A STUDY OF MODERN PRODUCTION TOOLS AND METHODS AS APPLIED TO THE MANUFACTURE OF A SMALL GASOLINE ENGINE

by

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INTRODUCTION

The machine tools as used in the industries, are essentially production machines with which the user endeavors to obtain the greatest possible production in a working day.

The early machine tools were designed with sufficient weight and power to get the most production with the carbon steel cutting tools in use at that time.

Upon the discovery of Mushet or air hardening steel, (about 1906) and a little later, high speed steel, it became necessary to make the machine tools heavier and more powerful in order to utilize these steels to the best advantage.

When tungsten carbide cutting tools were introduced into this country (1928) it was discovered that machine tools which had been designed to use high speed steel cutting tools, were utterly incapable of utilizing the new cutting tools to the best advantage. As a consequence the different machine tool manufacturers have been designing machines with the idea in view of making their machines rigid enough and with sufficient power to use the new tools at the high cutting speeds demanded.

PURPOSE

It is essential that instructors teaching machine shop practice be familiar with the latest kinds of machines and cutting tools as used in the industries.

Since there has been very little information published regarding the performance of modern machine tools, particularly when using the new tungsten carbide and tantalum carbide cutting tools, this study was undertaken for the purpose of compiling whatever information could be obtained.

The information contained in this study was obtained from recommendations of leading machine tool manufacturers regarding the machines and tools best adapted to manufacture certain parts of a small gasoline engine.

GENERAL METHODS

In order to apply the study of modern manufacturing methods to a specific case, a study was made of all the small gasoline engines of recent manufacture available.

Using the information obtained, drawings were made of a single cylinder, four cycle, horizontal, air cooled, gasoline engine which would be suitable for manufacturing by modern high production methods.

All of the copies of Machinery, American Machinist, and Automotive Industries magazines as far back as 1928 were searched for articles describing modern manufacturing methods, but scarcely any information was obtained which could be applied to the problem.

Blue prints of the principal parts of the engine were then sent to twenty-six manufacturers of machine tools, together with a letter requesting their recommendations for machines to produce one thousand engines per eight hour day, together with the cost of the machines and necessary equipment.

The information obtained was studied and the machine tool, for making a specific part of the engine, selected which would give the production desired at the least cost per piece.

Types of Cutting Tools Used

Modern manufacturing methods utilize five different compositions of cutting tools.

1. Carbon Steel.
2. High Speed Steel.
3. Stellite.
4. Tungsten Carbide.
5. Tantalum Carbide.

High speed steel (first used about 1908) is essentially a high carbon steel alloyed with tungsten, tungsten-vanadium, etc., the object being to raise the temperature at which the steel loses its hardness, thereby enabling more metal to be removed in a given length of time than with carbon steels. Some research work has been done to determine the temperature a cutting tool is subjected to under heavy cuts and feeds at high speed, this temperature was found to be as high as 700 degrees Centigrade, which means the point of the tool would be red hot.

On work where a carbon steel would operate successfully at say 35 feet per minute without losing its hardness, high speed steel will operate at twice the cutting speed with the same feed and depth of cut.

Machines which had been designed to operate successfully with carbon steels, were entirely too light and underpowered to get the maximum production when using high speed steel. The machine tool makers consequently re-designed their machines to enable high speed steel tools to be used to the best advantage.

About 1912, Elwood Haynes, automobile builder, invented Haynes Stellite. Stellite contains no steel or iron but is an alloy of cobalt, chromium, and tungsten or molybdenum. It cannot be forged or heat treated, but must be melted in an electric furnace and then cast to shape in molds and ground.

Due to its high cost ($7.00 to $8.00 per pound) stellite is not used in large solid pieces like high speed or other steels but is used as small pieces brazed onto the steel body of the tool.

For machining certain metals, such as cast iron, semi-steel, malleable iron, and bronze, stellite gives a marked increase in production over high speed steel, due to its ability to retain its hardness at high temperatures.

When machining cast iron, if a cutting speed of 60 feet per minute were used with high speed steel, stellite tools can be operated at 120 feet per minute using the same feed and depth of cut.

This cutting tool material again caused certain machine tools, which could use stellite to advantage, to be re-designed because it requires a stronger and more powerful machine to cut metal at 120 than at 60 feet per minute.

In 1926 a German firm discovered how to employ cemented tungsten carbide (tungsten, carbon, cobalt alloy) as a metal cutting tool. This new cutting tool was introduced into the United States in 1928 and almost at once made obsolete some of the machine tools which had been designed to use high speed steel or stellite tools.

Where cast iron would be machined at 60 feet per minute with high speed steel or at 120 feet per minute with stellite; with cemented tungsten carbide, the cutting speed was increased to as high as 400 feet per minute.

Tungsten carbide tools are now manufactured in this country through trade agreements with the Krupp Company of Germany, under the trade names of Carboloy, Firthite, Carmet and imported from the Krupp Company of Germany under the trade name of Widia.

Tungsten carbide, due to its high cost, (about $1.00 per gram) is used as small pieces brazed to a high carbon steel shank.

Cemented tungsten carbide is not suitable for machining steel. Steel seems to have an affinity for the carbide and a hollow is soon formed in the face of the tool, which makes the cutting edge thin and weak so that it breaks off. This difficulty has recently been overcome by using tantalum carbide, either alone or in combination with the tungsten carbide but no figures are available at the present time regarding cutting speeds.

The following speeds can be successfully used with properly designed inserted-blade tungsten carbide milling cutters.

Material	Roughing Feet per Minute	Finishing Feet per Minute
Cast iron, soft and medium	150 to 300	200 to 400
Malleable iron	200 to 400	300 to 500
Yellow brass	200 to 400	350 to 600
Bronze, ordinary	200 to 350	250 to 500
Aluminum	800 to 1500	1000 to 2000

The feed per tooth for these materials will vary from 0.007 to 0.012 inch, although 0.009 to 0.010 inch will be found to be a good average.

A decided advantage in using tungsten carbide when machining cast iron is the fact that the carbide tool due to its great hardness will cut the surface scale nearly as easily as the metal underneath, consequently not as much excess metal must be allowed for finish as when other cutting tools are used.

The accompanying graph illustrates the difference in the amount of metal removed by the different cutting tools, the depth of cut and feed per tooth being constant. Number "1" is carbon steel, "2" high speed steel, "3" stellite and "4" is tungsten carbide.

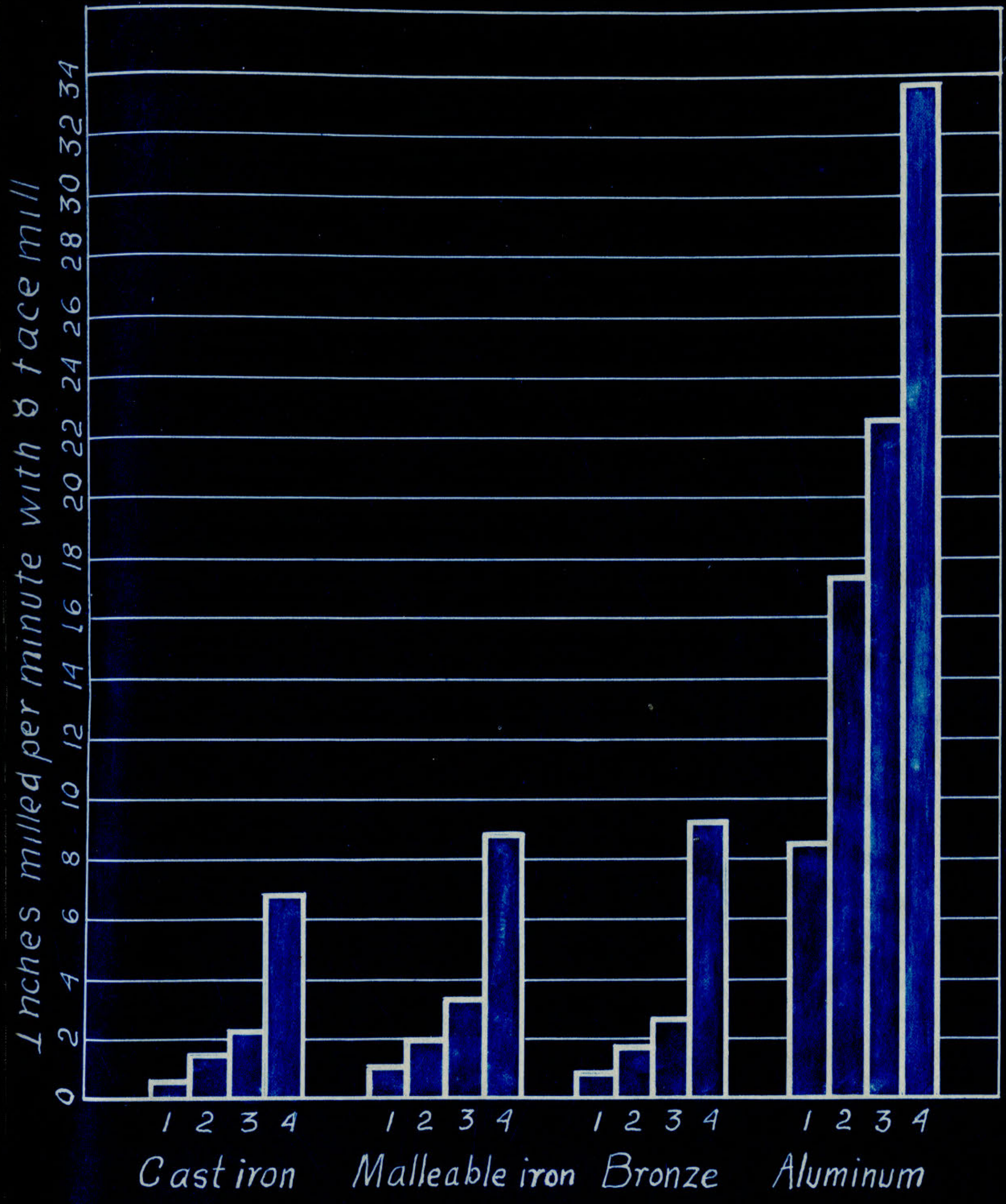
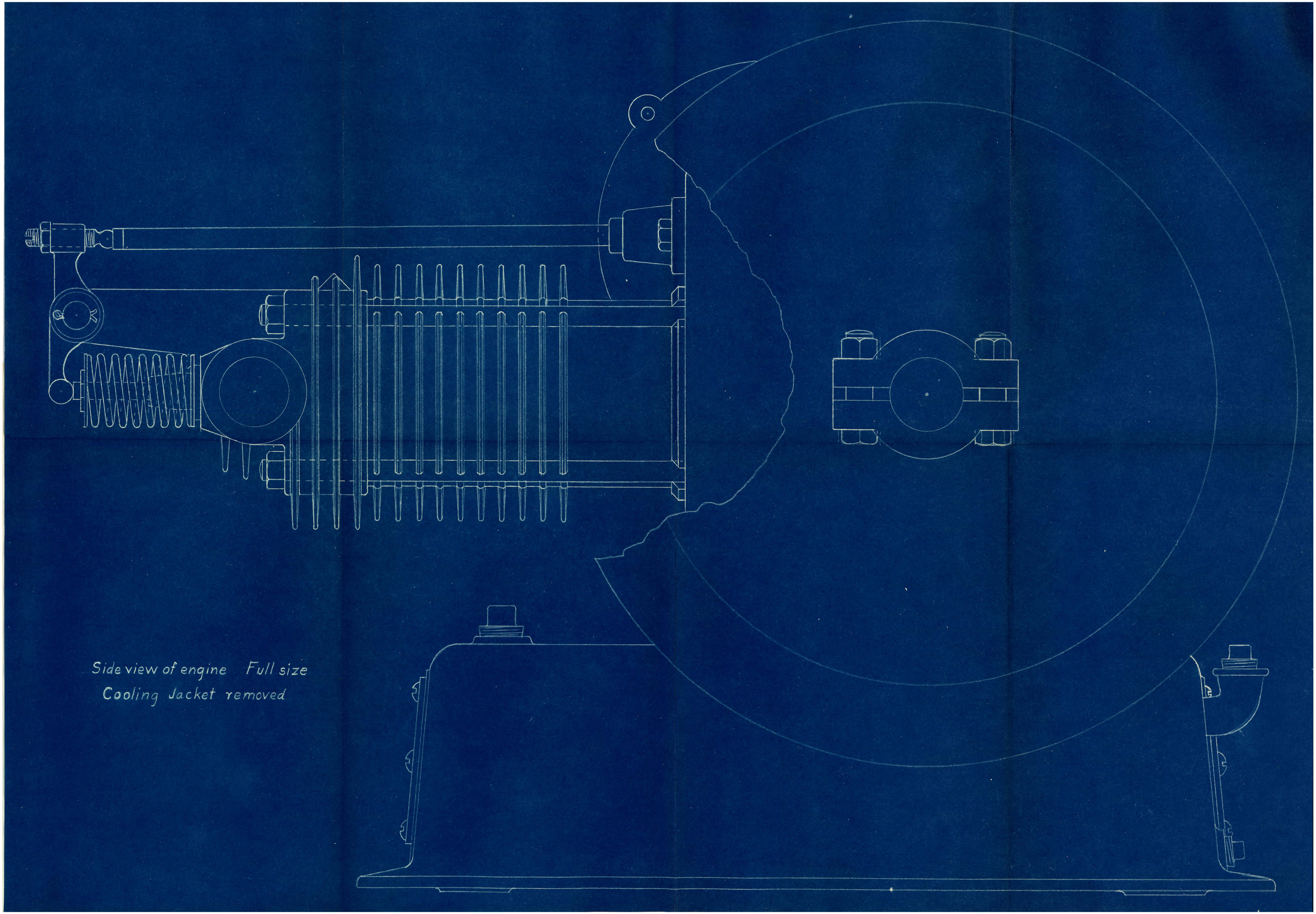
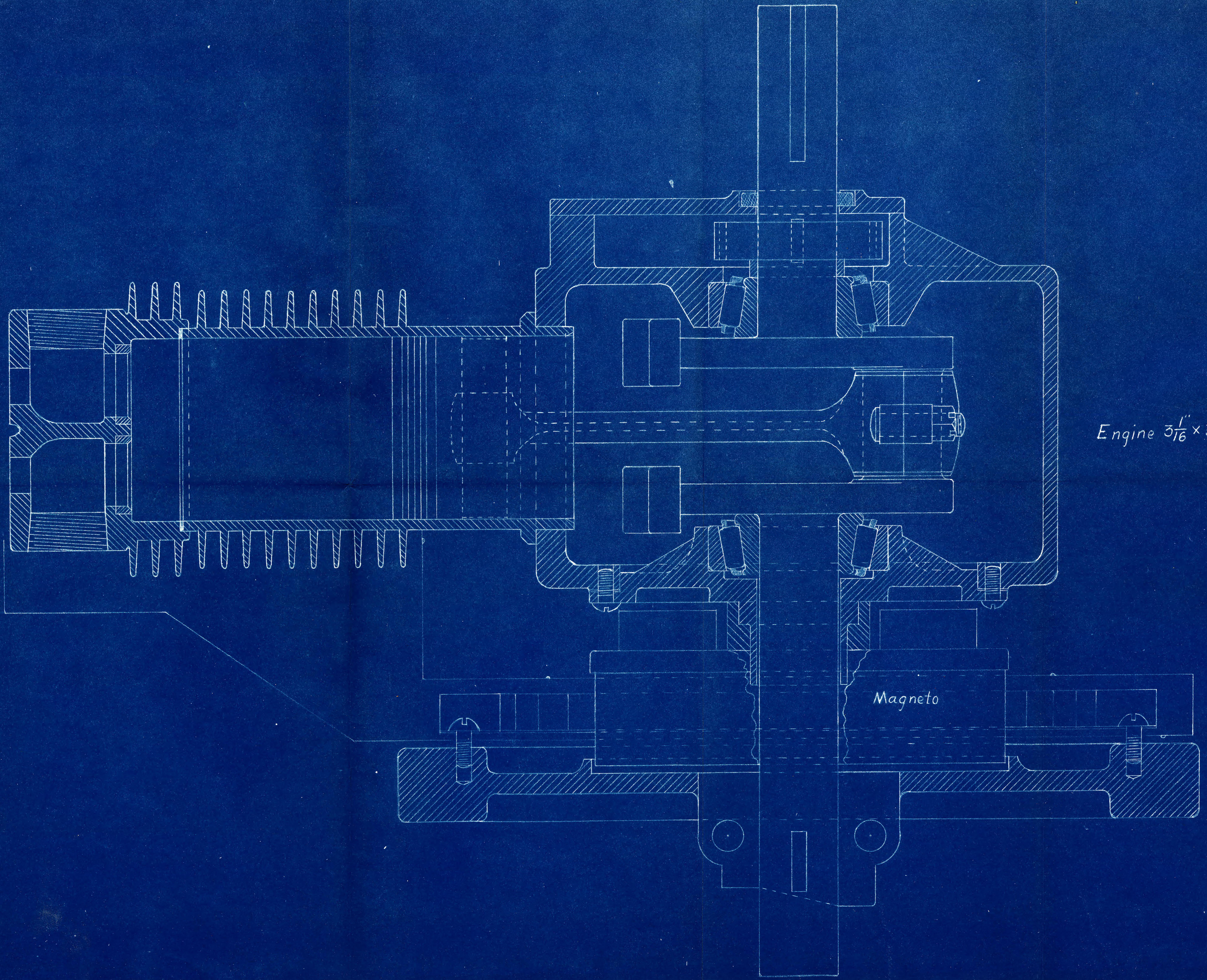


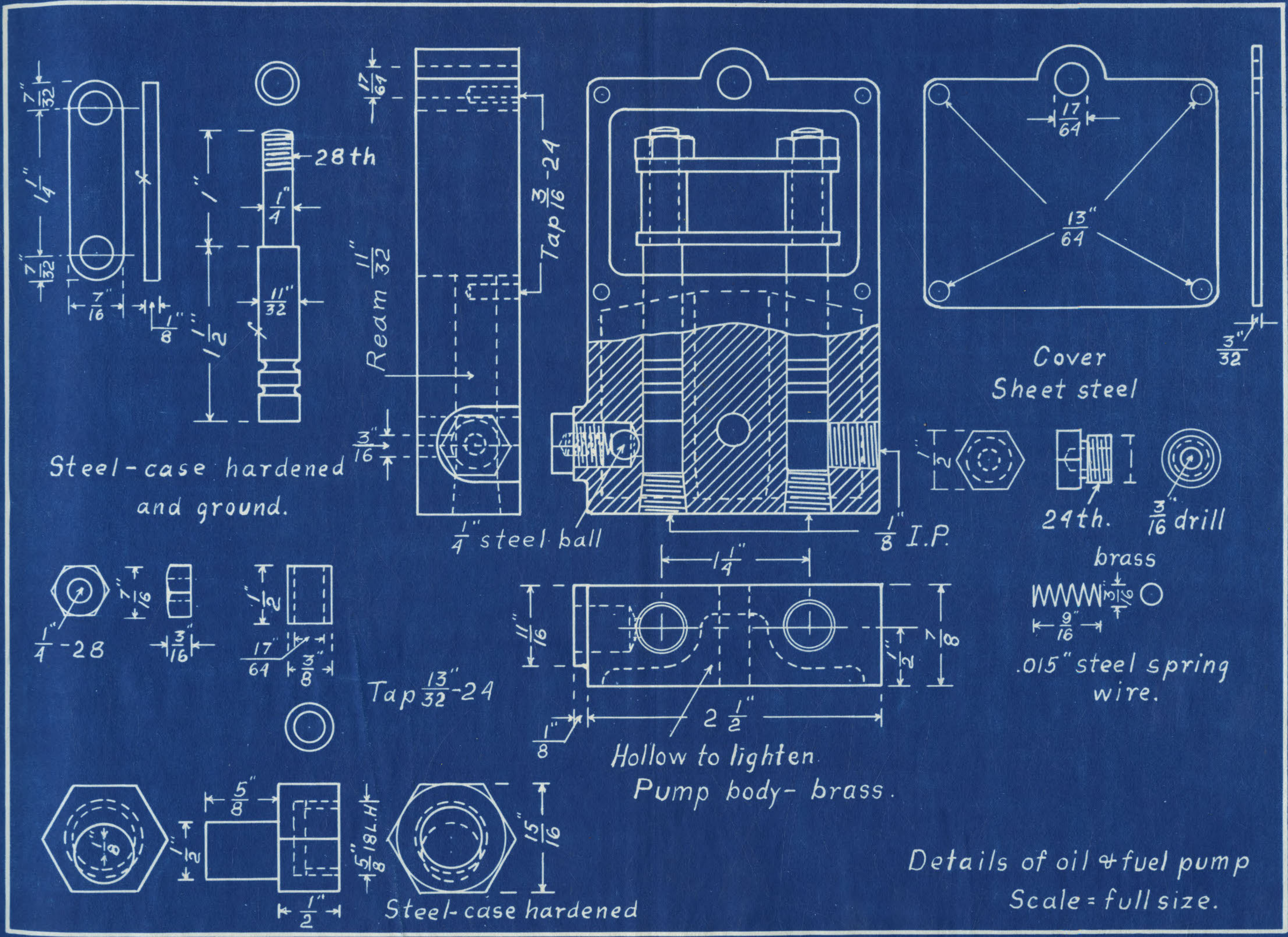
Fig 1. Comparative amount of metals removed by different composition cutters.



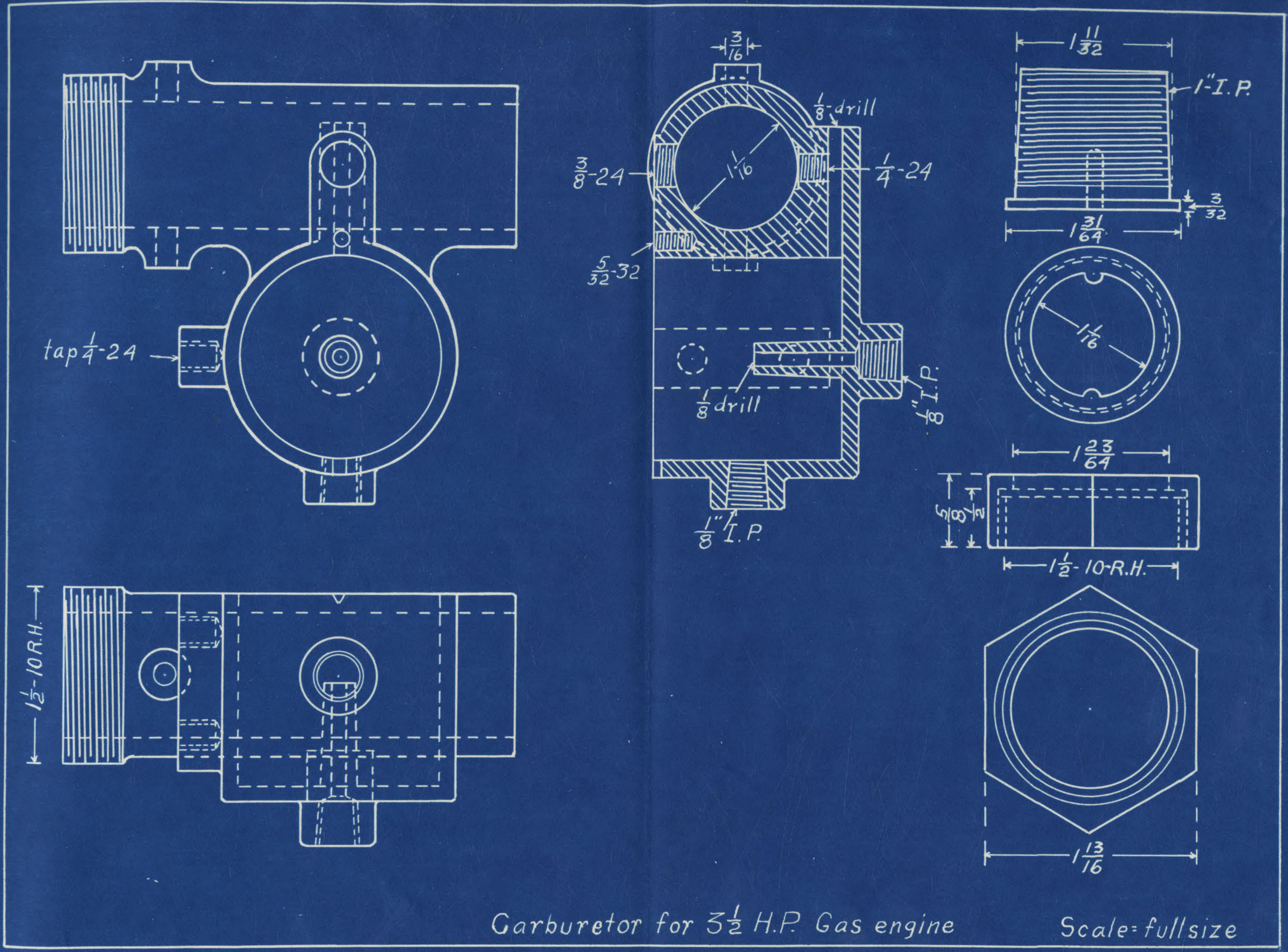
Side view of engine Full size
Cooling Jacket removed



Engine $3\frac{1}{16}'' \times 3\frac{1}{2}''$

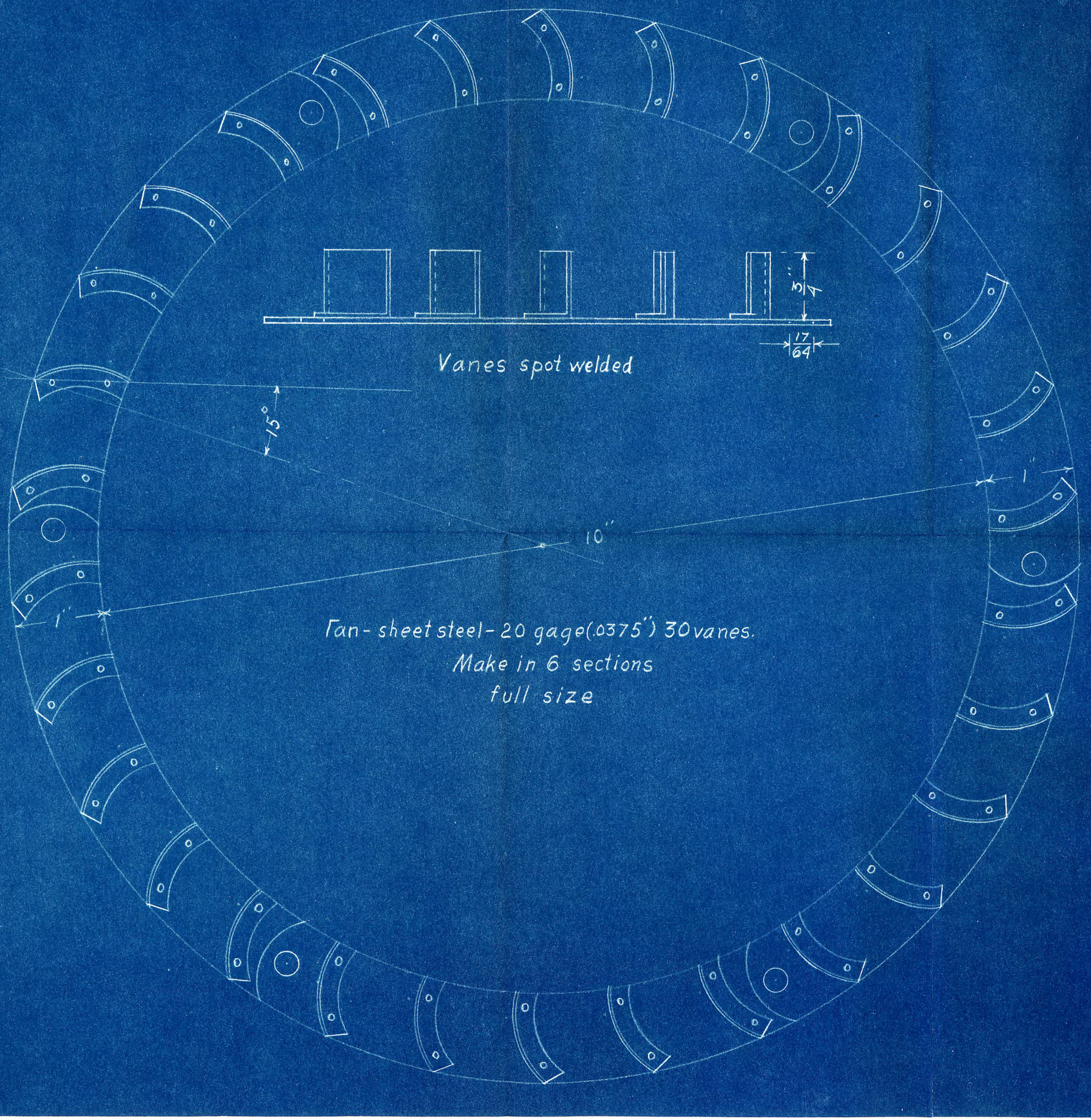


Details of oil & fuel pump
Scale = full size.



Carburetor for 3½ H.P. Gas engine

Scale = fullsize



Vanes spot welded

Fan- sheet steel- 20 gage(.0375") 30 vanes.
Make in 6 sections
full size

Design of Gasoline Engine

(3-1/16" bore by 3-1/2" stroke, compression
ratio 5-1/2 to 1)

In designing the gasoline engine to be used in this study, it was necessary to calculate the size of some parts. The size of other parts was obtained by taking measurements of similar parts of standard makes of engines.

The calculations for the most part were made by using empirical formulas obtained from Volume I, "The Gasoline Automobile" by P. M. Heldt, other calculations were made by using formulas and methods familiar to all engineers.

Displacement Volume.

Area of piston = $.7854 \times 3.0625^2 = 7.37$ sq. in.

Displacement volume = $7.37 \times 3.5 = 25.8$ cu. in.

Clearance volume = $25.8 \div (5.5 - 1) = 5.73$ cu. in.

Clearance distance, since the combustion space is the same diameter as the cylinder, = $3.5 \div (5.5 - 1) = 0.7777$ inches.

Allowing 1/16 inch for the gasket, the depth of the combustion space = $0.7777 - 0.0625 = 0.7152$ inch.

Compression Pressure.

$$P_1V_1^n = P_2V_2^n \quad \text{or} \quad P_2 = P_1\left(\frac{V_1}{V_2}\right)^n$$

$$P_2 = 12.5 \; \frac{25.8}{5.73}^{1.3} = 88 \text{ lb. per sq. in.}$$

P_1 = initial pressure = 12.5 lb. per sq. in.
P_2 = final pressure
V_1 = initial volume = 25.8 cu. in.
V_2 = final volume = 5.73 cu. in.
n = 1.3 for gasoline vapor

Explosion pressure (Heldt) = 88 x 3.75 = 330 lb. per sq. in.

Thickness of Cylinder Wall. Pressure tending to split cylinder longitudinally on one side = $\frac{3.0625 \times 330}{2}$ = 505 lb. per inch of length.

For cast iron of 20,000 lb. per sq. in. ultimate, the thickness of wall will be $\frac{505}{20000}$ = 0.0252 inches with no factor of safety. Using a factor of safety of 8 = 0.0252 x 8 = 0.2016 inch thick, or using a method advocated by P. M. Heldt:

$$t = \frac{\text{bore}}{30} + \frac{1}{8} = \frac{3.0625}{30} + \frac{1}{8} = .102 + .125 = .227 \text{ inch.}$$

Using a cast iron of the following chemical composition will give an iron having a tensile strength of 36,000 lb.

per sq. in., which will give a lighter cylinder of better wearing qualities:

Carbon = 3.30%
Manganese = .55%
Nickle = 1.00%
Chromium = .30%
Steel = .20%
Silicon = 2.10%

In this case the thickness will be, using the same factor of safety, $\frac{505 \times 8}{36000} = 0.1122$ inch, which is rather thin to machine so it will be better to increase this to 0.156 inch, which is 5/32 inch.

<u>Size of Fly Wheel</u>. Horse power = $0.4D^2N = 0.4 \times 3.0625^2 \times 1 = 3.75$ horse power at a piston speed of 1000 feet per minute.

The piston speed of a 3-1/2 inch stroke engine will be at 1600 revolutions per minute $\frac{3.5 \times 2}{1000}\ 1600 = 933$ feet per minute. Therefore the horse power will be $\frac{933 \times 3.75}{1000} = 3.5$.

Using a formula by P. M. Heldt:

$$\Delta E = \frac{C \times H.P. \times 33000}{R.\ P.\ M.} = \frac{2.4 \times 3.5 \times 33000}{1600} = 172 \text{ ft.lbs.}$$

$$W = \frac{\Delta E \times g \times 900 \times K}{\pi^2 \times P^2 \times N^2} = \frac{172 \times 32 \times 900 \times 50}{9.86 \times .25 \times 2560000} = 39 \text{ lbs.}$$

for the rim.

C = constant for 1 cylinder engine

g = 32

K = coefficient of fluctuation, the more constant the speed the larger it must be, it varies from 30 to 250.

N = R. P. M. = 1600

P = radius of gyration in feet = 0.5

Or using an empirical formula from P. M. Heldt:

$$W = 10.6 \left(\frac{bl}{r}\right)^2 = 10.6 \left(\frac{3.062 \times 3.5}{6}\right)^2 = 33.92 \text{ lbs.}$$

b = bore in inches

l = stroke in inches

r = radius of gyration in inches

Using the average of the two will give a weight of 36 pounds for the rim of the fly wheel when driving a direct current generator. Since the engine will probably be used mostly for other purposes, it will be better to use a fly wheel whose rim weighs one-half this amount, and install a second fly wheel when the engine is used to drive a machine where smaller speed variation is desired.

Cross Section of the Fly Wheel Rim.

Weight of rim = 18 lbs.

1 cubic inch of cast iron weighs 0.26 pound

18 ÷ .26 = 69 cu. in. in rim

Mean circumference = 3.14 x 12 = 37.68 inches

Cross sectional area = 69 ÷ 37.68 = 1.83 sq. in.

Making the rim 1-1/4 inches wide will give a depth of 1.46 inches.

Size of the Crank Shaft. The pressure on each crank shaft bearing will be, $\frac{\text{area of piston x explosion pressure}}{2}$ $= \frac{7.37 \times 330}{2} = 1216$ pounds.

The smallest Timken bearing recommended by the manufacturer for carrying this load has an inside cone bore of 1-5/16 inches, consequently it will be necessary to use this size shaft although it is larger than is required for strength. The object in using an aluminum crank case was to make a light engine. The crank shaft could be drilled 11/16 inch if it was thought advisable to make it lighter.

Valve Spring. (Heldt).

Mean diameter = 1-3/16 inch

Pressure when valve is closed = 40 pounds

Valve lift = 5/16 inch

Pressure when valve is lifted = 60 pounds

$$W = \frac{\pi S d^3}{8D} = \qquad 60 = \frac{3.14 \times 50000 \times d^3}{8 \times 1.187}$$

$$d^3 = \frac{60 \times 8 \times 1.187}{3.14 \times 50000} \qquad d^3 = \frac{569.76}{157000}$$

$$d = \sqrt[3]{.00362} \qquad d = .1536 \text{ inches} = \text{No. 9 wire}$$

$$F = \frac{8nPD^3}{Ed^4} = 5/16 = \frac{8 \times n \times 20 \times \left(1\frac{3}{16}\right)^3}{12{,}000{,}000 \times .15^4}$$

$$n = \frac{5/16 \times 12{,}000{,}000 \times .15^4}{8 \times 20 \times \left(1\frac{3}{16}\right)^3} = \frac{1875}{216.8} = 8 \text{ turns.}$$

D = mean diameter of coil

W = maximum safe load in pounds

F = compression of spring

d = diameter of wire

n = number of coils in spring

S = maximum safe fibre stress of material

E = torsional modulus of elasticity = 12,000,000

P = load in pounds to compress spring 5/16 inch when valve lifts

Length of spring when valve is closed = 1-7/8 inch, its initial compression under 40 pounds pressure and it closes 5/16 inch under 20 pounds pressure = $\frac{40 \times 5/16}{20}$ = 5/8 inch.

The spring should be wound to a length of 1-7/8 + 5/8 = 2-1/2 inches.

<u>Size, and Number of Teeth in Timing Gears</u>. Due to the cam shaft passing completely across the crank case it is necessary to have a sufficient distance between centers of the crank and cam shafts so that there will be no interference.

The maximum radius of throw of the crank shaft and connecting rod toward the cam shaft is 3-1/8 inches. Using a cam shaft of 7/8 inch diameter and a cam raise of 5/16 inch gives a maximum cam shaft radius of 7/16 + 5/16 = 3/4 inch. Consequently the center distance between the crank and cam shafts must be greater than the sum of 3-1/8 + 3/4 = 3-7/8 inches to allow for mechanical clearance. This requirement can be fulfilled by using gears having 32 teeth and 64 teeth, 12 diametral pitch. This gives the following dimensions for the gears:

N = 32

dP = 12

Pitch diameter = 32 ÷ 12 = 2.666 or radius = 1.323 inch.

Outside diameter = (32 + 2) ÷12 = 2.833 inches.

N = 64

dP = 12

Pitch diameter = 64 ÷ 12 = 5.333 or radius = 2.666 inches.

Outside diameter = (64 + 2) ÷ 12 = 5.5 inches.

This gives a center to center distance of 1.333 + 2.666 = 3.999+ or 4 inches, this gives a clearance of 4 - 3-7/8 = 1/8 inch.

Counter Balances. To determine the size of counter balances needed on the crank shaft to balance the crank pin and cheeks and the crank end of the connecting rod; the maximum radius of the outside of the counter weight cannot be more than 3 inches and still not interfere with the cam shaft or its bearings.

By making the counter balance supports the same size as the crank sides, the two will balance, however, it will be necessary to add weight enough to balance the crank pin and one-half of the connecting rod.

The volume of the crank pin is: Area of end x length of pin = $.7854d^2l$ = $.7854 \times 1.312^2 \times$ 1-13/16 = 2.446 cu. in.

The weight = volume x weight per cu. in. = 2.446 x .28 = .68 pound.

There are two disks, one at each end of the crank pin 1/16 inch thick by 1-5/8 inch diameter = $.7854 \times 1.625^2 \times$ 1/8 = .33 cu. in. .33 x .28 = .09 pound.

The large end half of the connecting rod weighs 10 oz. or .625 pound. Total weight to balance will be 0.09 + 0.68 + 0.625 = 1.395 pound, or 1.4 pound; 1.4 ÷ 2 = .75 pound on each side.

The weight of the pin and large end of connecting rod will be concentrated at the center of the pin or 1-3/4 inch from the center of the crank shaft. Resolving this into inch pounds gives .65 lb. x 1-3/4 in. = 1.137 inch pounds to be balanced by a weight on the diametrically opposite side of the crank shaft.

Using the size counter balance as shown on the drawing gives a net volume (using planimeter to obtain area) of

(2.46 sq. in. x 1.125) - (.75 sq. in. x 1/2 in.) = 2.755 - .375 = 2.38 cu. in.   2.38 x .28 = .676 pound.

The center of gravity of the added mass is 2-3/8 inches from the center of the crank shaft.

2.375 x .676 = 1.6 inch pounds, which gives an excess of .2 inch pound on each side or a total of .4 inch pound on both. This can be taken care of by grinding or drilling to obtain exact balance.

Capacity of the Fuel Pump. The engine develops 3-1/2 horse power at 1500 R. P. M. and will use about .6 of a pound of fuel per H. P. hour. Gasoline weighs 6-1/2 pounds per gallon.

Number of cubic inches of fuel required per hour = $\frac{.6 \times 3.5}{6.5}$ = 0.315 gallon, and since one gallon contains 231 cu. in. of fuel required, it will be necessary to use a pump whose capacity is considerably in excess of this amount so there will be a constant level of fuel in the carburetor bowl.

Using a pump whose plunger is 11/32 inch in diameter (so the hole can be tapped for 1/8 inch iron pipe) by 1/8 inch stroke and driven from the cam shaft will give at 1500 R. P. M. engine speed, 750 strokes per minute of the pump. To obtain the volume of one stroke of the pump, $.7854d^2l$ = $.7854 \times .343^2 \times .125$ = 0.011 cu. in.

0.011 x 750 x 60 = 495 cu. in. per hour.

Air Required to Cool Engine.

3-1/2 HP output using .6 pound of fuel per HP hour

3.5 x .6 = 2.1 pound fuel per hour

Assume fuel has 19,000 B. T. U. per pound.

2.1 x 19000 = 39,900 B. T. U. per hour going into engine, of this amount 30% must be radiated from the cylinder and head.

39900 x 0.3 = 11970 B. T. U. per hour, or

11970 ÷ 60 = 199.5 B. T. U. per minute (use 200)

The specific heat of air at constant pressure = 0.24

Assume 100° F. temperature rise in the air, then

$\frac{200}{100 \times .24}$ = 8.3 pounds of air required per minute. Since air weighs 0.08 pound per cu. ft. under standard conditions the volume of air blown past the cylinder per minute = 8.3 ÷ 0.08 = 103.75 cu. ft. (use 104).

Using a sirocco type fan 12 inches in outside diameter, the dimensions of the blades (from catalogue) are:

Radial depth of blades = 0.066 d = 0.066 x 12 = 0.792 inch.

Axial length of blades = 0.52d = 0.52 x 12 = 6.25 inches.

A standard wheel 12 inches in diameter with blades 6.25 inches long delivers 1500 cu. ft. of air per minute at 1274

R. P. M.

The volume of air delivered varies as the first power, therefore, the volume of air delivered by this fan at 1500 R. P. M. would be $1500 : x :: 1274 : 1500$, $x = \frac{1500 \times 1500}{1274} =$ 1766 cu. ft.

It is necessary to deliver 104 cu. ft. of air per minute, the length of the blades will be in direct proportion to the length of the standard blade, or

$x : 6.25 :: 104 : 1766$, $x = \frac{6.25 \times 104}{1766} = 0.368$ inch.

The standard wheel uses 60 blades, but for mechanical reasons it will be necessary to use 30 blades, hence the above length will have to be multiplied by 2, or

$0.368 \times 2 = 0.736$ inch, use 3/4 inch.

Engine Base – full size. C.I.
(or aluminum)

Cast Iron Engine Base

For machining the pads on the top and bottom of the base, a duplex miller seems to be the logical machine to use as both surfaces can be machined at once. The Duplex Mil-waukee-Mil has been designed to use the cemented tungsten carbide cutters and is so designed that each cutter may be operated at its most efficient speed.

Machining the bottom of the base will require a 11-1/4" cutter, and a 8-1/2" cutter for the top. Using Carboloy cutters and a feed of 32 inches per minute for the 8-1/2" cutter with 18 teeth feeding 0.010" per tooth, the cutter will have to run at 177 revolutions per minute. The 11-1/4" cutter having 26 teeth and using the same feed per tooth will run 123 revolutions per minute.

Using a plain clamping fixture holding one base, the length of table travel to machine the bottom of the base will be 16 inches. At a feed of 32 feet per minute and a table return at 64 feet per minute, including 6 inches to feed up to the cut, it will require 0.09 minute to complete the cycle. Allowing 18 seconds or 0.30 minute for the operator to remove the machined part and replace it with a rough one, the floor to floor time will be 0.09 plus 0.30

or 0.39 minute. This is at the rate of 153 per hour or 1224 for 8 hours, allowing for a 15% decrease for delays, tool changes, etc., will give a net production of 1040 per 8 hour day.

For milling the pads on the ends of the base, it will be necessary to machine one end at a time due to inclination of the surface to be machined. By using a Simplex Milwaukee-Mil and a rotatable fixture holding two bases, so one base can be changed while the other is being machined, no time need be lost while loading and unloading the fixture.

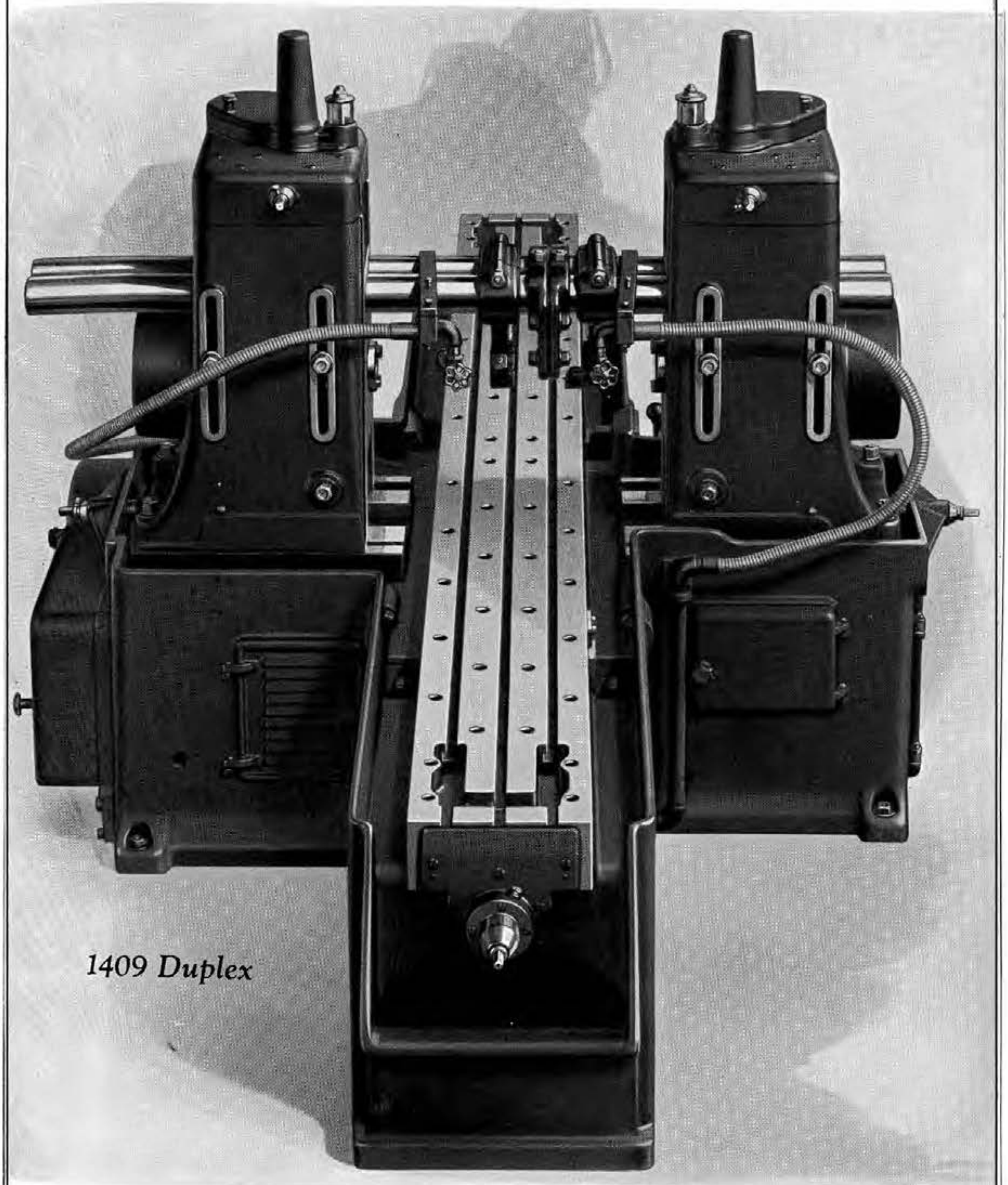
It will be necessary to use a 3-1/2" cutter and a table travel of 6 inches. The cutter will have 9 teeth, consequently the feed per revolution at 0.010" per tooth will be 0.09". At 300 feet per minute cutting speed, the cutter will make 330 revolutions per minute which will give a feed of 330 times 0.09 or 30 inches per minute. At 30 inches per minute it will take 0.20 minute to make the cut. The return will be at twice the feed consequently it will take 0.30 minute for the cycle.

Allowing 6 seconds for the operator to index the fixture, the floor to floor time per piece will be 0.30 plus 0.10 or 0.40 minute. This will give a gross production of 150 pieces per hour or 1200 per 8 hour day. At 85% efficiency to allow for delays, tool changes, etc., the net production will be 1020 pieces per 8 hour day.

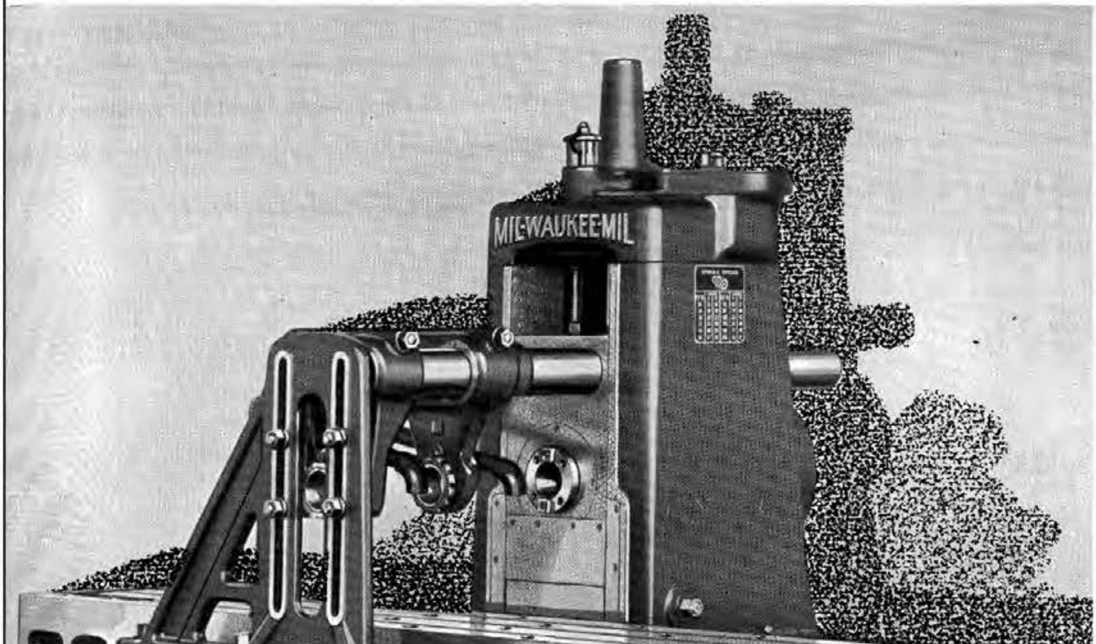
If the base were made of aluminum, this production could be increased by about 25%, the actual machining could be done in one-fourth the time, but the operators time would remain the same.

Drilling the holes in the base would be done on a multiple spindle drill, such as "NATCO", all the holes being drilled at the same time, the production being at the net rate of 1280 per 8 hour day.

The holes would be tapped on the same type machine using a tapping attachment, the production in this case would be the same as drilling, provided high speed steel taps were used.

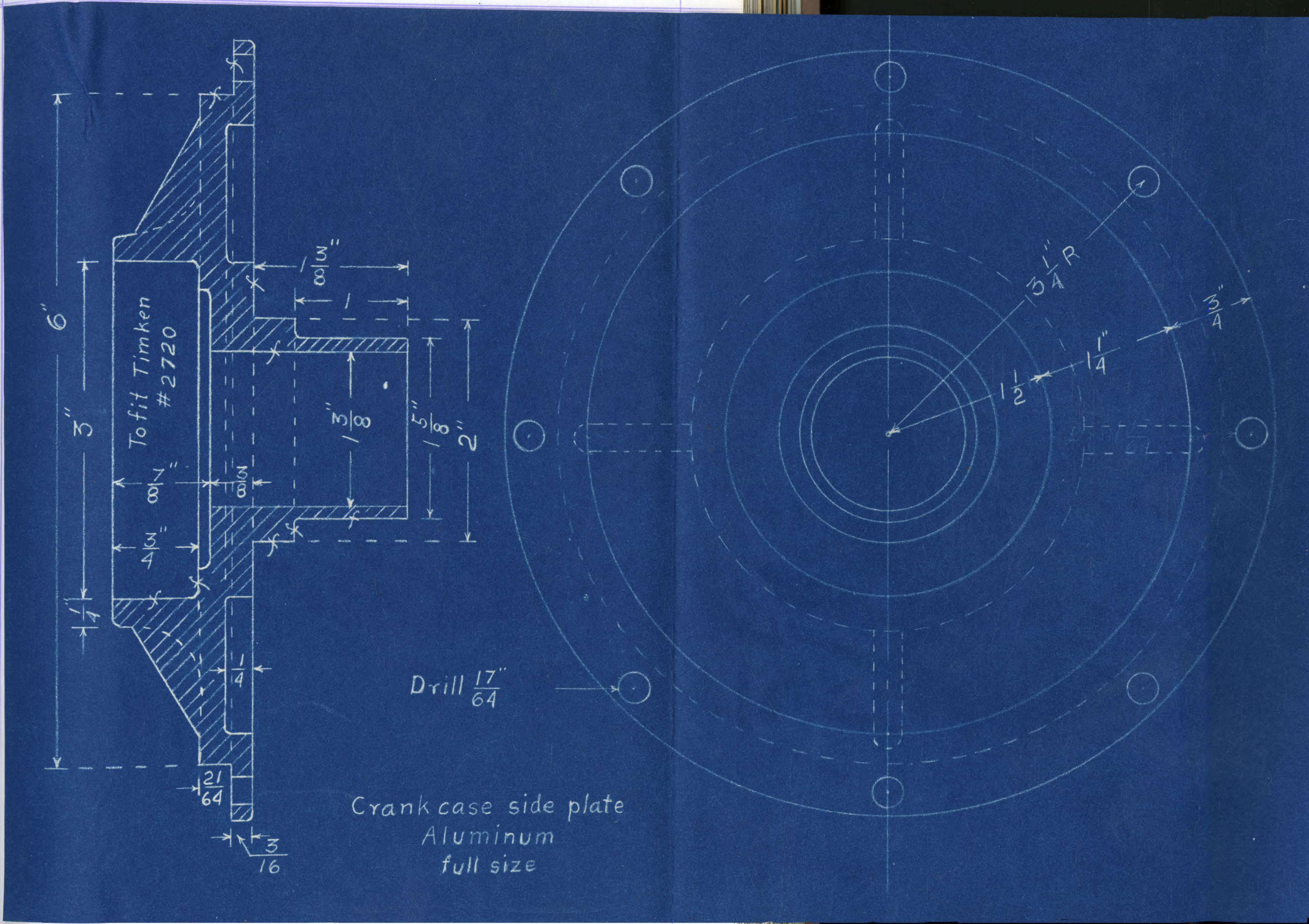


1409 Duplex



1404 Simplex

Crank case-Aluminum
full size



Crank case side plate
Aluminum
full size

Crank Case

The aluminum crank case could be machined on the top and bottom surfaces also the side surfaces on duplex milling machines, such as the Mil-waukee-Mil.

For the top and bottom surfaces also the cylinder end of the crank case, it would be necessary to use a fixture which would locate the piece from the crank shaft opening. When machining the side faces, the crank case can be located from the sides of the case. Three milling machines, two duplex and one simplex can easily produce the output required.

Machining the crank shaft openings can be done very nicely on a double spindle heavy duty vertical drill press by using a simple clamping fixture and a combination tool which will machine the roller bearing seat and the hole for the side plate at the same time. It would be necessary to use a guide for the bottom end of the tool bars, rough machine on the first spindle and finish on the second.

The hole for the cylinder would be machined in the same manner, only in this case no tool guide would be necessary.

Machining the crank case side plate would be handled by a turret lathe, such as the Jones and Lamson. A different set-up would be required for each side, with a net production of 75 pieces per hour per machine when using Carboloy tools.

The drilling and tapping operations on the crank case and side plates would be performed on a "NATCO" or similar machines, the sequence of operations being as shown on the accompanying operation sheets.

CRANKCASE*

Material - Aluminum.
Production Required - 1000 pieces per 8 hour day.

The following machine is for drilling 4 faces of the Crankcase simultaneously and we recommend as follows:

Three - A4H "NATCO" Semi-automatic Hydraulic Feed Drillers, each equipped with one rear head for drilling 2 holes for 5/16" tap and 4 holes for 3/8" tap, one left hand head for drilling 8 holes for 1/4" U. S. S. tap and half way through on 2 - 7/16" holes, one right hand head for drilling 10 holes for 1/4" tap and half way through on 2 - 7/16" holes, one vertical head for drilling 8 - 1/4" holes. Machine to be completely equipped with motors and electrical equipment which includes - one 2 HP 1200 RPM motor for rear head, one 3 HP 1200 RPM motor for left hand head, one 3 HP 1200 RPM motor for right hand head, one 2 HP 1200 RPM motor for vertical head, and one 5 HP 1200 RPM motor for the hydraulic pump.

Price - Each machine - approximately	$6,000.00
Price - For each fixture	740.00
Price - One set of tools for each machine . . .	21.35

Floor Space - 10' x 6'.
Shipping Weight - 12,000 lbs.

These machines would be equipped with a stationary type fixture to hold one crankcase and one operator could successfully operate the three machines.

The production is based on the largest hole and the greatest depth which is 7/16" drill running at 1050 RPM with .005" feed and 2-7/8" depth.

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*Estimate, National Automatic Tool Co., Richmond, Indiana.

Operation Time -

The operator loads 1 part into fixture	6	seconds
Start machine	1	"
Rapid forward of heads	2	"
Drilling time	33	"
Rapid return of heads	4	"
Unload part from fixture	6	"
TOTAL	52	"

Estimated Net Production - 46 parts per hour.

It is necessary to tap the 4 faces of this same Crankcase and we recommend:

One - 4-way "NATCO" Lead Screw Tapper having one rear head for tapping 2 - 5/16" and 4 - 3/8" holes, one left hand head for tapping 8 - 1/4" holes, one right hand head for tapping 10 - 1/4" holes and one vertical head for tapping 8 - 1/4" holes. Machine to be equipped with one 1-1/2 HP motor for the rear head, one 1-1/2 HP motor for left hand head, one 2 HP motor for right hand head, one 1-1/2 HP motor for vertical head and all electrical equipment.

Price -	$5,000.00
Price - Stationary type fixture to hold 1 part	385.00
Price - One set of tools	17.40

Floor Space - 8' x 5'.
Shipping Weight - 10,000 lbs.

One machine and one operator only will be necessary for the production required and the operation is computed as follows:

Load 1 part into the fixture	6	seconds
Start machine	1	"
Tap	10	"
Unload the part	6	"
TOTAL	23	"

Estimated Net Production - 125 parts per hour.

CRANKCASE SIDE PLATE*

Material - Aluminum.
Production required - 1000 per 8 hour day.
Operation - Drill 8 - 17/64" holes.

Machine Recommended:

One - B225H Semi-automatic Hydraulic Feed "NATCO" Multi-Driller equipped with one 8 spindle drill head, one self contained motor driven coolant pump, all electrical equipment - including one 5 HP 1200 RPM motor.

Price - Approximately	$1,600.00
Price - Fixture	340.00
Price - Tools, per set	4.80

Floor Space - 26" x 50".
Shipping Weight - 4000 lbs.

Simple stationary type fixture is used into which the operator places one part. Machine is arranged for 1830 RPM and .002" feed, depth 3/8".

Loading time	5	seconds
Start	1	"
Rapid traverse down	2	"
Drilling time	7	"
Rapid return	3	"
Unload fixture	5	"
TOTAL	23	"

Estimated Production - 130 parts per hour net, one operator.

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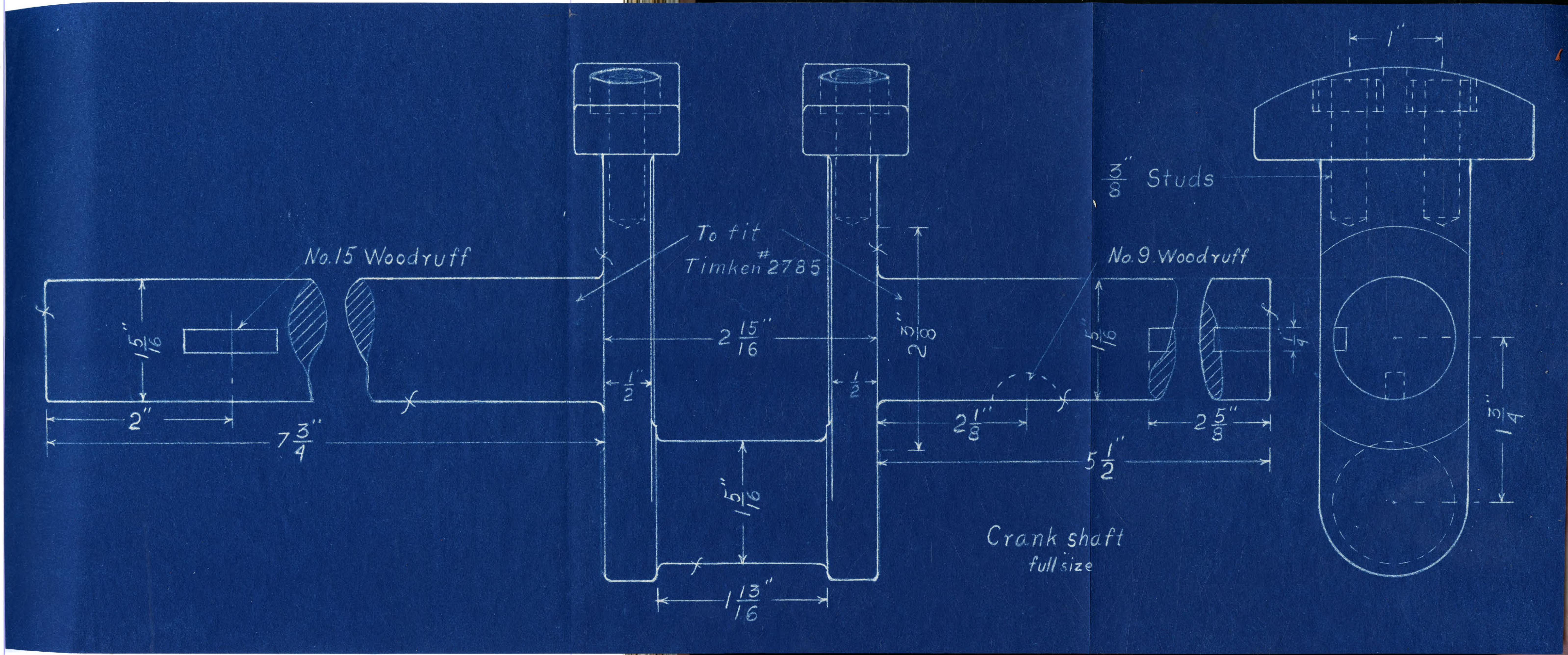
*Estimate, National Automatic Tool Co., Richmond, Indiana.



Crank shaft
full size

Crank Shaft

The first operation in machining the crank shaft is to mill to length, using a duplex miller and a fixture locating from the side of the crank webs.

The second operation is to center both ends, using a double head centering machine such as the one made by the Sundstrand Machine Tool Co.

The third operation would be to mill the flats for the counter weights to bear against.

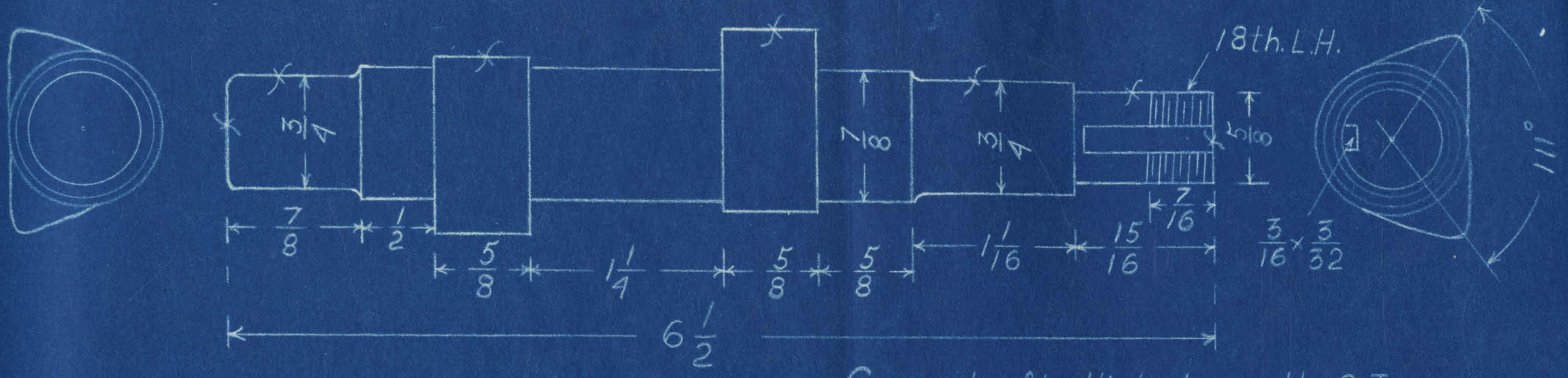
The fourth operation would be to drill and tap the crank webs for the counter weight studs, using a multiple spindle drill press.

The fifth operation would be to rough turn the ends, leaving a small amount for grinding. The grinding would be done in two steps, rough and finish, the production per operation per machine would be about 20 shafts per hour.

The seventh operation would be to rough and finish grind the crank pin, using a plunge type grinder and finishing the pin in two operations. Production about 20 shafts per hour per machine.

The eighth operation would be to mill the key seats on hand milling machines, and since there are three different key ways on the shaft, and the production would be about 20 shafts per hour per machine, it will require 21 machines to give a production of 1000 shafts per 8 hour day.

The last operation is to finish grind the shaft ends to size, the production per machine will be about 25 shafts per hour because only 8 to 10 thousandths of an inch of stock is left for finish.



Cam shaft. High strength C.I.
Cams 1" diameter $\frac{5}{16}$" rise.

Cam Shaft

Former practice in making cam shafts has been to use carburized and hardened steel, but since the introduction of high strength cast iron, (tensile strength of 60,000 pounds per square inch) a number of manufacturers are using this material as it is cheaper and gives results fully as good as steel.

CAM SHAFT GRINDER*

Production estimate on machines recommended for grinding line diameters as well as cam contours of cam shaft for 3-1/16" x 3-1/2" stroke single cylinder, air cooled gas engine.

First, for grinding the two line bearings as well as the gear fit, 5/8" diameter, we recommend our 6" x 18" Type C Plain Hydraulic type grinding machine as illustrated on pages two to five of catalogue A-32, four copies being sent you, under separate cover, the specifications of the machine also being given on page thirteen. The equipment including one machine complete with dead spindle headstock, lever operated footstock, plain wheel feed mechanism, hand traversing mechanism, wheel guard to accommodate 18" diameter, 1-1/2 inch face wheel, wheel center, diamond holder, XX diamond, special work driving pin to engage with cam, set of wrenches, water guards and rods, water pump, water service complete, grinding wheel 18" diameter, 1-1/4" face, 8" hole, type C Arnold sizing gauge complete with all electric motors with their starting equipment, to be operated from 220 volt, 3 phase, 60 cycle, alternating current. Price complete, f.o.b. our factory, Waynesboro, Penna., $2366.80.

Estimated production, removing .015" to .018" diameter, finishing both line bearings 3/4" diameter and gear fit 5/8" diameter -- 50 complete shafts per hour, or 400 per eight-hour day. Figuring 80% efficiency, giving a net of 320 complete shafts per eight-hours, thus requiring three machines to obtain a production of 1000 parts per eight hours.

For grinding the cam contours we recommend our 6" Type C machine as shown in our catalogue A-32 and as specified for the line bearing grinding operation, with the exception that instead of the regular headstock, footstock and swivel table, the machine will be equipped with a cam grinding fixture as shown on blue print S-1955, two views, being mailed

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*Estimate, Landis Tool Company, Waynesboro, Pennsylvania.

in quadruplicate, together with the catalogues specified above, the capacity being 5" swing x 15" between centers.

A two-speed work drive motor is used, 1800/3600 RPM, the higher speed being used throughout for the rough grinding operation, the slower speed being used for the last two or three revolutions of the work upon the final finishing of the cam, thus giving a more accurate contour. This slow speed is obtained by the operator engaging limit switch as shown on front view of machine, blue print S-1955.

The machine as shown is equipped with a foot-pedal arrangement which withdraws the plunger from the spacing bar and allows hydraulic pressure to enter the cylinder, thus pulling the swinging bracket away from the master cam roller. With the foot pedal held in down position, the work table is traversed by hand, bringing the wheel in line with a second cam, also automatically shifting the master cam roller in line with the corresponding cam of the master shaft. During the shifting of the work carriage the foot pedal is released and upon the table coming in to correct position the spacing plunger enters the notch which automatically releases the hydraulic pressure for holding the swinging bracket back, thus allowing the swinging bracket to return to working position in contact with the master cam roller.

The machine is arranged with reciprocating wheel spindle, plain hand wheel feed to the grinding wheel, machine is motor driven and the price includes all motors and starting equipment to operate from 220 volt, 3 phase, 60 cycle, alternating current, the machine being fully equipped for grinding cam contours as per print of cam shafts for a 3-1/16" x 3-1/2" stroke, single cylinder air cooled gas engine as attached to your letter. The equipment included consists of two special work drive dogs to be clamped on the 5/8" gear fit diameter which will be positioned radially by engaging the keyway in same, which we assume is held in a certain angular relation to the center of cams in question, wheel guard for 18" diameter, 1-1/2" face wheel, wheel center, grinding wheel 18" diameter, 1" face, 8" hole, XX diamond, set of wrenches, water pump, water service, set of water guards, spacing bar and control mechanism, and oil pump. Price complete, f.o.b. our factory, Waynesboro, Penna. $3516.50.

The above price does not include the following:

1 -	Master Camshaft, one (intake and one exhaust cam) required for each machine, which can be furnished at an extra price of (each).	$165.00
1 -	Pair of Model Cams, intake and exhaust, one only required for one or a battery of machines . . .	$225.00
1 -	Wheel Balancing Arbor, one only required for one or a battery of machines	$10.00

Estimated production, grinding from the rough casting, removing 1/8" diameter (1/16" from a side) -- 80 cams or 40 complete shafts per hour. Finish grinding, removing .006" to .008" diameter -- 100 cams or 50 complete shafts per hour.

Thus at 80% efficiency would require four roughing and three finishing machines to obtain a net production of 1000 shafts per eight-hour day. These figures are based on the following accuracy:

"Over the quieting contour on that portion of the cam up to the opening point the error not to vary more than .0005" in any 3°, with a total variation up to and including the timing point not to exceed .001".

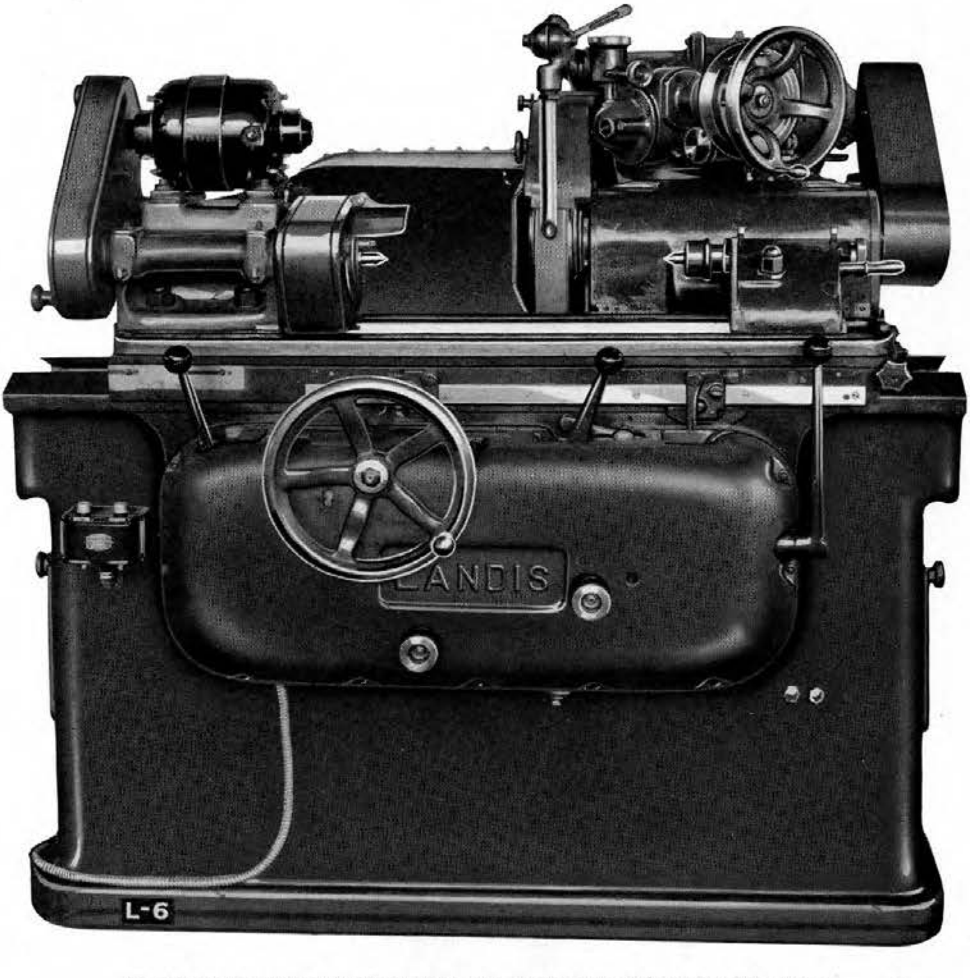
From the timing point to 10° above, error not to vary more than .0005" in any 2° with a total variation up to and including the 10° point not to exceed .002".

Above the 10° point error not to vary more than .001" in any 3° and a total variation not to exceed .003" from the specifications given by the purchaser."

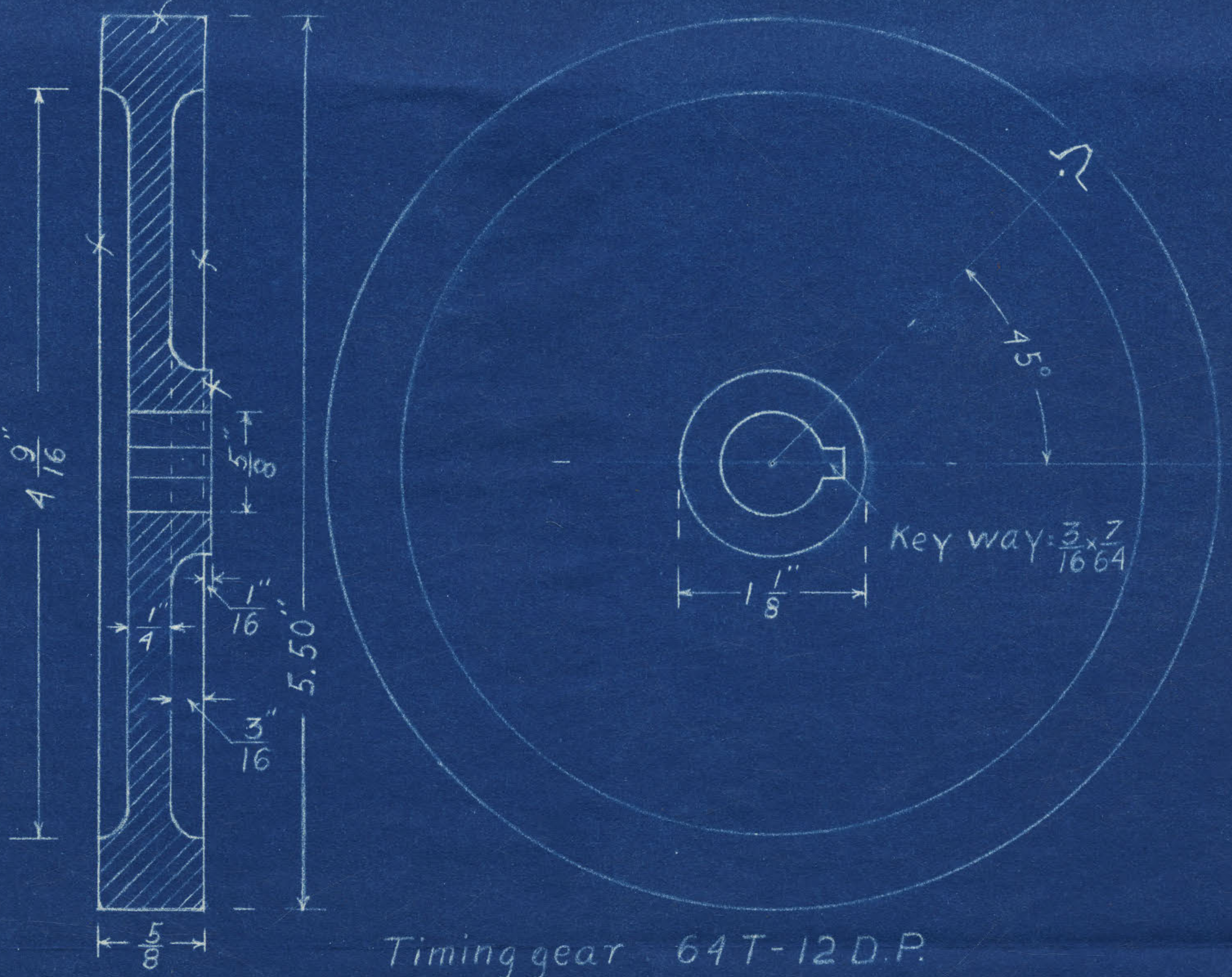
As to the power requirements for both the line bearing and cam contour machines, the electrical specifications on page 13 of catalogue A-32 can be used. You will understand that the motor specifications are such to take care of peak loads and that the average power consumption should be approximately one-half of the horsepower stated.

The depreciation costs on a machine of this type should not be figured in excess of 10% per year, as the equipment with the exception of a few details, such as the model cams, master cam shaft, spacing bars, are not special for this particular piece, but can be changed over as the requirements demand.

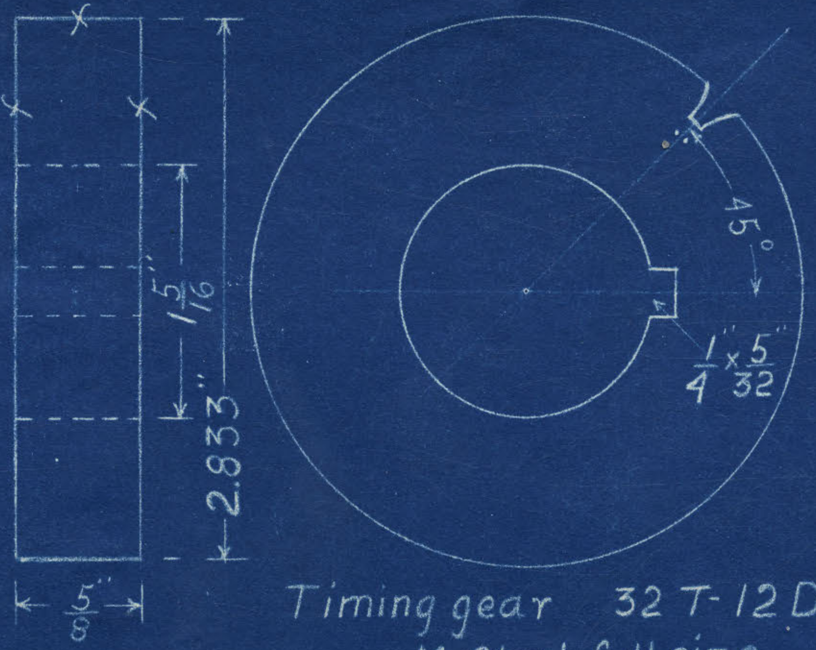
6″ & 10″ Type C Plain Hydraulic Grinding Machines



Front view of 6″ x 18″ Type C Plain Hydraulic Grinding Machine



Timing gear 64 T-12 D.P.
Cast iron-full size



Timing gear 32 T-12 D.P.
M. Steel-full size.

Timing Gears

Thirty-two Tooth Timing Gear. As this gear is made of mild steel, it can most economically be machined directly from bar stock by means of an automatic screw machine such as the Cleveland Model M, 4 spindle. The time per piece will be the time required for the longest operation, which will be for drilling the hole 3/4" deep. The time required will be (at 100 feet per minute cutting speed) 0.31 minute. This is at the net rate of 164 per hour, or 1312 per 8 hour day.

Sixty-four Tooth Timing Gear. This is a cast iron gear and if it is machined on a six spindle Mult-Au-Matic, the time per piece will be the time required for the longest operation, which will be for turning the outside diameter, plus about one second for indexing.

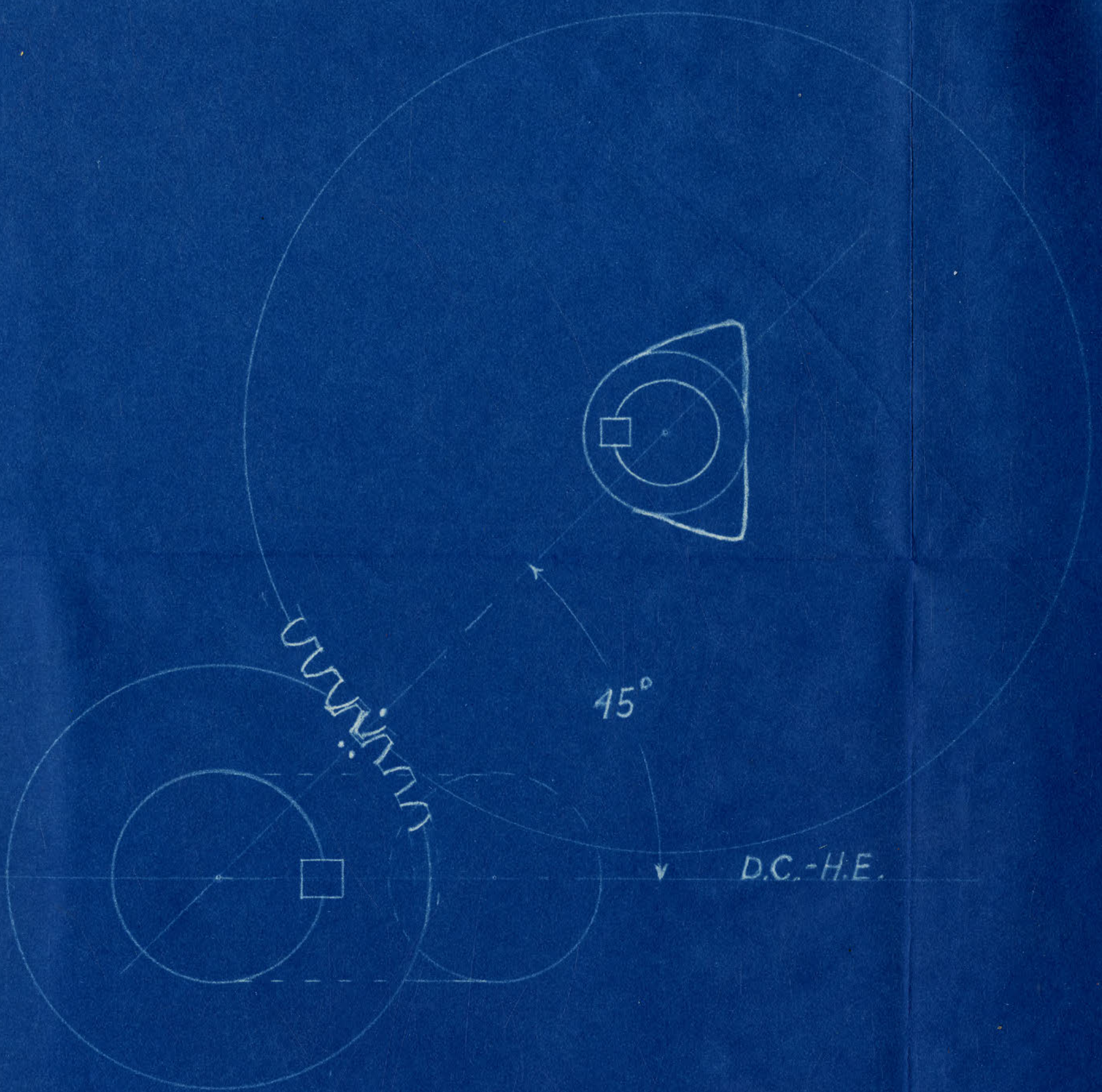
The time required to turn the outside diameter, using stellite tipped tools will be (at 120 feet per minute cutting speed) 0.36 minute. This is at the net rate of 131 pieces per hour or 1048 per 8 hour day. The production can be increased by 50% if necessary, by substituting tungsten carbide for the stellite cutting tools.

Both gear blanks would next have the key ways cut in them. The key ways and teeth are in definite relationship to each other, as will be noticed by inspection of the timing diagram, and it makes it easier to maintain this relationship if the key ways are cut prior to cutting the teeth.

The gear blanks would next go to a hobbing machine, such as the Barber-Colman. Four of the steel blanks or six of the cast iron blanks would be mounted on a mandrel at a time.

The actual cutting time is shown on the accompanying operation sheet.

Both gear blanks would next have the key ways cut in



Timing diagram for cam shaft

ESTIMATE OF PRODUCTION

Barber-Colman Company
General Offices and Plant
Rockford, Ill., U. S. A.

FOR Kansas State College

Part of Proposal No. 254

Date 3-28-33

PART SPECIFICATIONS

Drawing No. Part No.

Name Timing Gear

Teeth 32 No. Splines

Pitch 12 R. D. K. Width

Face 5/8" Length

Diameter 2.666" Diameter

Material Machine Steel

PRODUCTION ESTIMATES

Number per Load 6 No. Cuts 1

	ROUGHING	FINISHING
Hob Speed		230
Feed per Rev.		.035"
Cutting Time	Min.	17.5 Min.
Reloading Time	Min.	1.0 Min.
Total Time	Min.	18.5 Min.
Time per Piece	Min.	3.1 Min.

Production per Hour (85% Efficiency) 16.5

Production per Day (Hours)

HOB SPECIFICATIONS

~~Roughing~~ { ~~Ground~~ ~~Unground~~ }

Finishing { Ground ~~Unground~~ }

Diam. 2" Face 2" Hole 3/4"

Keyway No. Threads S

1 only $24.90

MACHINE RECOMMENDED

No. and Type No. 3 Hobbing Machine

$1500.00

SPECIAL FEATURES

Motor drive arrangement including motor and starter

$190.00

TOOLING EQUIPMENT

Work Arbor and two collars

$28.50

REMARKS

2 H. P. motor required. One operator could run both machines and have some time idle.

ESTIMATE OF PRODUCTION

Barber-Colman Company
General Offices and Plant
Rockford, Ill., U. S. A.

FOR Kansas State College

Part of Proposal No. 254

Date 3-28-33

PART SPECIFICATIONS

Drawing No. Part No.

Name Timing Gear

Teeth 64 No. Splines

Pitch 12 R. D. K. Width

Face 5/8" Length

Diameter 5.333" Diameter

Material Cast Iron

MACHINE RECOMMENDED

No. and Type No. 3 Hobbing Machine

SPECIAL FEATURES

PRODUCTION ESTIMATES

Number per Load 4 No. Cuts 1

	ROUGHING	FINISHING
Hob Speed		380
Feed per Rev.		.045"
Cutting Time	Min.	13.5 Min.
Reloading Time	Min.	1.25 Min.
Total Time	Min.	14.75 Min.
Time per Piece	Min.	3.7 Min.

Production per Hour (85% Efficiency) 14

Production per Day (Hours)

TOOLING EQUIPMENT

Work Arbor and 3 collars

$40.00

HOB SPECIFICATIONS

Roughing { Ground / Unground

Finishing { Ground / Unground

Diam. Face Hole

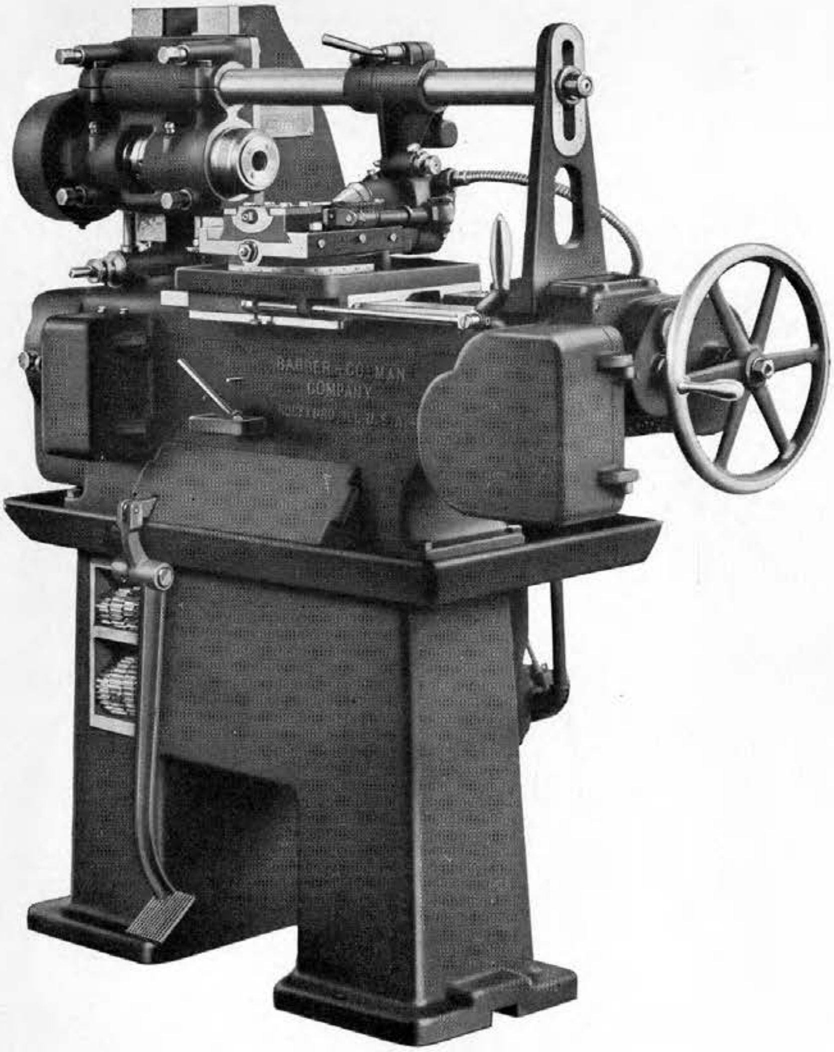
Keyway No. Threads

Same as for 32 teeth

REMARKS

BARBER-COLMAN

NO. 3 HOBBING MACHINE

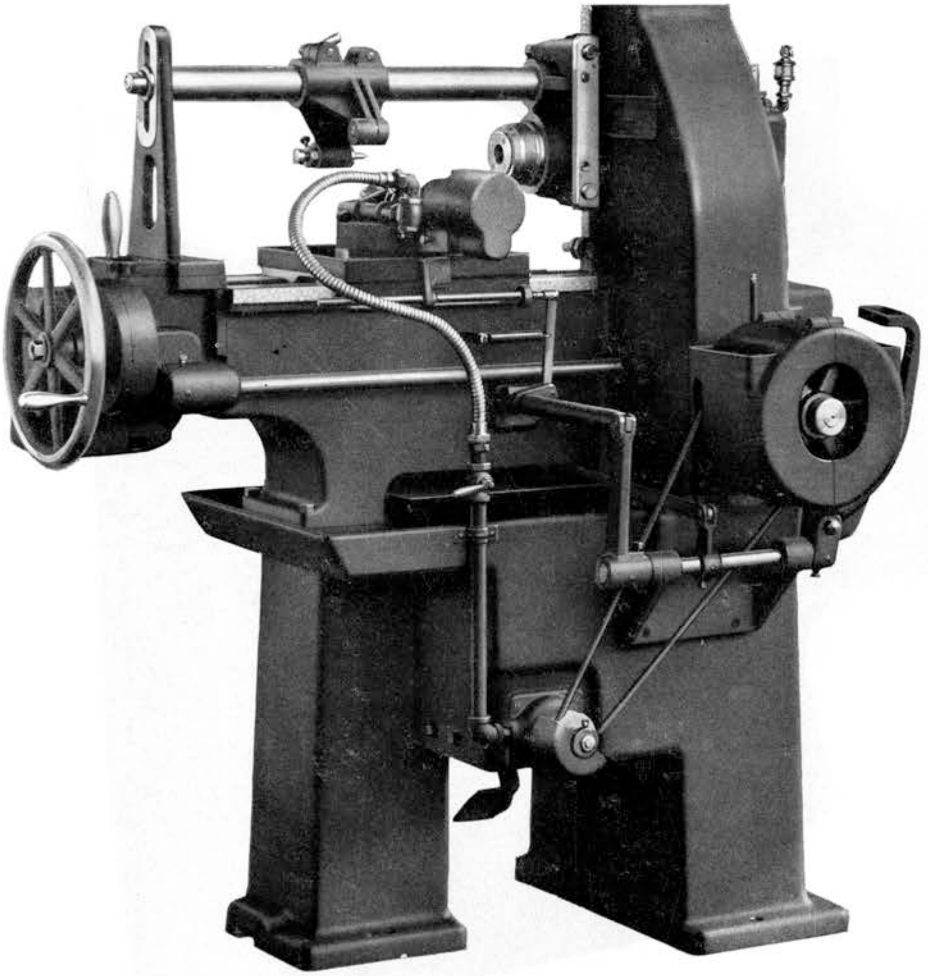


GENERATING MACHINE
FOR
SPUR AND SPIRAL GEARS, SPROCKETS, RATCHETS,
SPLINE SHAFTS AND SPECIAL FORMS

BARBER-COLMAN COMPANY
ROCKFORD, ILL., U. S. A.

NO. 3 HOBBING MACHINE

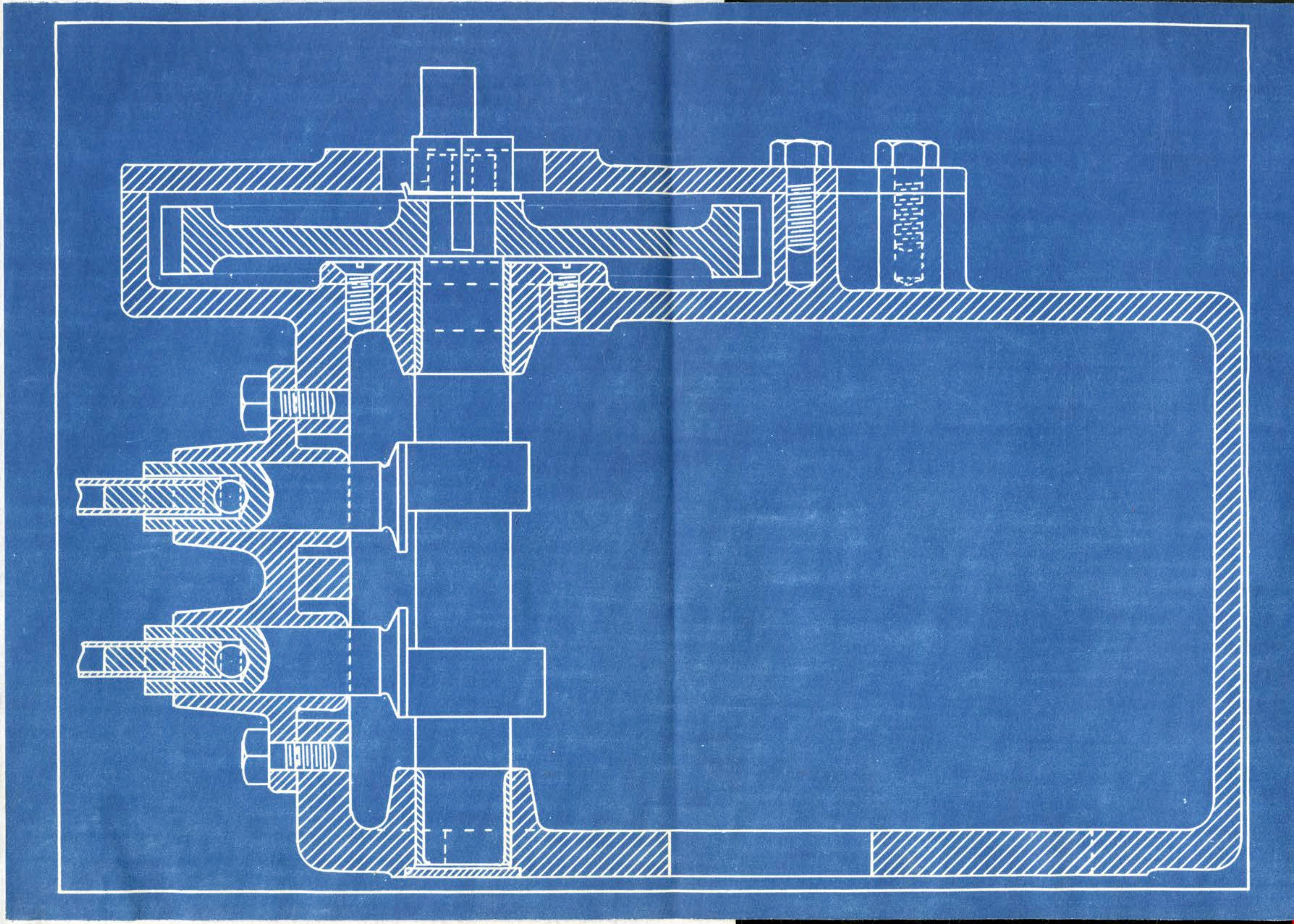
(CONTINUED)



BACK VIEW

GENERAL SPECIFICATIONS

Capacity, diameter	5″
Capacity, width of face	7″
Capacity, diametral pitch	12
Diameter of hob spindle	¾″
Maximum diameter of hob	2 1/16″
Taper hole in spindle	No. 9 B & S
Driving pulley	8″x1⅞″
Speed of driving pulley	350 to 450 r. p. m.
Number changes of hob speed	8
Hob speeds	100 to 500 r. p. m.
Range of feed	.015″ to .150″
Floor Space	30″x50″
Net weight, approximately	1700 lbs.
Shipping weight, domestic, skidded, approximately	2000 lbs.
Shipping weight, boxed for export, approximately	2250 lbs.
Size of shipping case, without vertical feed attachment	47″x38″x56″ . . 58 cubic feet
Size of shipping case with vertical feed attachment	47″x38″x60″ . . 64 cubic feet



TIME GEAR CASE COVER*

Material - Aluminum.
Production Required - 1000 parts per 8 hour day.

Operation:
Drill 2 holes for 1/4" U. S. S. tap and 8 - 17/64" holes. Total - 10 holes.

Machine Recommended:

One - B225H Semi-Automatic Hydraulic Feed "NATCO" Multi-Driller equipped with a 10 spindle drill head.

Price - Approximately	$1,650.00
Price - One fixture	275.00
Price - One set of tools	5.80

Floor Space - Approximately 26" x 50".
Shipping Weight - Approximately 4000 lbs.

For operating this machine one 5 HP 1200 RPM motor is required.

The drilling depth on this part is only 1/4" and one operator will produce a net production of - 125 pieces per hour.

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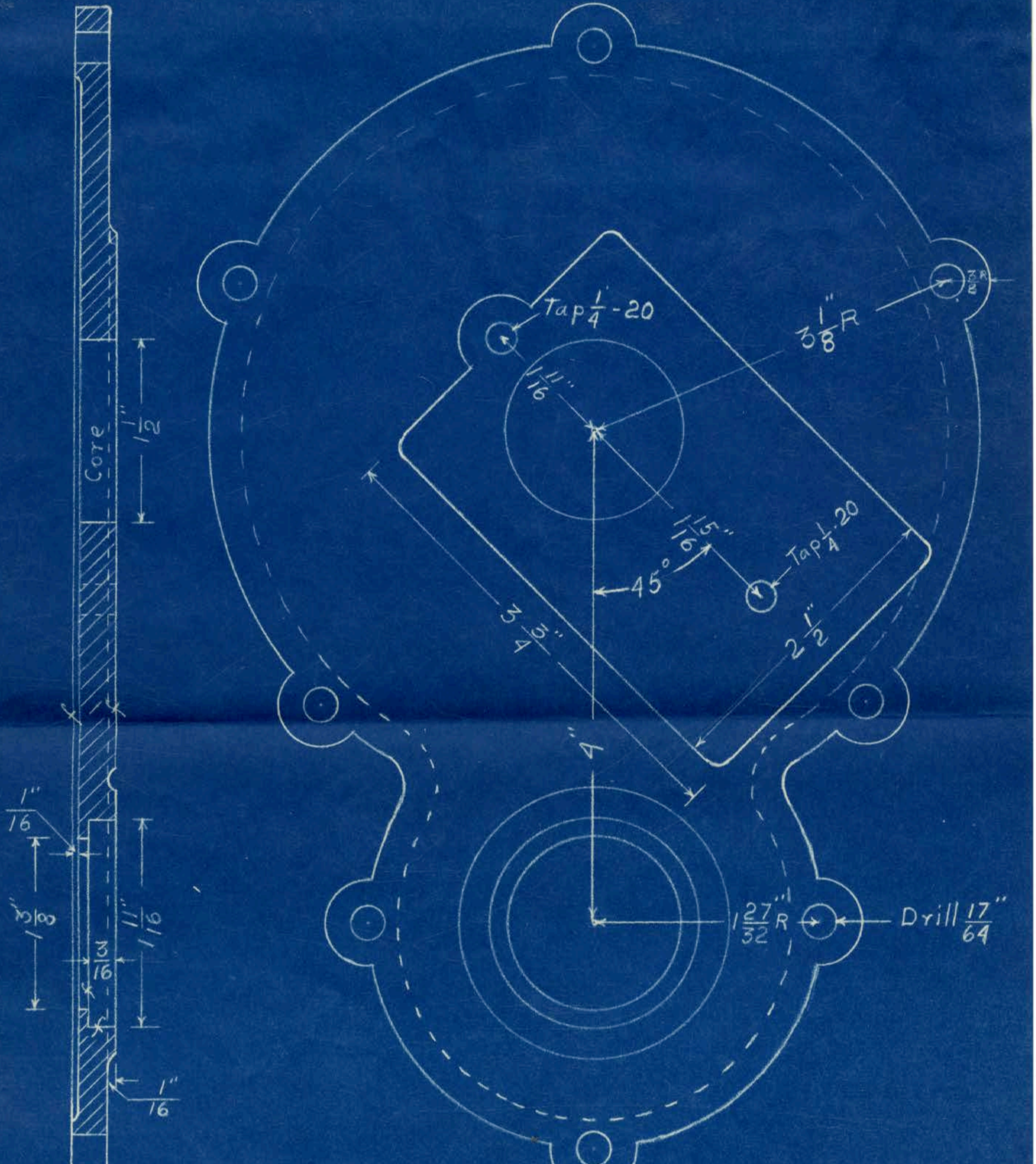
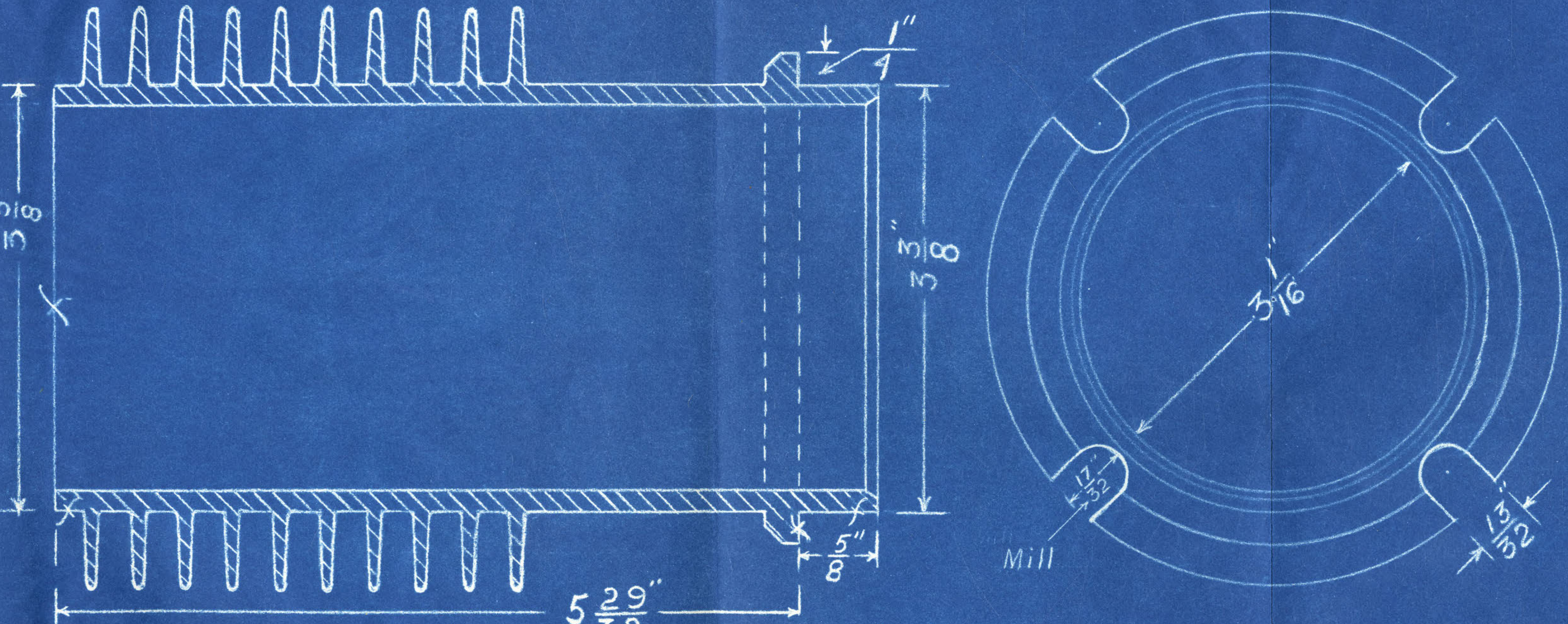
*Estimate, National Automatic Tool Co., Richmond, Indiana.



Timing gear case cover
Aluminum - fullsize



Cylinder - C.I. - full size

Cast Iron Cylinder Sleeve

The casting should be annealed before machining, to remove casting strains.

The first machining operation on a 2-1/2" x 24" Jones and Lamson turret lathe would be to grip the casting on the smooth outside surface between the flange and cooling fins, using a three jaw air operated chuck, and stopping against the rear of the flange.

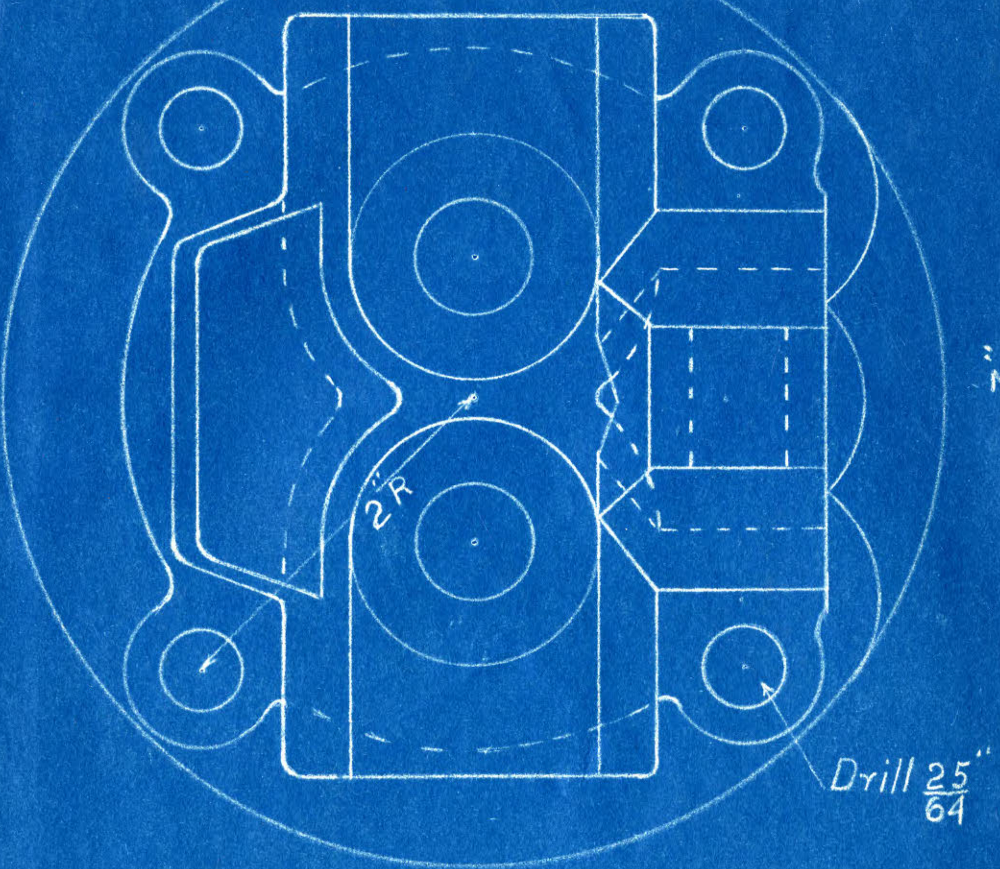
Rough bore the inside of the cylinder at the same time rough turn the 3-3/8" outside diameter and face end of cylinder. Finish bore the inside of cylinder and finish turn the 3-3/8" diameter. Finish face shoulder and end of cylinder and chamfer end. Ream inside of cylinder.

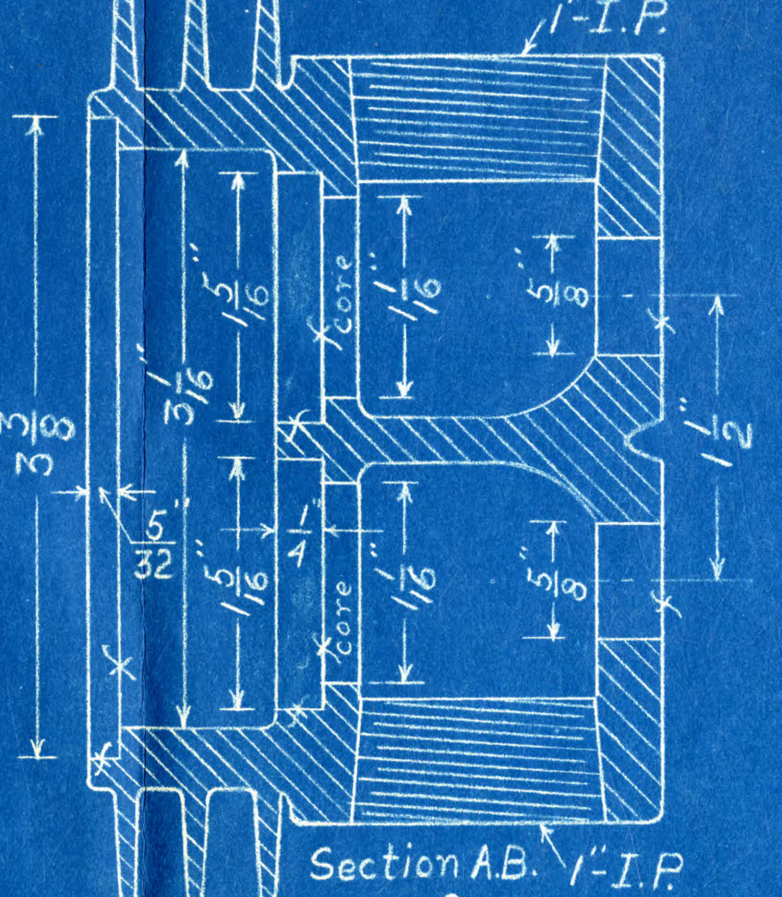
The production per machine as outlined will be 20 per hour with tungsten carbide tools. This is at the rate of 160 per 8 hour day, therefore, it will require 7 machines to produce 1000 pieces in 8 hours and allow time for tool changes, etc.

The next operation is to turn and face the opposite end. This operation would also be performed on a turret lathe, the piece being held on an expanding fixture which is a close fit in the bore of the cylinder. This end would be finished in two operations. Rough turn outside and rough face end. Finish turn outside and finish face end.

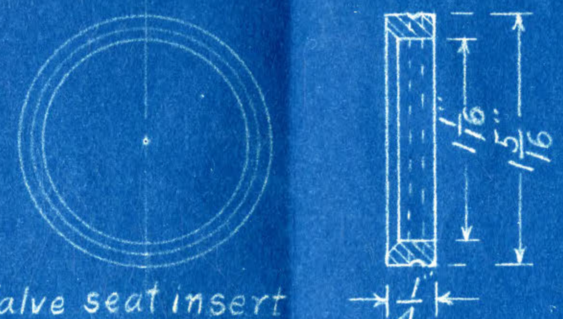
The production per machine is at the rate of 80 per hour or 640 per 8 hour day. Two machines will be required to produce 1000 pieces in 8 hours.

Cylinder head-aluminum full size

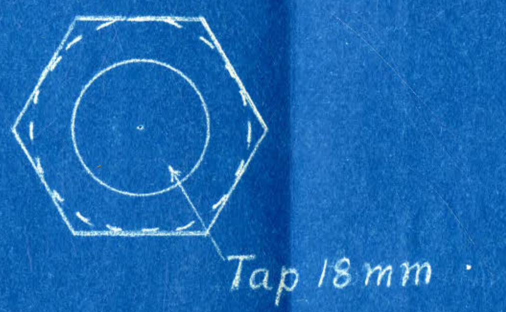


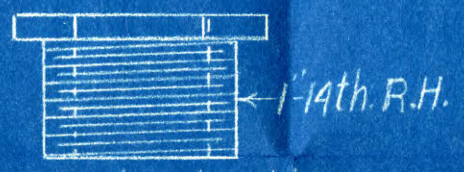


Section A.B.

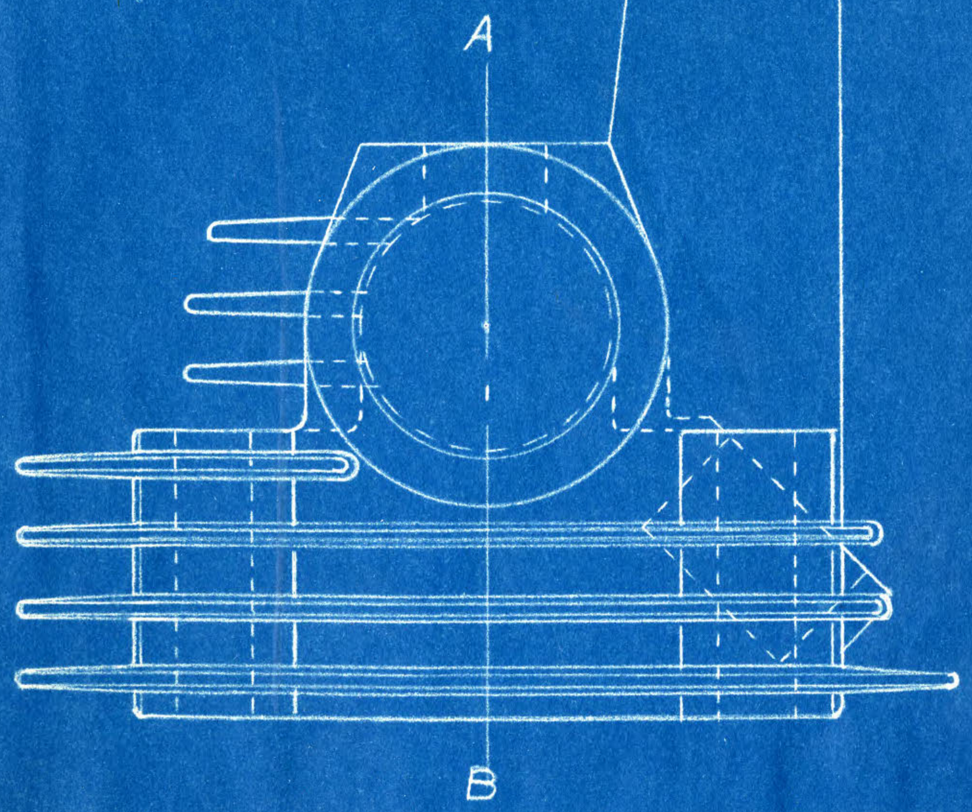


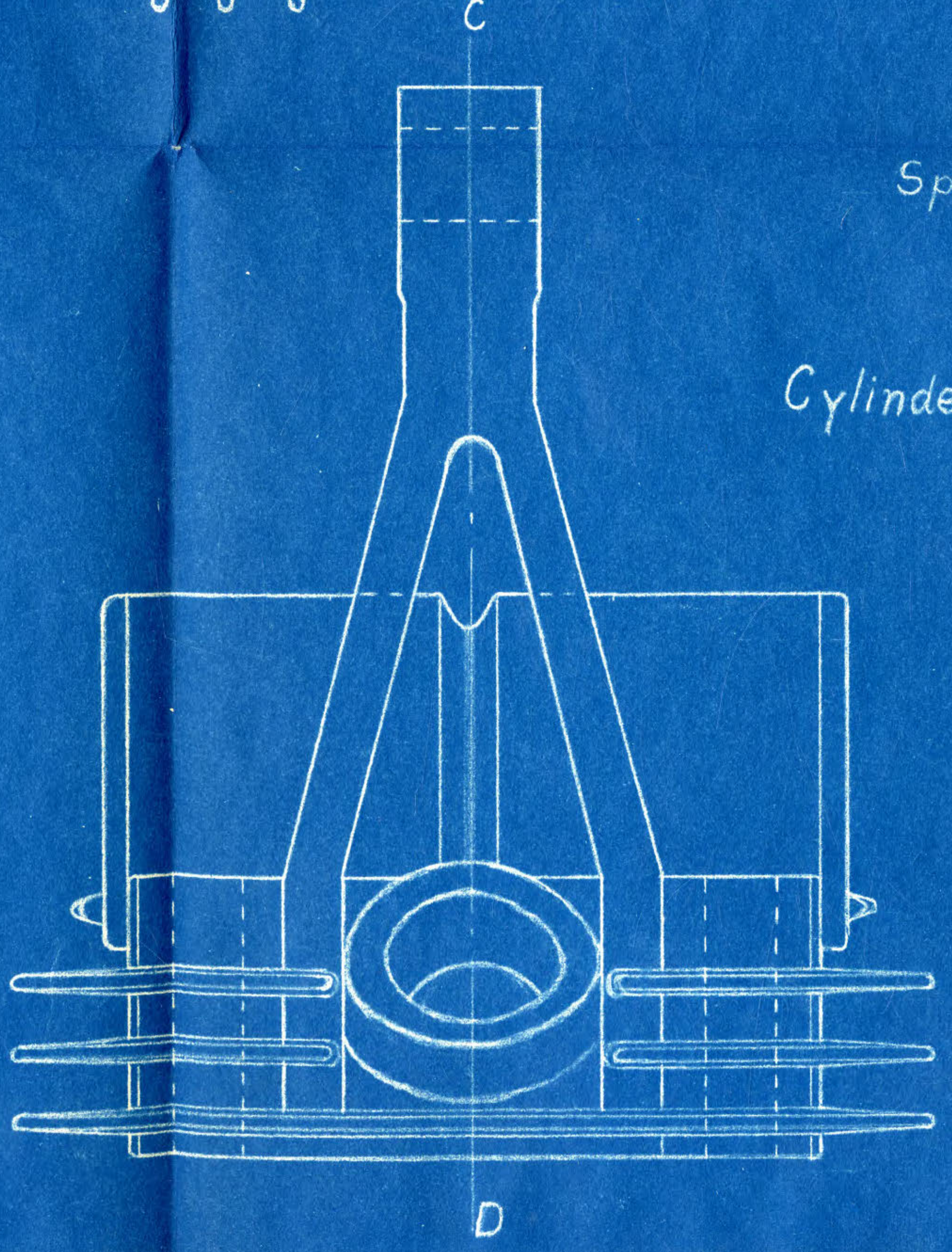
Valve seat insert
H.S.S.

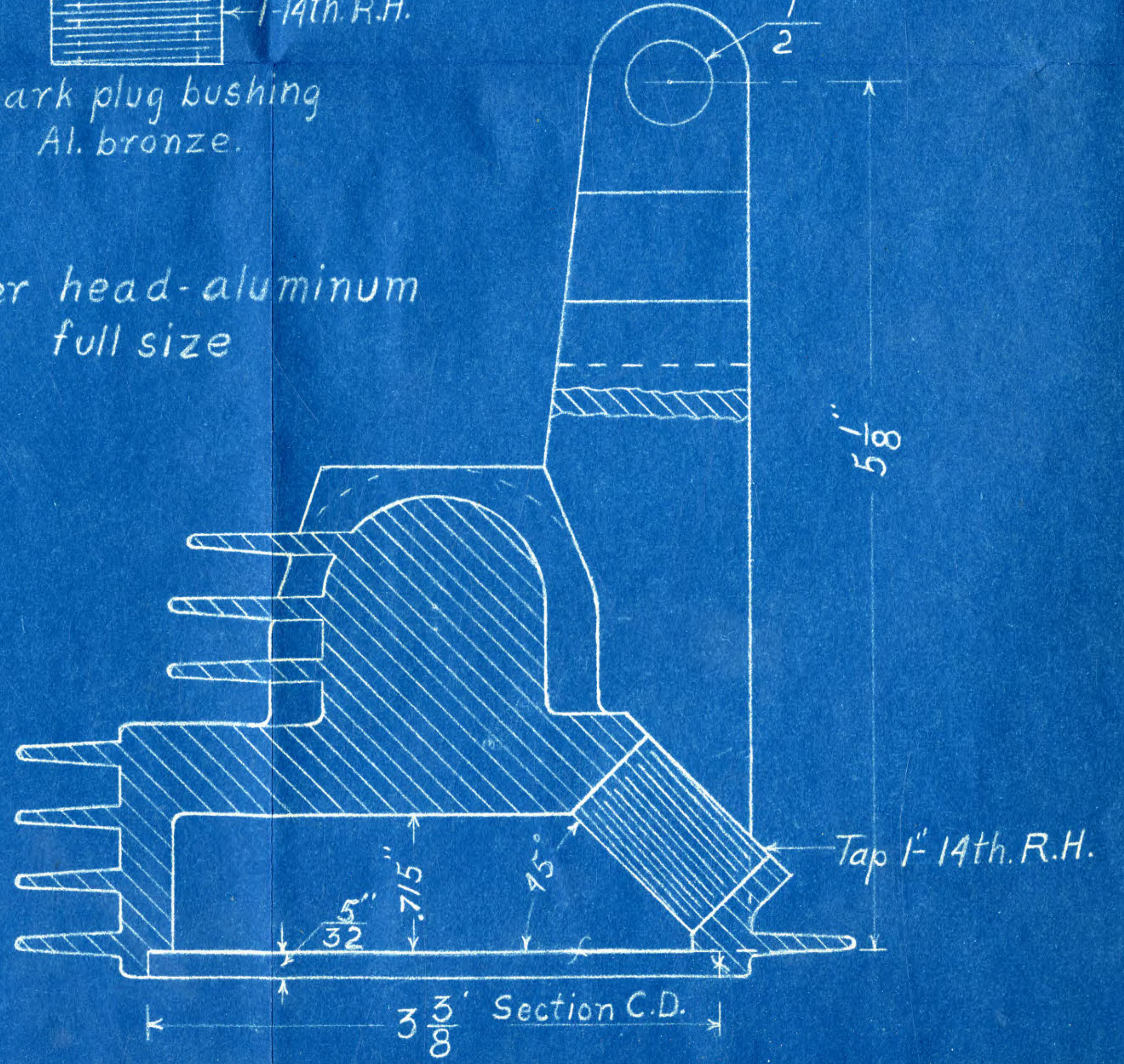




Spark plug bushing
Al. bronze.







Section C.D.

Aluminum Cylinder Head

The castings should be well annealed to remove casting strains before any machining operations are started.

The first operations, that of boring the 3-3/8" diameter and facing the shoulder, would be performed on a turret lathe, using an air operated chuck equipped with special jaws.

Rough bore the 3-3/8" diameter and rough face shoulder. Finish bore 3-3/8" diameter and finish face shoulder.

The production would be at the rate of 82 per machine per hour, or 656 per 8 hour day. Two machines will be required to produce 1000 pieces in 8 hours.

The subsequent operations are outlined on the accompanying "NATCO" estimates.

CYLINDER HEAD*

Material - Aluminum.
Production Required - 1000 per 8 hour day.

Machine No. 1 for the cylinder head will drill 4 - 25/64" holes, drill and ream 2 - 5/8" holes, rough, finish counterbore 2 - 1-5/16" diameter holes in the top.

Machines Recommended:

Two - C12H Semi-automatic Hydraulic Feed "NATCO's" each having a flat slide and fixed center cluster box or head containing 12 spindles, 22" rotating table having 4 positions, one 7-1/2 HP 1200 RPM motor for driving the head, one 5 HP 1200 RPM motor for the hydraulic pump and all electrical equipment including delayed reverse attachment which permits the head to dwell at the bottom of the stroke for accuracy to depth of the counterbore.

Price - Each - approximately	$3,300.00
Price - Each, two fixtures	1,090.00
Price - Per set, two sets of tools	76.00

Floor Space - 48" x 83", each machine.
Shipping Weight - Approximately 8500 lbs., each machine.

Operations are as follows:

Four fixtures 90 degrees apart are mounted on a 22" rotating table and set on the table of the machine. In the first position the operator unloads and reloads one part during the cycle of the head and indexes 90 degrees to the second position where 2 - 25/64" holes are drilled and at the same time with combination tools 2 - 1-5/16" and 2 - 1-1/16" diameter holes are rough counterbored. The table is again indexed 90 degrees to the third position where 2 more 25/64" holes and 2 holes for 5/8" ream are drilled. Again the table is indexed 90 degrees

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*Estimate, National Automatic Tool Co., Richmond, Indiana.

to the fourth position and with combination tools the 2 - 1-5/16" holes are finish counterbored and 2 - 5/8" holes are reamed. The operator has of course loaded one part in each position, position No. 1 of each cycle, and now with all fixtures loaded one part is completed with each cycle of the head.

One operator is sufficient for both machines and the production is as follows - it is based on the 25/64" drill at 1220 RPM, feed .004" and depth 1-3/4".

Start machine	1	second
Rapid down of heads	3	"
Drill	21	"
Dwell	3	"
Rapid up travel of heads	3	"
Index rotating table	3	"
TOTAL	34	"

Production Estimate:

70 parts per hour net each machine with one operator.

Machine No. 2 - For same cylinder head.

This machine is for drilling the angular 1" 14 thread tapped holes and 2 - 1" 'I'. 'P'. tapped holes and 1 - 1/2" hole.

Machines Recommended:

Two - A4H 3-way Semi-automatic Hydraulic Feed "NATCO" Drillers, each equipped with one rear angular head for drilling the 1" 14 thread tapped hole and one left hand head for drilling the 1" I. P. tapped hole on one side and one right hand head for the same size hole on opposite side. This right head also drills the 1/2" hole at the same time. The machine is equipped with 1 - 1-1/2 HP 1200 RPM motor for the rear angular head and one motor of same size for right hand, one for left hand, and one 3 HP 1200 RPM motor for the hydraulic pump, with all other electrical equipment.

Price - Each machine - approximately	$3,500.00
Price - Each, two fixtures	335.00
Price - Each set, two sets of tools	13.25

Floor Space - 10' x 4'.
Shipping Weight - Approximately 8000 lbs.

Fixtures to be of stationary type and arranged to hold one part while drilling is performed.

Production estimate is based on the 1/2" drill at 900 RPM and feed .005" and depth of 1".

Load	6	seconds
Start machine	1	"
Rapid forward of heads	3	"
Drilling time	15	"
Rapid return of heads	3	"
Unloading time	6	"
TOTAL	34	"

Estimated Production:

75 parts per hour net from each machine with one operator.

Machine No. 3 - For the same cylinder head.

This machine is for tapping 2 - 1" I. P. tapped holes, and 1 - 1" 14 thread hole.

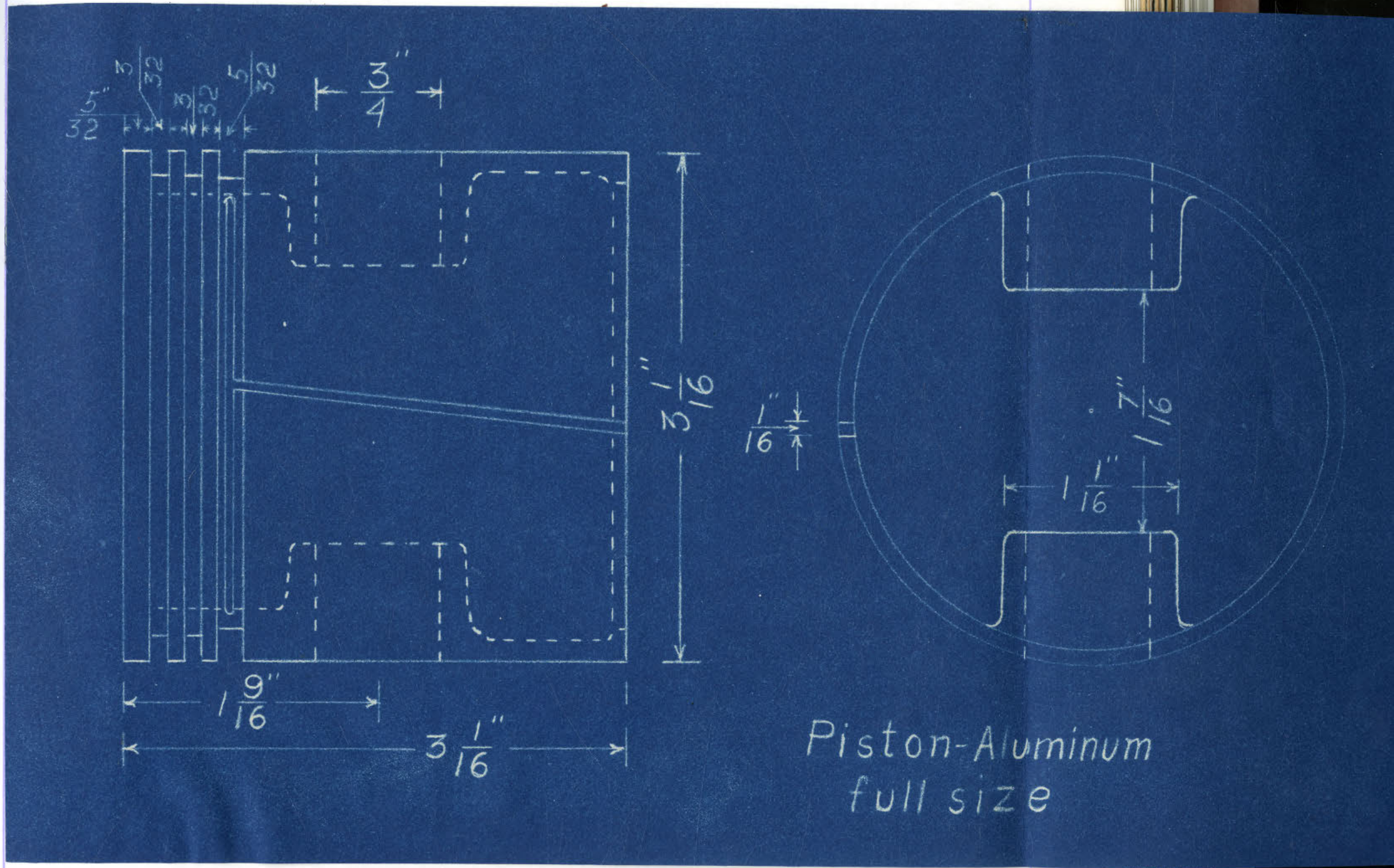
Machine Recommended:

One - 3-way "NATCO" Lead Screw Tapper having one rear angular head for tapping of one 1" 14 thread hole, one right hand horizontal head for tapping 1 - 1" I. P. tapped hole and one left hand head for tapping 1 - 1" hole. Machine is equipped with all electrical equipment including 3 - 1-1/2 HP 1200 RPM motors.

Price - Approximately	$3,200.00
Price - Fixture	235.00
Price - One set of taps	16.25

Floor Space - Approximately 8' x 4'.
Shipping Weight - Approximately 6000 lbs.

One part is placed in stationary type fixture and all holes tapped at the same time with an estimated production of 125 per hour with one operator.



Piston-Aluminum
full size

Aluminum Piston

The castings should be well annealed to remove casting strains before machining operations are started. There are several methods used for machining pistons, including high priced Multi-Matics, the method depending on the production required.

For the production required in this investigation (1000 per 8 hour day) they would be machined on a high production lathe such as the Porter-Cable Carbo lathe, which is a lathe designed especially to use tungsten carbide cutting tools. Machining in this manner means that a lug for a center would have to be cast on the head of the piston, this lug being removed in one of the later machining operations.

The first operation on the piston is to bore, face and chamfer the open end of the piston, at the same time the head end of the piston would be centered by means of a centering attachment operating through the head stock spindle of the lathe, the piston being held in a two jaw air operated chuck.

The production for this operation is at the rate of 150 pistons per hour or 1200 per 8 hour day. One machine would give the required production and still leave plenty of time for tool changes.

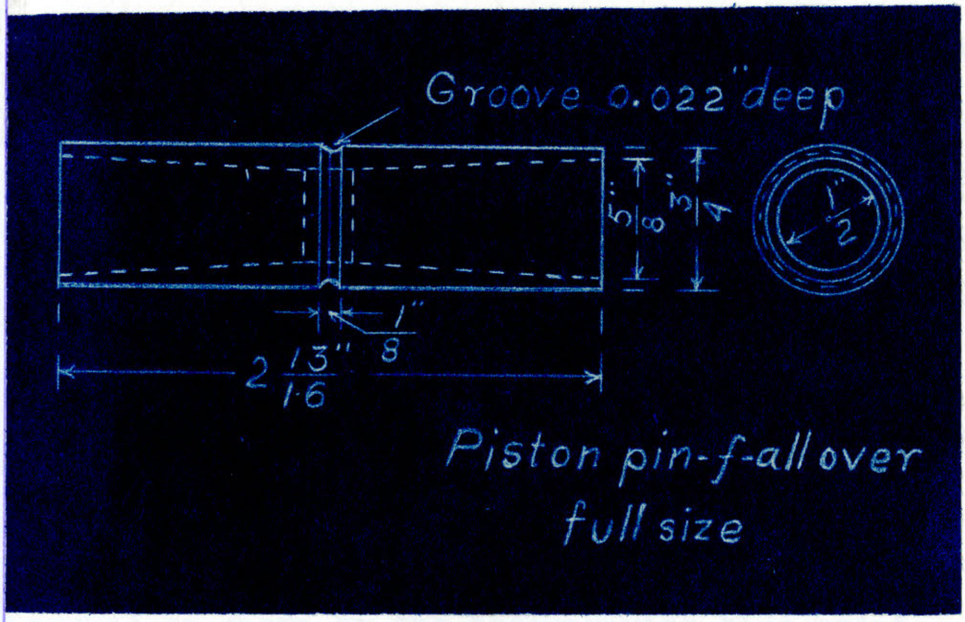
In the second operation, the piston would be held on a special locating and driving fixture fitting the previously machined open end, a ball bearing center in the tail stock holding the piston in place.

By using multiple tooling, all of the rough machining operations; turning outside diameter, facing head end and cutting ring grooves, would be performed simultaneously. The production would be at the rate of 65 pieces per hour or 520 per 8 hour day. Two machines would give the required production.

The next operation is to bore and ream the piston pin hole using a machine such as that built by the Kingsbury Machine Tool Corporation. One machine would give the required production.

The next operation is to finish turn the outside diameter, finish machine the ring grooves and finish face the head, removing the center boss. The piston would be supported on a special locating and driving fixture, being held in place by means of an air operated draw rod with a pin through the piston pin hole. The production would be at the rate of 65 pieces per hour or 520 per 8 hour day, two machines giving the required production.

The final operation would be the slotting of the skirt and ring groove. This would be done on a plain milling machine, using a vertical attachment and a revolving fixture for the slot in the ring groove and an advancing and receding fixture for slotting the skirt. One machine for each operation would give the required production.


Groove 0.022" deep
5"/8
3"/4
1"/2
1"/8
2 13"/16
Piston pin-f-all over
full size

Piston Pin

The recommended procedure in making piston pins is to cut the blanks to length from bar stock and then carburize the blanks before proceeding with the machining operations, this leaves the center soft.

Proposals were submitted by three firms, namely, The New Britain-Gridley Machine Company, The National Acme Company, and The Cleveland Automatic Machine Company.

In the case of the first two, it would be necessary to provide a second machine to machine the groove around the center of the pin, while the Cleveland Automatic four spindle machine, machines this groove, chamfers the ends and cuts off.

After the blanks are carburized, the machine operations proved as shown by the accompanying blue prints, the pins being left slightly over-size (0.008") to allow for grinding. The pins are now hardened and are then ground in two operations (rough and finish) using centerless grinders.

It will be necessary to take two roughing cuts, leaving about 0.003" for finishing, and since each machine is capable of grinding 250 pins per hour, the roughing can be done on one machine. This would be done by taking the first roughing cut on 1000 pins, then adjust the machine for the second cut and pass the pins through again. The finishing would be handled in the same manner, two finishing cuts being required to produce a satisfactory finish.

SHEET NO.

THE CLEVELAND AUTOMATIC MACHINE CO.

CLEVELAND, OHIO

Kansas State College of
Agriculture and Applied Science
Manhattan, Kansas

PROPOSAL NO. 17657 74

DATE April 7, 1933

MACHINE AND EQUIPMENT	PRICE
1-1/4" Model M 4 Spindle Bar Machine Motor drive including motor base, chain, chain guard, clutch and motor sprockets. Less motor and control With Accelerated tool holder lower rear position 6 Sets of spindle change gears 1 Stock reel and stand 1 Chip pan and oil guard 1 Set of wrenches. 1 Double top slide 1 Square turret turning attachment	
Machine Price	$4975 00
ATTACHMENTS:	
1 Accelerated spindle upper rear position	25 00
ELECTRICAL EQUIPMENT:	
7-1/2 HP 1800 R.P.M. 3 Phase 60 cycle 220 volt ball bearing motor, control and push button station	112 00
If customer is to furnish motor and control, please furnish motor data sheet with order.	
Weight of machine with motor 9800 lbs. Floor space required 43" x 116"	
Spindle bearings Front 3-1/4" O.D. x 3-7/8" Long Spindle bearings Rear 3-1/8" O.D. x 3-5/8" long.	

Proposal Form No. 181 forms a part of this quotation. The conditions of sale outlined apply on machinery and equipment quoted therein.

CONTINUATION OF PROPOSAL NO. 17657 FOR Kansas State College SHEET NO. 2

1-1/4 MODEL M 4 Spl.Bar MACHINE

NAME OF SAMPLE Piston Pin PART NO. 3/4 Dia. DWG. NO. 2-13/16 Long

MATERIAL SPECIFICATIONS S.A.E.1020 C.R.Steel Bar SIZE

SPINDLE SPEED 614 R. P. M. 122 SURFACE FEET ON .765 DIAMETER.

THREADING SPEED R. P. M. SURFACE FEET ON THREAD DIAMETER.

H. S. ATTACH. SPEED R. P. M. COMBINED SPEED R. P. M. ON

MACHINE TIME 8 SECONDS EACH. ESTIMATE PRODUCTION 450 PER HOUR Gross 1st OPERATION

360 " " Net 1st

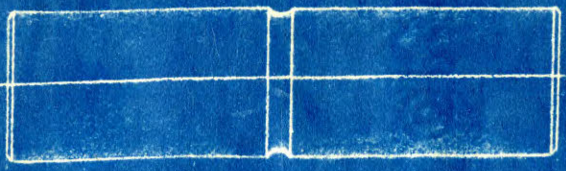
TOOL POS.	QUAN	TOOLING EQUIPMENT	CODE	TOOL PRICES	LENGTH OF CUT.	FEED PER REV.	RPM	DETAIL TIME	TIME IN SEC.
Lower Rear	1	K-39 roller rest		26.00					
	2	O.S.tool posts		0.00					
	2	H.S.cutters to chamfer O.D. and form groove		19.00	093	0018	614	5	
Lower Front	1	K-294 straight cutoff tool and post to cutoff part way		24.50	.110	0022	"	5	5
Upper Front	1	Spec. str. cutoff tool and post to cutoff part way		40.00	.110	0022	"		
Upper Rear	1	Spec. str. cutoff tool and post to cutoff balance		40.00	.110	0022	"		
	4	.765 Rd. corr. C & S and bushings		0.00					
		Setup and testing tools		30.00					
		Have considered bars will be C.R.drawn .015 large as noted above for grinding, as is common practice among auto manufacturers.							
					IDLE MOVEMENT TIME				3
		TOTAL COST OF TOOLS		$ 179.50	TIME PER PIECE				
					TIME PER				8

REMARKS: Large Dia. considered stock size and will break corners at O.D. and cutoff only as per B/P sketch attached.

NOTE: CODE COLUMN IS FOR MANUFACTURING PURPOSES ONLY

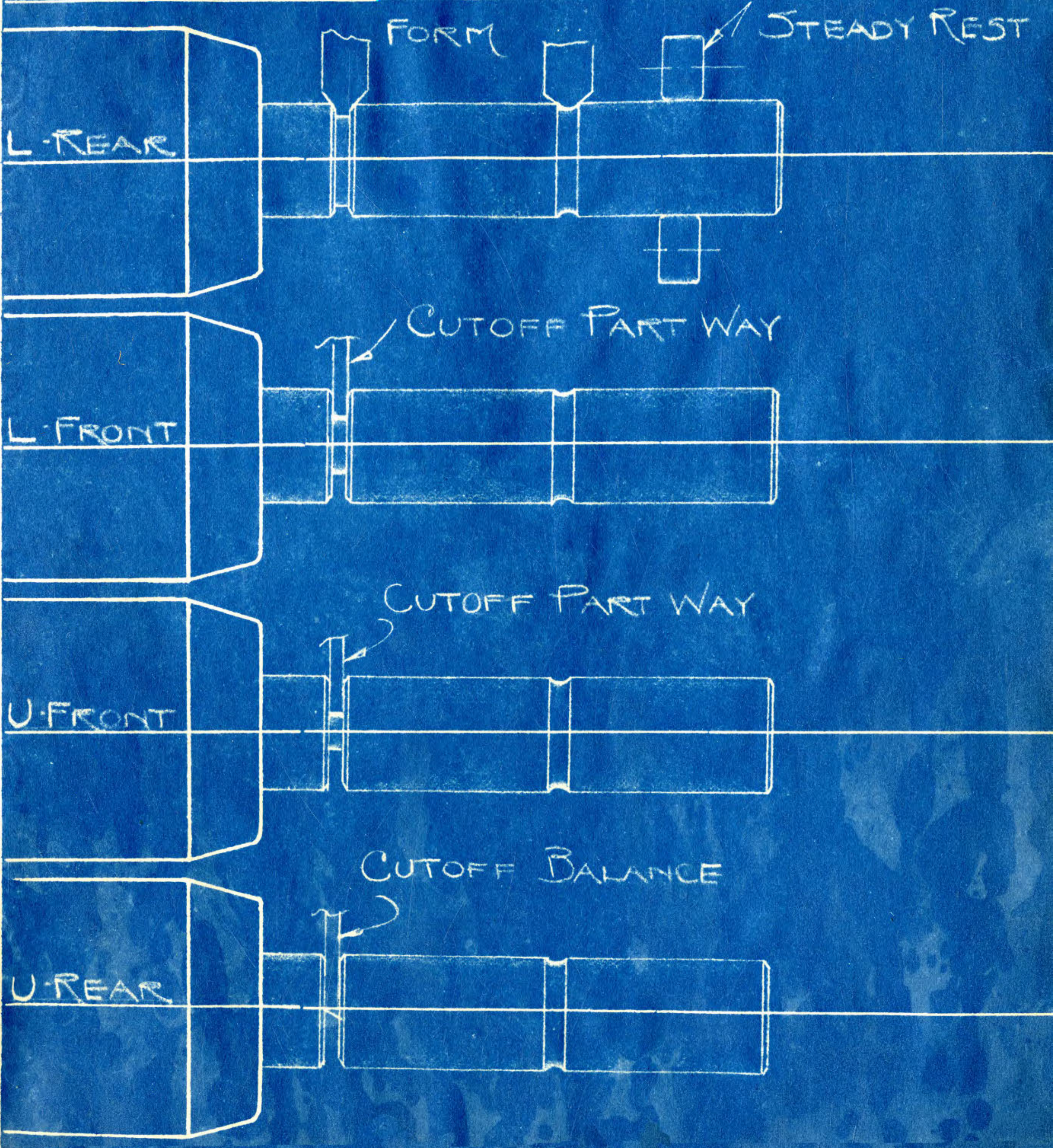
SEE SKETCH OF SAMPLE ON REVERSE SIDE

Material #1020 S.A.E.-C.R.S. BAR
Size 3/4" DIA.
Spindle Speed 614
Surface feet 122
Feed - turret –
Feed - forming .0018
Feed - cut-off .0022
Spindle gears
Feed gears
Handles



Name of piece PISTON PIN Bp. No. 1ST OPE

Customer's Name KANSAS STATE COLLEGE Order No. –
Machine 1¼ MOD. M-4 SPL. BAR Date 4-7-33
The Cleveland Automatic Machine Co., Cleveland, Ohio Proposal No. 17657



CONTINUATION OF PROPOSAL NO. 17657 FOR Kansas State College SHEET No 3

1-1/4 MODEL M 4 Spl. Bar MACHINE

NAME OF SAMPLE Piston Pin PART NO. 3/4 Dia. DWG. NO. 2-13/16 Lg.
MATERIAL SPECIFICATIONS S.A.E.1020 C.R.Steel Blanks SIZE
SPINDLE SPEED 789 R. P. M. 127 SURFACE FEET ON 5/8 Hole DIAMETER.
THREADING SPEED R. P. M. SURFACE FEET ON THREAD DIAMETER.
H. S. ATTACH. SPEED R. P. M. COMBINED SPEED R. P. M. ON
MACHINE TIME 10 SECONDS EACH. ESTIMATE PRODUCTION 360 PER HOUR Gross 2nd & 3rd OPERATION
270 Net 2nd & 3rd

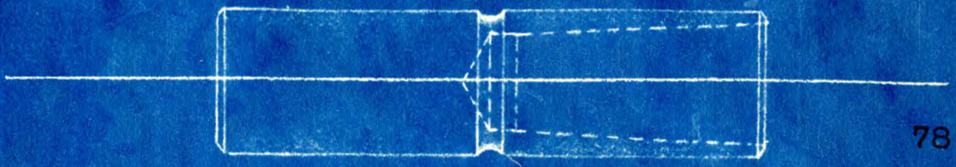
TOOL POS.	QUAN	TOOLING EQUIPMENT	CODE	TOOL PRICES	LENGTH OF CUT.	FEED PER REV.	RPM	DETAIL TIME	TIME IN SEC.
	1	Vertical hopper type magazine mounted at rear of spl's. with magazine bushing and ejector rod & 4 guide tubes and & retaining plate		430.00					
	4	Feedshells with light grip		0.00					
Lower	1	K-48 tool post		12.00					
Rear	1	Cross slide gauge stop		3.50					
	1	Drill HS to drill part way		2.50	.533	006	789	7	7
	1	Drill holder		11.00					
Lower	1	Drill HS to drill part way		2.50	.533	006	"	7	
Front	1	Drill holder		11.00					
Upper	1	Drill HS to drill to center of pin		2.40	.533	006	"	7	
Front	1	Drill holder		11.00					
Upper Rear	1	H.S. taper counterbore to ream taper at one end		16.50	1"	011	"	7	
	1	Counterbore holder		15.00					
	4	.765 Rd. corr. chucks		——					
		Setup and testing tools		10.00					
		For 3rd operation invert piston pin and repeat operation as listed for 2nd oper.							
					IDLE MOVEMENT TIME				3
		TOTAL COST OF TOOLS		$ 97.40	TIME PER PIECE				
					TIME PER				10

REMARKS: Parts will come to machine cut to length, chamfered at O.D. and carbonized and will feed from mag. thru spindle to gauge and will drill and taper counterbore one end only per operation as per B/P sketch attached.

NOTE: CODE COLUMN IS FOR MANUFACTURING PURPOSES ONLY
SEE SKETCH OF SAMPLE ON REVERSE SIDE

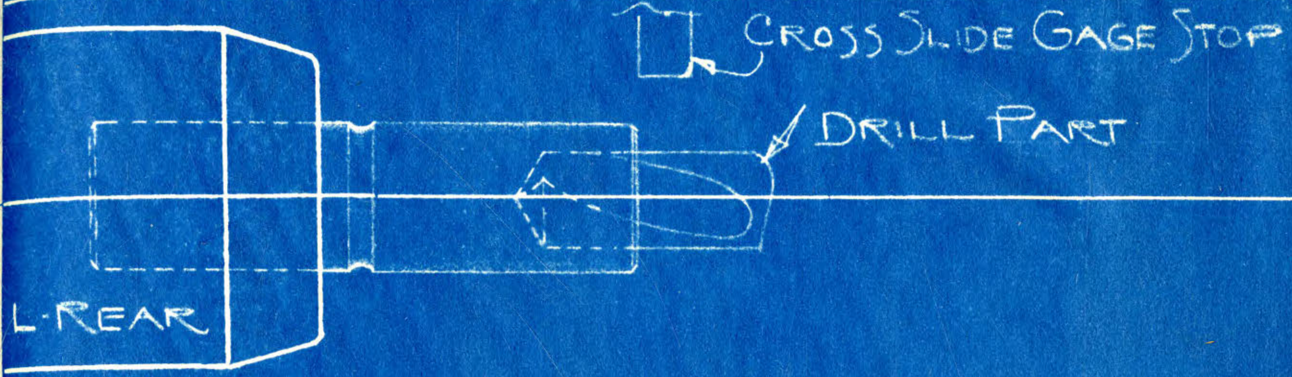
Machine time 10 SEC. EACH
Material 1020 SAE – C.R.S. BLANKS
Size 3/4" DIA.
Spindle Speed 789
Surface feet 127
Feed - turret .006
Feed - forming –
Feed - cut-off –
Spindle gears
Feed gears
Handles

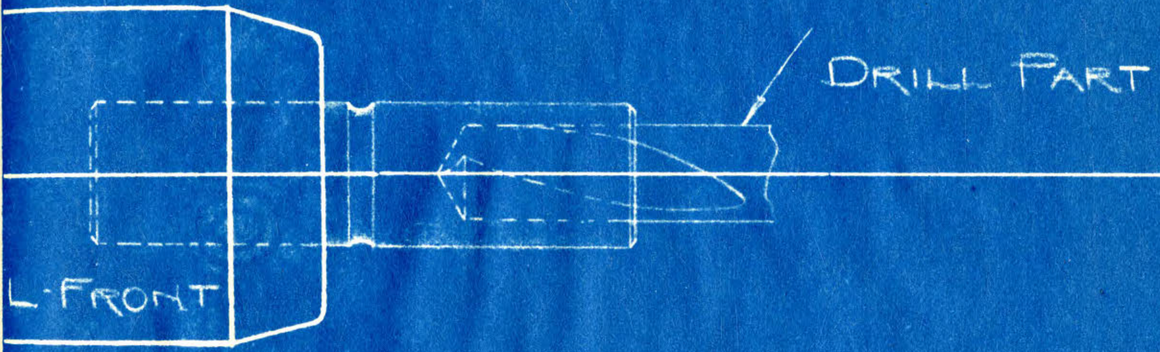
Sketch FULL SIZE

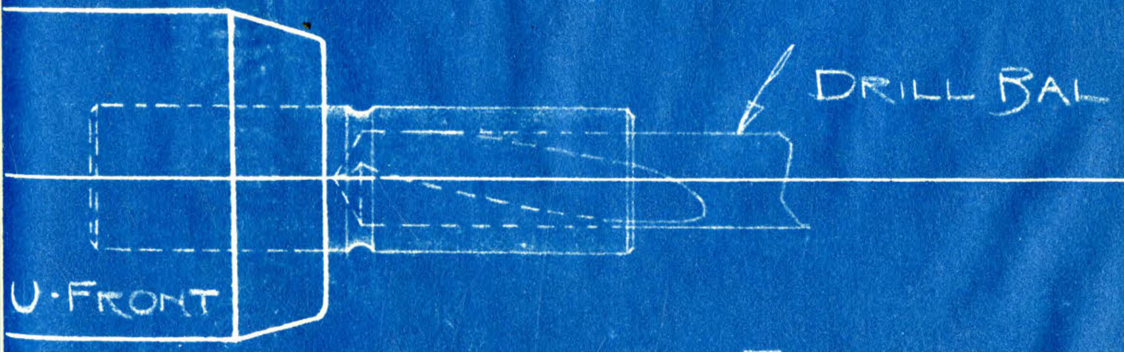


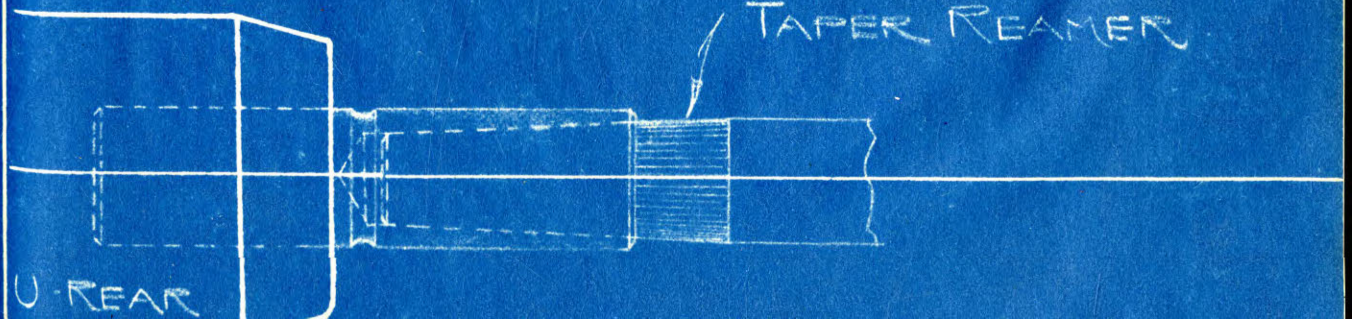
Name of piece PISTON PIN **Bp. No.** 2ND OPER.

Customer's Name KANSAS STATE COLLEGE **Order No.** –
Machine 1¼ MOD. M. 4 SPL. BAR **Date** 4-7-33
The Cleveland Automatic Machine Co., Cleveland, Ohio **Proposal No.** 17657



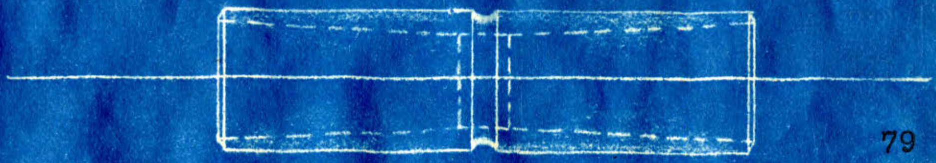






Machine time 10 SEC EACH
Material 1020 S.A.E – C.R.S. BLANKS
Size 3/4" DIA
Spindle Speed 789
Surface feet 127
Feed - turret .006
Feed - forming —
Feed - cut-off —
Spindle gears
Feed gears
Handles

Sketch FULL SIZE

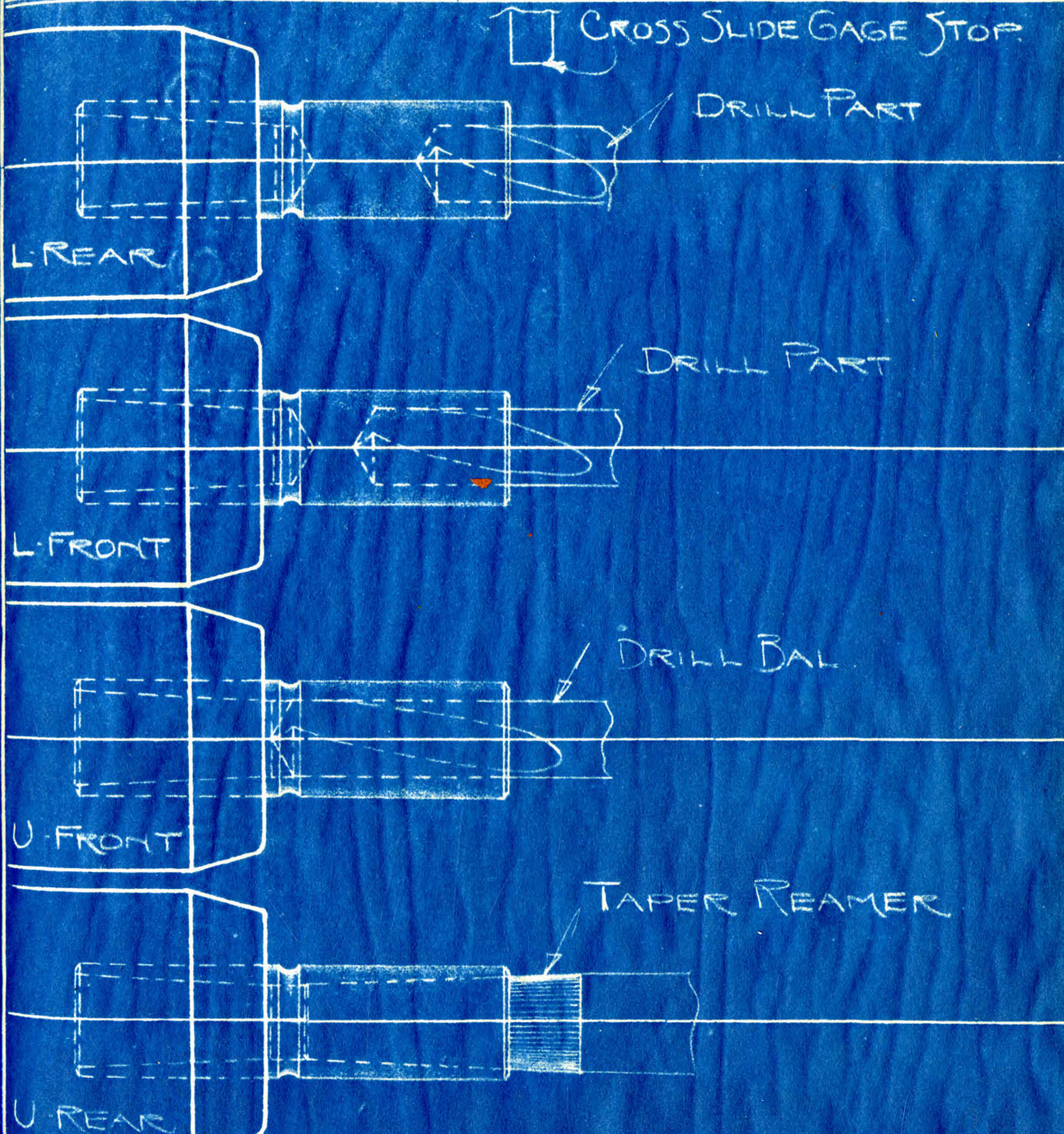


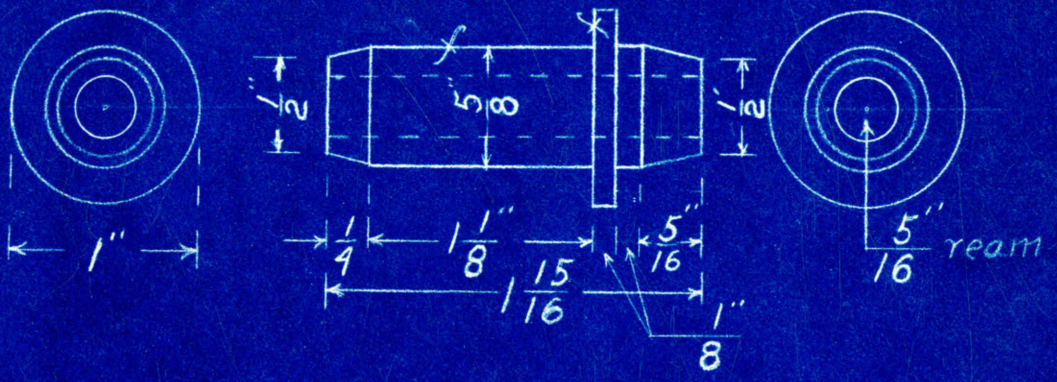
Name of piece PISTON PIN **Bp. No.** 3RD OPER

Customer's Name KANSAS STATE COLLEGE **Order No.** —

Machine 1 1/4" MOD-M.4 SPL BAR **Date** 4-7-33

The Cleveland Automatic Machine Co., Cleveland, Ohio **Proposal No.** 17657





Valve stem guide C.I.

full size.

Valve Stem Guide

The Cleveland four spindle automatic machine was selected for machining the valve stem guide because the cost of the machine and tools was less than for other machines that would give the required production.

The production as given on the accompanying estimate sheet is 220 per hour for stellite cutting tools. By substituting tungsten carbide cutters in place of stellite, the required production can easily be obtained.

THE CLEVELAND AUTOMATIC MACHINE CO.
CLEVELAND, OHIO

OR Kansas State College of
Agriculture and Applied Science
Manhattan, Kansas

PROPOSAL No. 17658

DATE April 7, 1933

MACHINE AND EQUIPMENT	PRICE
1-1/4" Model M 4 Spindle Bar Machine Motor drive including motor base, chain, chain guard, clutch and motor sprockets. Less motor and control With accelerated tool holder lower front position 6 Sets of spindle change gears 1 Stock reel and stand 1 Chip pan and oil guard 1 Set of wrenches 45 degree angle chuck hoods and adapters arranged with slots in hoods for chips. 1 Double top slide 1 Square turret turning attachment	
Machine Price	$5135 00
ATTACHMENTS:	
1 Accelerated spindle upper front position	100 00
1 H.S.Drilling attachment upper rear position	75 00
ELECTRICAL EQUIPMENT:	
7-1/2 HP 1800 R.P.M. 3 Phase 60 cycle 220 or 440 volt ball bearing motor, control and push button station	112 00

If customer is to furnish motor and control, please furnish motor data sheet with order.

Weight of machine with countershaft 9650 lbs.
Weight of machine with motor 9800 lbs.
Floor space required 43" x 116"

Spindle bearings Front 3-1/4" O.D. x 3-7/8" long.
Spindle bearings Rear 3-1/8" O.D. x 3-5/8" Long.

Proposal Form No. 181 forms a part of this quotation. The conditions of sale outlined apply on machinery and equipment quoted therein.

CONTINUATION OF PROPOSAL NO. 17658 FOR Kansas State College SHEET NO. 2

1-1/4 MODEL M 4 Spl. Mag. MACHINE

NAME OF SAMPLE Valve Guide PART NO. DWG. NO.
MATERIAL SPECIFICATIONS Grey Iron Castings SIZE
SPINDLE SPEED 6XX 789 R. P. M. 205 SURFACE FEET ON 1" Collar DIAMETER.
THREADING SPEED R. P. M. SURFACE FEET ON THREAD DIAMETER.
H. S. ATTACH. SPEED R. P. M. COMBINED SPEED R. P. M. ON
MACHINE TIME 12.3 SECONDS EACH. ESTIMATE PRODUCTION 292 PER HOUR Gross OPERATION
220 " " Net

TOOL POS.	QUAN	TOOLING EQUIPMENT	CODE	TOOL PRICES	LENGTH OF CUT.	FEED PER REV.	RPM	DETAIL TIME	TIME IN SEC.
Lower	1	Chain type magazine arranged with clips		400.00					
Front	1	Spec. conveyor and holder		45.00					
Upper Front	1	3 Tool roughing mill with Stellite Cutters to rough turn body dia. and with center drill in shank of mill		65.00	1.437	012	789	9.3	9.3
	1	O.S. tool post		0.00					
	1	Stellite tipped cutter to face collar		10.50	.250		789	9.3	
Upper	1	Drill H.S.		1.30	2"	008	1532	9.3	
Rear	1	Drill holder		11.00					
Lower Rear	1	3 Tool finishing mill with Stellite Cutters to finish body dia. and with H.S. reamer and floating adapter arranged in shank		75.00	2"	016	789	9.3	
	4	45° angle chuck jaws with 3 point bearing		0.00					
	4	Ejector heads for feed tubes		48.00					
	1	Set ejector cams in exchange for stock feed cams		0.00					
		Setup and testing tools		30.00					

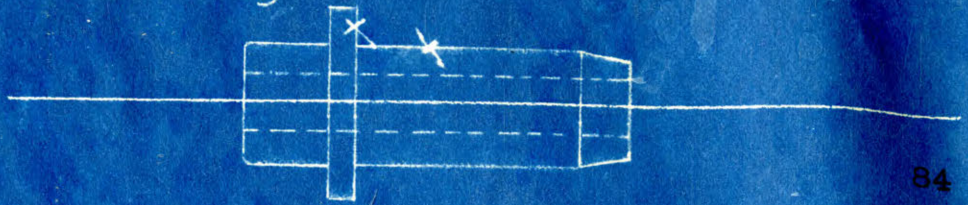
		IDLE MOVEMENT TIME	3
TOTAL COST OF TOOLS	$ 685.80	TIME PER PIECE	
		TIME PER	12.3

REMARKS: Have considered parts will be cast straight at short end and not vary more than .010 to facilitate chucking and will convey from magazine to chuck and rough and finish turn body dia. face collar and drill and ream hole as per B/P sketch attached. Allowing grinding stock on turned dia.

NOTE: CODE COLUMN IS FOR MANUFACTURING PURPOSES ONLY
SEE SKETCH OF SAMPLE ON REVERSE SIDE

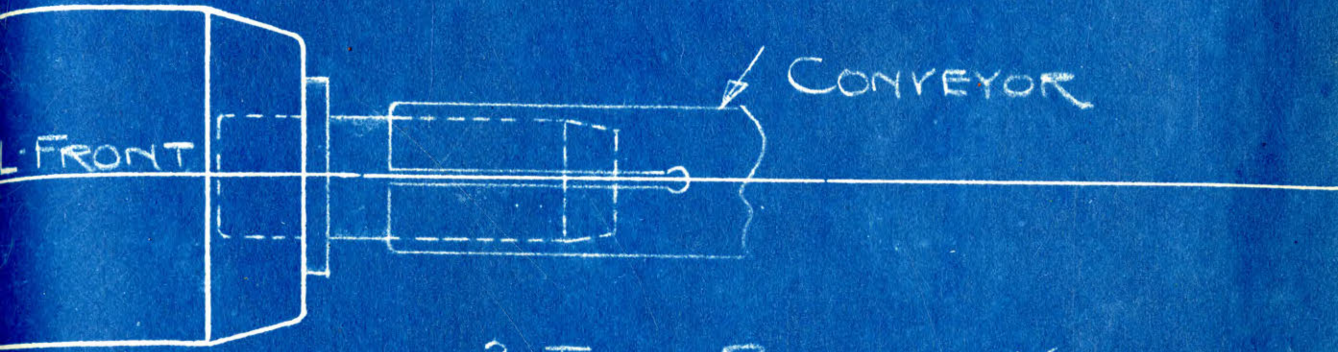
Machine time 12.3 SEC EACH
Material GRAY IRON CASTINGS
Size —
Spindle Speed 789
Surface feet 205
Feed - turret .012
Feed - forming —
Feed - cut-off —
Spindle gears
Feed gears
Handles

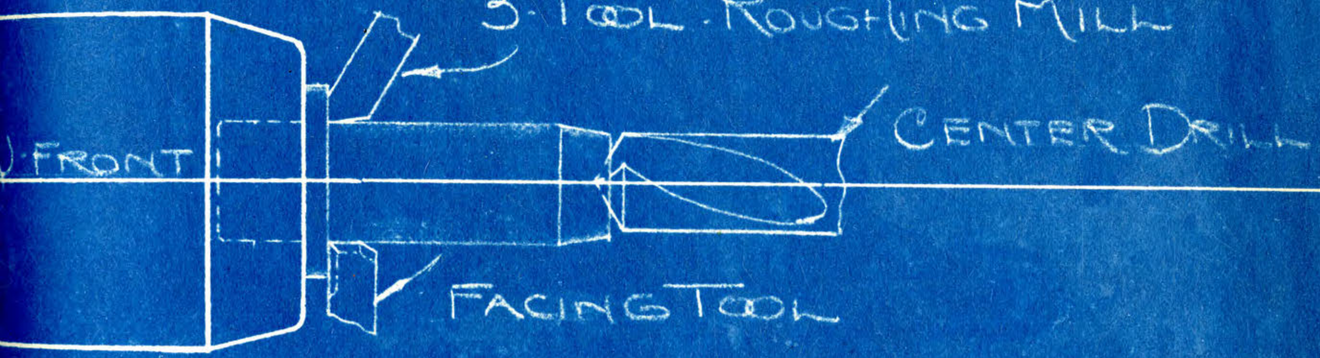
Sketch FULL SIZE

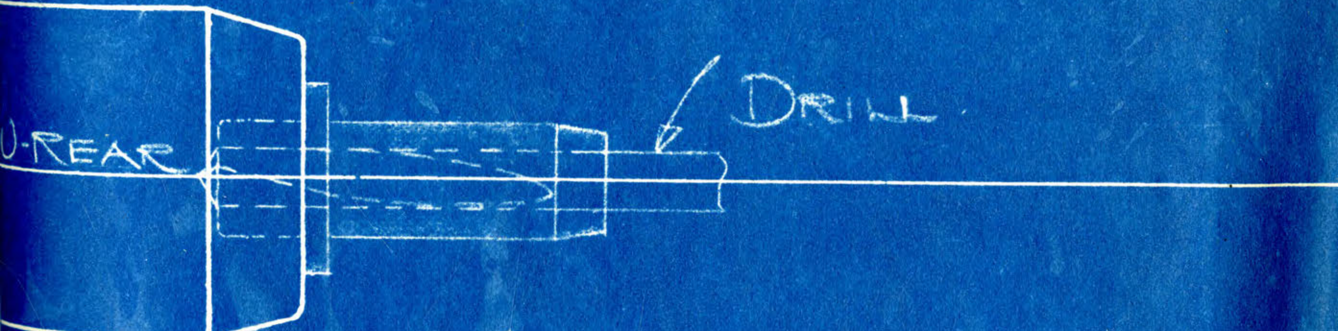


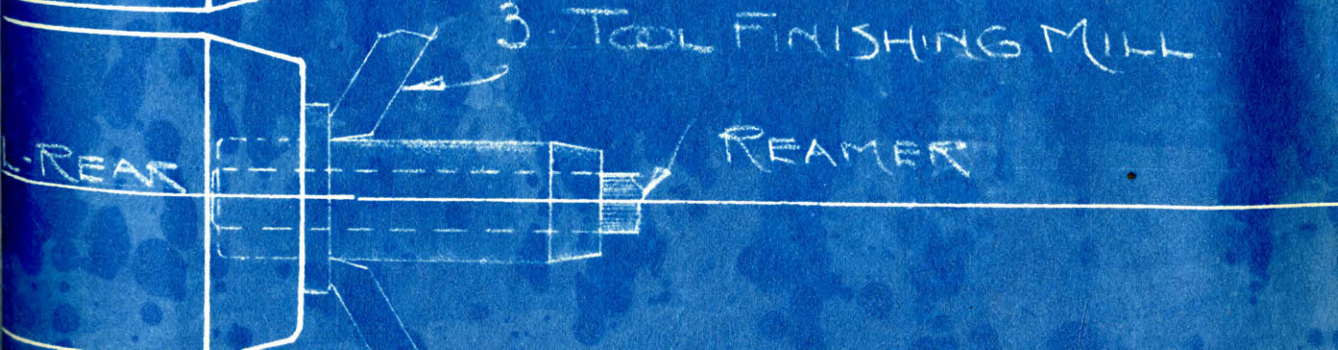
Name of piece VALVE GUIDE **Bp. No.** —

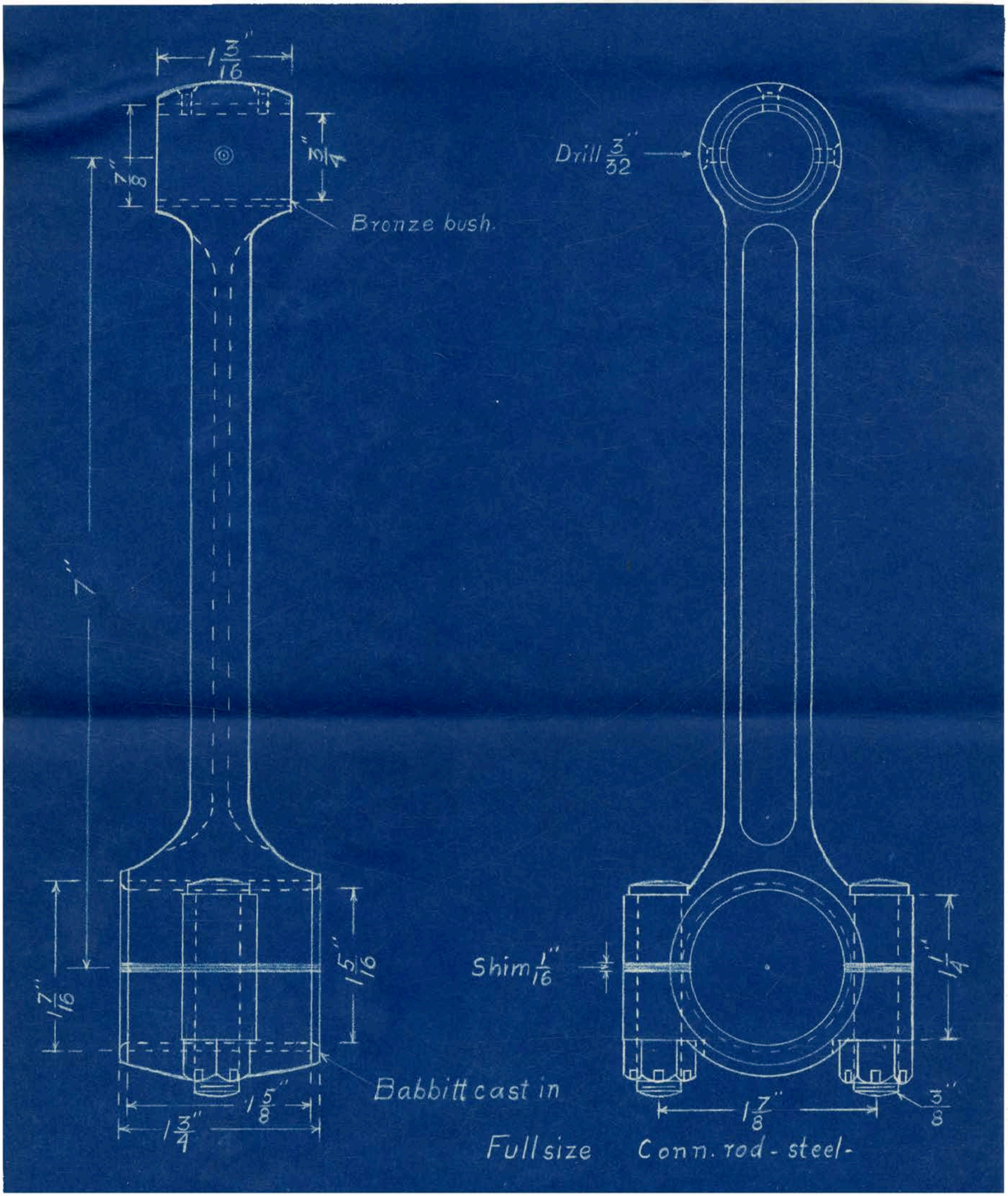
Customer's Name KANSAS STATE COLLEGE **Order No.** —
Machine 1 1/4 MOD. M 4 SPL. BAR **Date** 4-7-33
The Cleveland Automatic Machine Co., Cleveland, Ohio **Proposal No.** 17658










1 3/16"
7/8"
3/4"
7"
Bronze bush.
Drill 3/32"
1 7/16"
1 5/16"
Shim 1/16"
1 1/4"
Babbitt cast in
1 5/8"
1 3/4"
1 7/8"
3/8"
Fullsize
Conn. rod - steel-

Connecting Rod

After being milled, the next operation is to drill the bolt holes in the cap and large end of the rod.

This would be done on a machine such as made by the Kingsbury Machine Tool Corporation.

After the rod was assembled, it would next be necessary to drill and ream the small end and bore and ream the large end. This would be done on a "NATCO" driller, the operations being performed as shown by the accompanying estimate sheet, one machine giving the required production.

CONNECTING RODS*

The only milling on this part is the splitting of the cap and facing of the connecting rod bolt bosses, and the straddle facing of the large end. Sometimes the small end is straddle milled, although this operation is often done with a spot-facing tool on a drill press. Our photographs 1643, 2595, and 2596 show the usual method of splitting the cap. The work is held in an indexing fixture so that two pieces can be loaded while two are being machined. An operation of this kind can be handled in either a knee- or production-type machine, although we would strongly recommend the use of our Milwaukee Simplex which is a new product primarily designed for high production. A separate description sheet is enclosed covering specifications of this machine. We would recommend our No. 1218 at a cost of $2485.00, arranged for motor drive but exclusive of electrical equipment. The weight of this machine is approximately 7500 lbs. The fixture, including index base, would cost $625.00. The production would be 80 pieces per hour.

Sometimes the faces of both the rods and caps are finished after being split and for this operation we suggest the methods shown in our photographs 1623, 1565 and 1566. For this operation we would recommend one of our No. 2 Model K Manufacturing type milling machines which lists at $2725.00, the weight of which is approximately 5600 lbs. The fixture in this case would be power driven and would cost $1700.00. The production would be 150 to 175 pieces per hour.

For the straddle milling of both ends of rods we would recommend our No. 1218 Milwaukee Simplex which lists at $2485.00, similar to the machine specified above. For this setup we would propose two index milling fixtures, each of which would cost $425.00 or a total of $850.00. The production on this job would be 160 pieces per hour, which of course would include the milling of both ends. This setup is shown in detail in our photo 2927.

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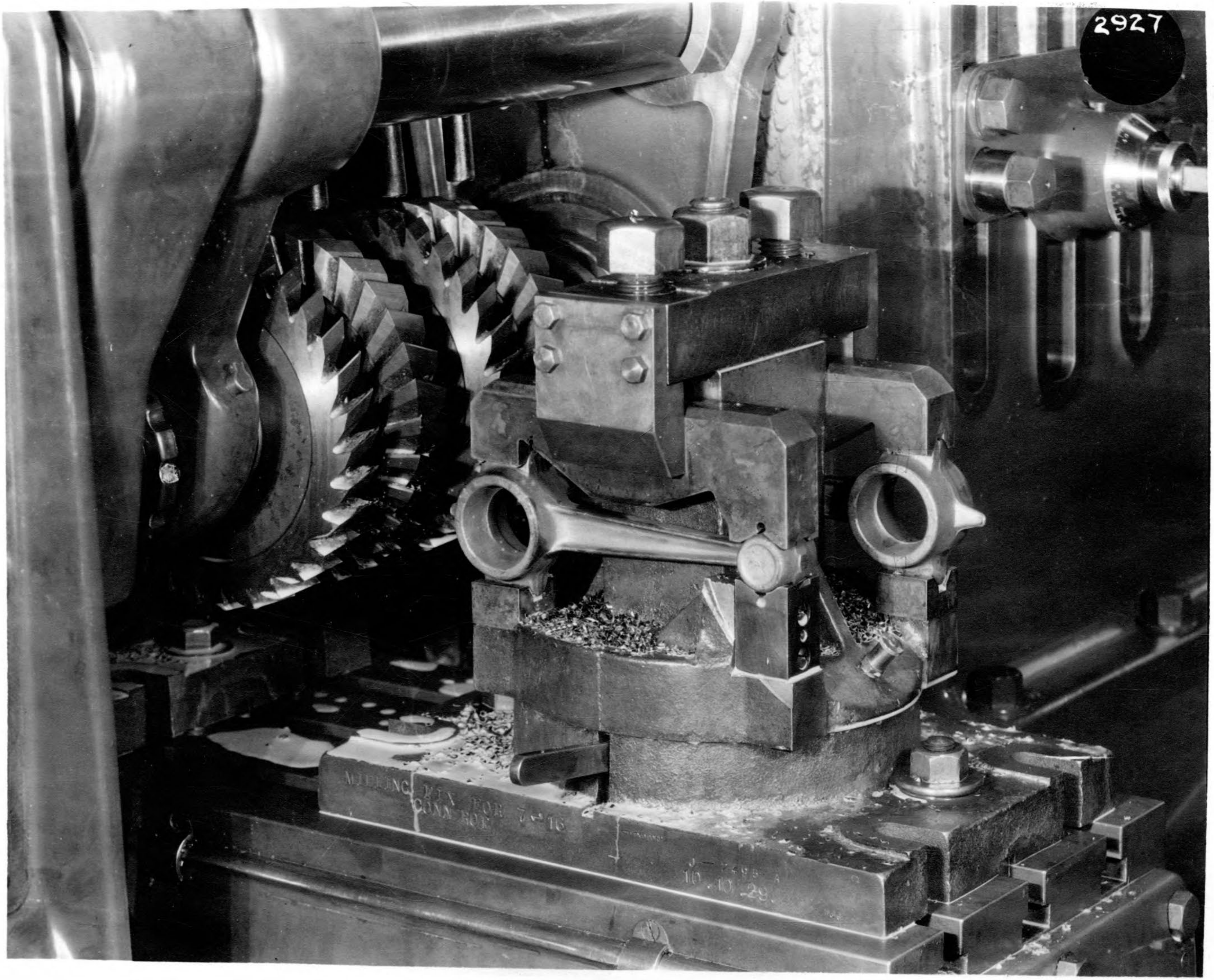
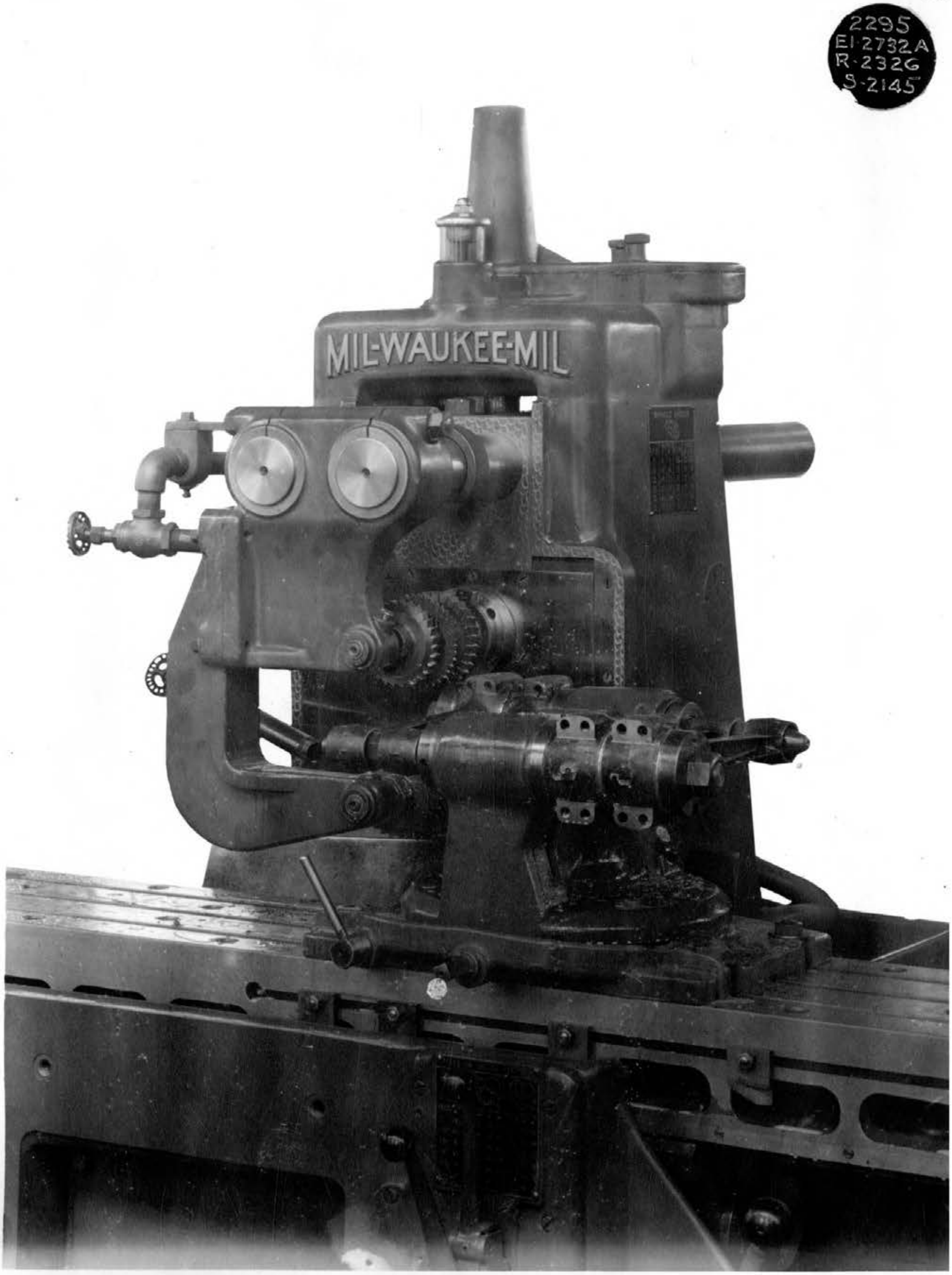
*Estimate, Kearney & Trecker Corp., Milwaukee, Wisconsin.

For all the above machines we would recommend a 5 HP constant speed motor. These motors, completely wired, would cost approximately $90.00 each. For floor space, you will find this material in our catalog. One operator would be required for each of the above machines. As for depreciation, we believe a fair allowance would be 10% a year on the machine and 25% per year on the special tooling.


2927
MILLING FIX FOR 7-16
CONN ROD
J-7495 A
10.10.29.


2295
E1-2732A
R-2326
S-2145
MIL-WAUKEE-MIL

CONNECTING ROD AND CAP*

Material - Drop Forging.
Production Required - 1000 in 8 hours.

Operation:
Drill and ream 2 bolt holes in each of 2 rods and 2 caps.

Machine Recommended:

One - C12H Semi-automatic Hydraulic Feed "NATCO" Multi-Driller equipped with a cluster box for head containing 16 spindles, 34" rotating table arranged for 3 positions, coolant pump, and all electrical equipment including one 10 HP 1200 RPM motor for driving the spindles and one 5 HP 1200 RPM motor for the hydraulic pump.

Price - Approximately	$3,500.00
Price - One 3 position fixture	725.00
Price - One set of tools	12.25

Floor Space - 48" x 83".
Shipping Weight - 10,000 lbs.

This drilling and reaming is performed by having a 34" rotating table on which is mounted the three position fixture. Each position arranged to hold 2 rods and 2 caps. The operator unloads and reloads at the first position then indexes to position No. 2 where the holes are drilled and then to position No. 3 where the holes are reamed. After all positions are loaded 2 rods and 2 caps are completed with each cycle of the head. The operation is based on 610 RPM, .003" feed and a depth of 7/8".

Starting time	1	second
Rapid traverse down	3	"
Drilling time	30	"
Rapid traverse up	5	"
Index the rotating table	5	"
TOTAL	44	"

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*Estimate, National Automatic Tool Co., Richmond, Indiana.

Estimated Production:

125 rods per hour net and 125 caps per hour net with one operator.

CONNECTING ROD AND CAP ASSEMBLY*

Operations:

Drill, rough and finish ream crank and piston pin holes after rods and caps are assembled.

Machine Recommended:

One - D16H Semi-automatic Hydraulic Feed "NATCO" Driller equipped with a 6 spindle cluster box for head, one 44" 4-position rotating table, self contained motor driven coolant pump, all electrical equipment including one 20 HP 1200 RPM motor for driving the spindles and one 3 HP 1200 RPM motor for the hydraulic pump.

Price - Approximately	$6,000.00
Price - One four position fixture	1,225.00
Price - One set of tools	175.00

Floor Space - 58" x 116".
Shipping Weight - Approximately 30,000 lbs.

The operations are perfomed as follows:

A 44" rotating table upon which will be mounted a four position fixture is set under the head of the machine. Each position on the fixture is arranged to hold three rods and caps assembled. The operator unloads and reloads three pieces in the first position and then indexes to the second position where the 1-7/16" diameter crank pin hole is core drilled and the 3/4" diameter piston pin hole is drilled. In the third position the 1-7/16" and the 3/4" holes are rough reamed. In the fourth position the holes are finish reamed, thus obtaining 3 rods with each cycle of the head. The operation time is based on the large core drill at 170 RPM, .015" feed and a depth of 2-1/8".

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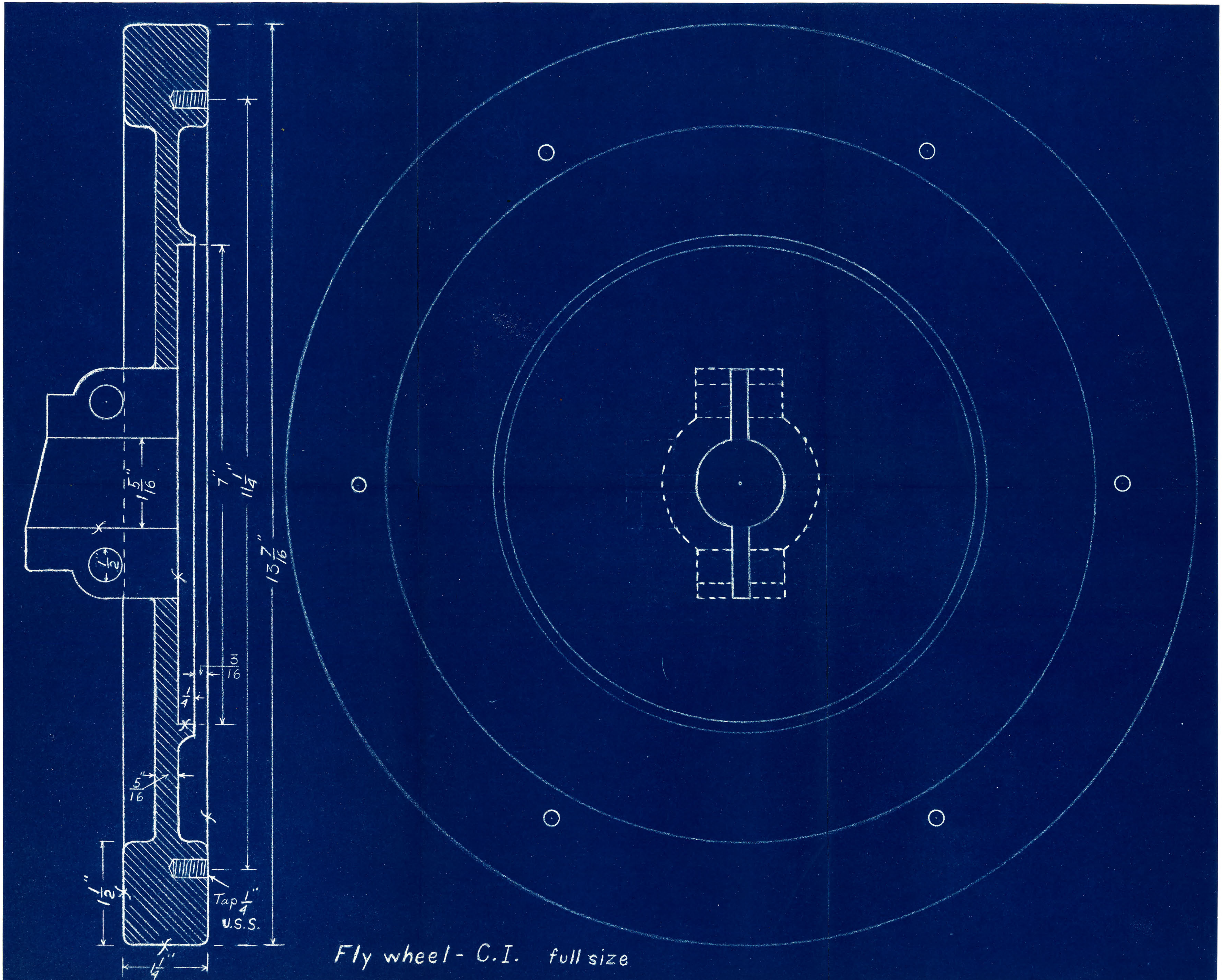
*Estimate, National Automatic Tool Co., Richmond, Indiana.

Starting time	1	second
Rapid traverse down	3	"
Cutting operation	50	"
Rapid traverse up	4	"
Index rotating table	4	"
TOTAL	62	"

Estimated Production - 125 per hour net with one operator.



Fly wheel - C.I. full size

Fly Wheel

The six spindle Bullard Mult-Au-Matic can be very profitably employed for machining the fly wheel. The fly wheel would be held on a chuck having special jaws, these jaws engaging three holes which would be cast in the fly wheel web.

The different events of the cycle would occur as follows:

Station	Event
1	Unload and load.
2	Rough turn outside, rough bore hole and 7" diameter cheek.
3	Rough face sides of rim and recess on web.
4	Finish turn outside, finish bore hole and 7" diameter cheek.
5	Finish face sides of rim and recess on web.
6	Round outside corners

The total time required per wheel is the time required for the longest operation plus about 2 seconds for indexing. The longest cut is necessary when boring the hole, which is 2-1/4" long. Using tungsten carbide tipped cutting tools at a cutting speed of 220 feet per minute and a feed of 0.030" per revolution, it will require 0.34 plus 0.03 or 0.37 minute for the operation. This is at the gross rate of 162 per hour, or 1296 per 8 hour day.

Allowing 15% off for tool changes, etc., gives a net production of 1100 per 8 hour day.

FLYWHEEL*

Material - Cast Iron.
Production Required - 1000 in an 8 hour day.
Operation - Drill 6 - 1/4" tapped holes and 2 - 1/2" holes.

Machine Recommended:

One - B225H Semi-automatic Hydraulic Feed "NATCO" Driller equipped with one fixed spindle drill head as the vertical head, and one self contained hydraulic unit for the horizontal head. Coolant pump, and all electrical equipment including one 5 HP 1200 RPM motor for the vertical head and one 1-1/2 HP 1200 RPM motor for the horizontal head.

Price - Approximately	$3,000.00
Price - Fixture - approximately	430.00
Price - One set of tools	5.50

Floor Space - Approximately 26" x 50".
Shipping Weight - Approximately 6000 lbs.

One stationary type fixture will be used and all holes drilled at the same time.

Time governing the operation is taken from the 1/2" drill with 610 RPM and .005" feed and a depth of 1-5/8".

Loading time	7	seconds
Starting time	1	"
Rapid traverse down	3	"
Drilling time	32	"
Rapid traverse up	3	"
Unloading	7	"
TOTAL	53	"

Three of these machines will be required to obtain the production necessary which will be 45 per hour with one operator. With the second machine we are tapping 6 - 1/4" holes in the same Flywheel.

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*Estimate, National Automatic Tool Co., Richmond, Indiana.

Machine Recommended:

One - C13 Lead Screw Tapper equipped with 6 spindles, coolant pump, and all electrical equipment including one 5 HP reversing motor.

Price - Approximately	$3,150.00
Price - Fixture	210.00
Price - One set of tools	4.50

Floor Space - 52" x 99".
Shipping Weight - 8000 lbs.

Estimated Production - 125 per hour net with one operator.

SUMMARY AND CONCLUSIONS

A survey of the production estimates submitted by the various machine tool manufacturers shows that the shaper and planer, familiar to all machinists, have been practically eliminated from the modern high production plant.

There are some cases where the gear shaper, which cuts in one direction only, must be used because the gear can not be cut by any other method. This includes internal, some types of herringbone, and cluster gears. For most of the other kinds of gears the gear hobber is used.

In place of the planer and shaper, the general practice is to use some type of milling machine on which the cutting action is continuous. The work is held in a fixture so constructed that as fast as one piece is finished it is replaced with an unfinished one, consequently it is not necessary to stop the machine.

In place of the lathe using a single tool, has been substituted automatic lathes carrying several tools so arranged that more than one tool is cutting at a time, the floor to floor time of the piece being governed by the length of the longest cut.

When a piece requires a number of holes to be drilled in it, instead of drilling the holes one at a time, a machine will be designed to drill all, or nearly all of the holes at one time, the total time required will be that necessary to drill the deepest hole.

When machining a fly wheel such as is included in this study, it used to be the practice to use turret lathes, but now the Mult-Au-Matic type is used whenever the production warrants it.

A comparison of the following figures will show why this is true.

Production on Turret Lathe

Operation No.	Operation
1	Rough turn O. D. and rough bore 1-5/16" hole.
2	Rough face booth sides rim and recess on web.
3	Finish turn O. D., finish bore 1-5/16" hole and finish bore 7" diameter cheek.
4	Finish face both sides of rim and recess on web.
5	Chamfer O. D. of rim.
6	Ream 1-5/16" diameter bore

For a production of 1000 pieces in 8 hour day it will require 37 machines since the average time per piece for one day's run is 19.66 minutes.

Cost of 1 machine and tools $3,513.00

Cost of 37 machines and tools $129,981.00

This production of 1000 fly wheels per 8 hour day can be obtained by one six spindle Mult-Au-Matic.

Production of Mult-Au-Matic

Station	Event
1	Unload and load.
2	Rough turn O. D., rough bore 1-5/16" hole and 7" diameter cheek.
3	Rough face sides of rim and recess on web.
4	Finish turn O. D., finish bore hole and 7" diameter cheek
5	Finish face sides of rim and recess on web.
6	Round outside corners.

Average time per piece for day's run is 0.37 minute. Production per 8 hour day per machine is 1100.

Cost of Mult-Au-Matic and tools $17,900.00

Difference in first cost in favor of Mult-Au-Matic is $129,981.00 - $17,900.00 = $112,081.00.

It will require 12 operators to run the 37 turret lathes while only one is required for the Mult-Au-Matic.

Floor space occupied by Mult-Au-Matic	72 sq. ft.
Floor space occupied by turret lathes	3746 sq. ft.

Cost of Machining

Turret Lathes

Cost of tools per year (37 machines)	$ 3,700.00
Depreciation	11,148.10
Labor (12 men, 300 days @ $4.00)	14,400.00
Rent (@ $0.20 per sq. ft.)	749.20
	$ 29,997.30

300 days @ 1000 pieces per day = 300,000 pieces

Cost per piece . . . . $ 0.0999

Mult-Au-Matic

Cost of tools per year	$ 180.00
Depreciation	1,700.00
Labor (1 man, 300 days @ $4.00)	1,200.00
Rent (@ $0.20 per sq. ft.)	14.40
	$ 3,094.40

Cost per piece . . . . $ 0.01031

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Le Blonde Machine Tool Co., Cincinnati, O.
Landis Tool Co., Waynesboro, Pa.
Gould and Eberhardt, Newark, N. J.

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