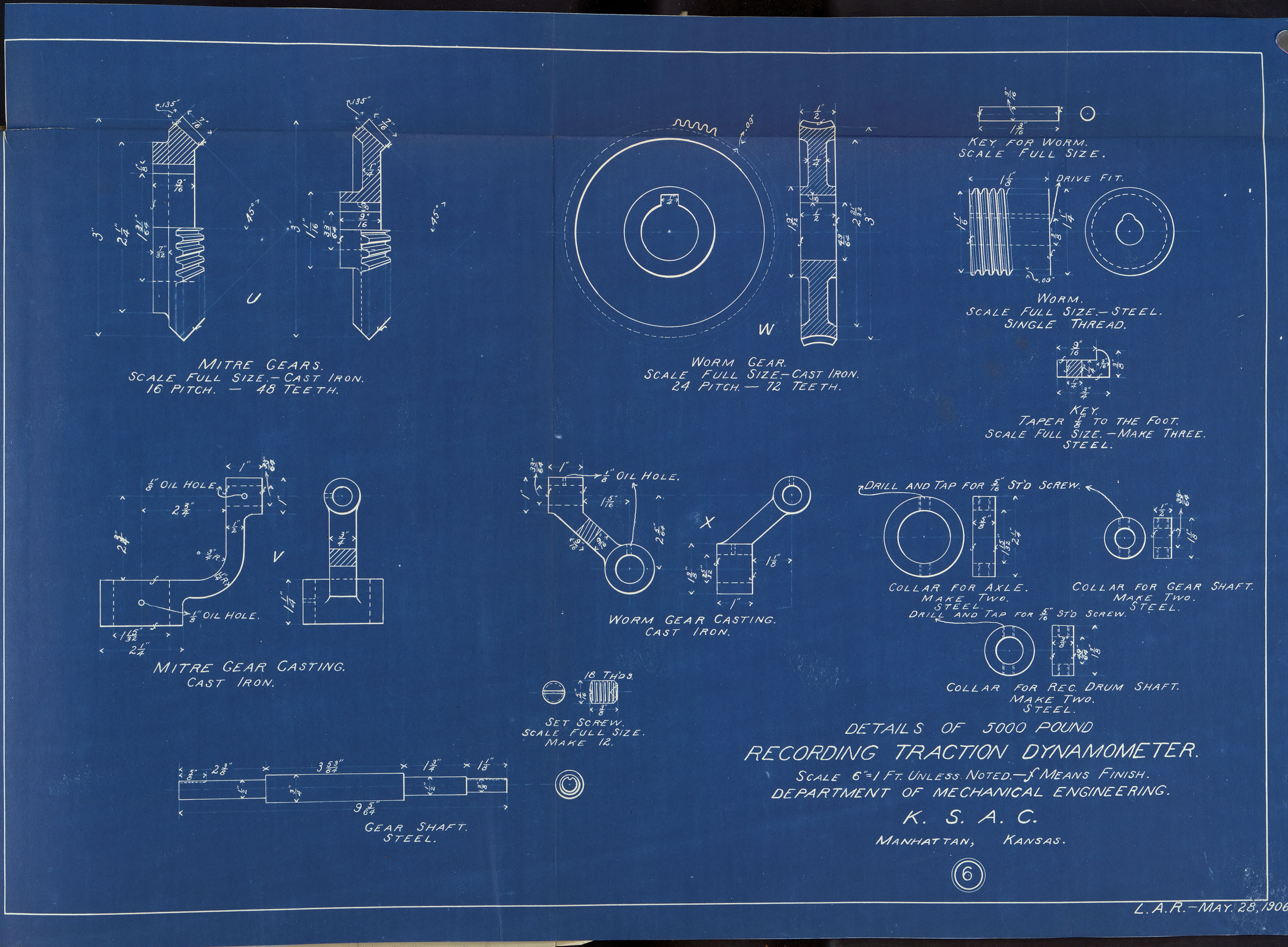
5
S.F.
JUNE 4, 1906.


KEY FOR WORM.
SCALE FULL SIZE.
DRIVE FIT.
WORM.
SCALE FULL SIZE.—STEEL.
SINGLE THREAD.
KEY.
TAPER 1/8" TO THE FOOT.
SCALE FULL SIZE.—MAKE THREE.
STEEL.
U
MITRE GEARS.
SCALE FULL SIZE.—CAST IRON.
16 PITCH. — 48 TEETH.
W
WORM GEAR.
SCALE FULL SIZE.—CAST IRON.
24 PITCH.— 72 TEETH.
1/8" OIL HOLE.
V
1/8" OIL HOLE.
MITRE GEAR CASTING.
CAST IRON.
1/8" OIL HOLE.
X
WORM GEAR CASTING.
CAST IRON.
DRILL AND TAP FOR 5/16" ST'D SCREW.
COLLAR FOR AXLE.
MAKE TWO.
STEEL.
COLLAR FOR GEAR SHAFT.
MAKE TWO.
STEEL.
DRILL AND TAP FOR 5/16" ST'D SCREW.
COLLAR FOR REC. DRUM SHAFT.
MAKE TWO.
STEEL.
18 TH'DS.
SET SCREW.
SCALE FULL SIZE.
MAKE 12.
GEAR SHAFT.
STEEL.
DETAILS OF 5000 POUND
RECORDING TRACTION DYNAMOMETER.
SCALE 6"=1 FT. UNLESS NOTED.—f MEANS FINISH.
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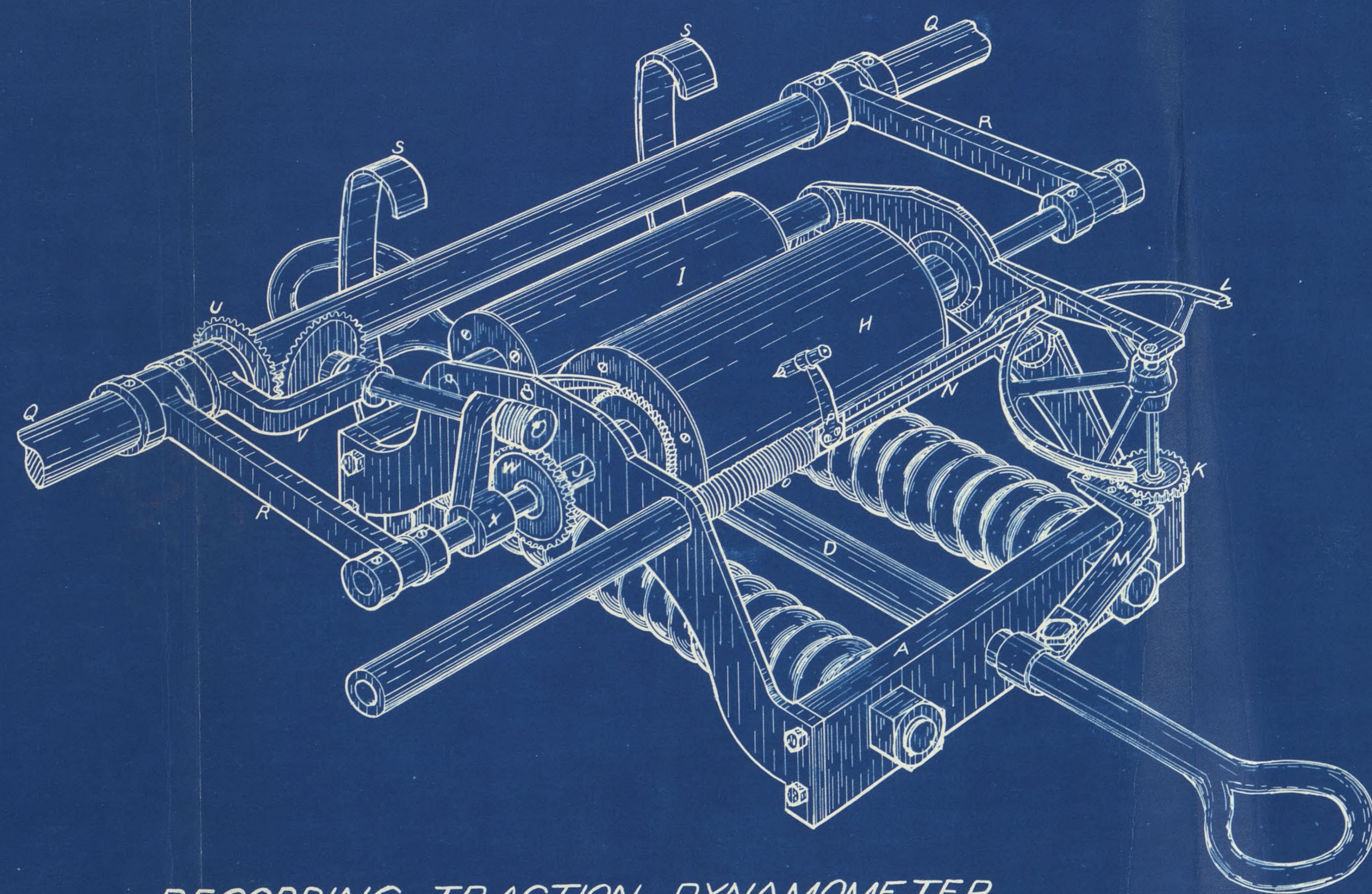
L.A.R.—MAY. 28, 1906.



RECORDING TRACTION DYNAMOMETER

7

S.F. JUNE 11, '06.