Patronsky-

Construction of a suitable equipment for the machinability of wood tests.

Patronsky. L.A.

CONSTRUCTION OF A SUITABLE EQUIPMENT FOR THE MACHINABILITY OF WOOD TESTS

by

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A Thesis as Partial Fulfilment
Of the Requirements for the
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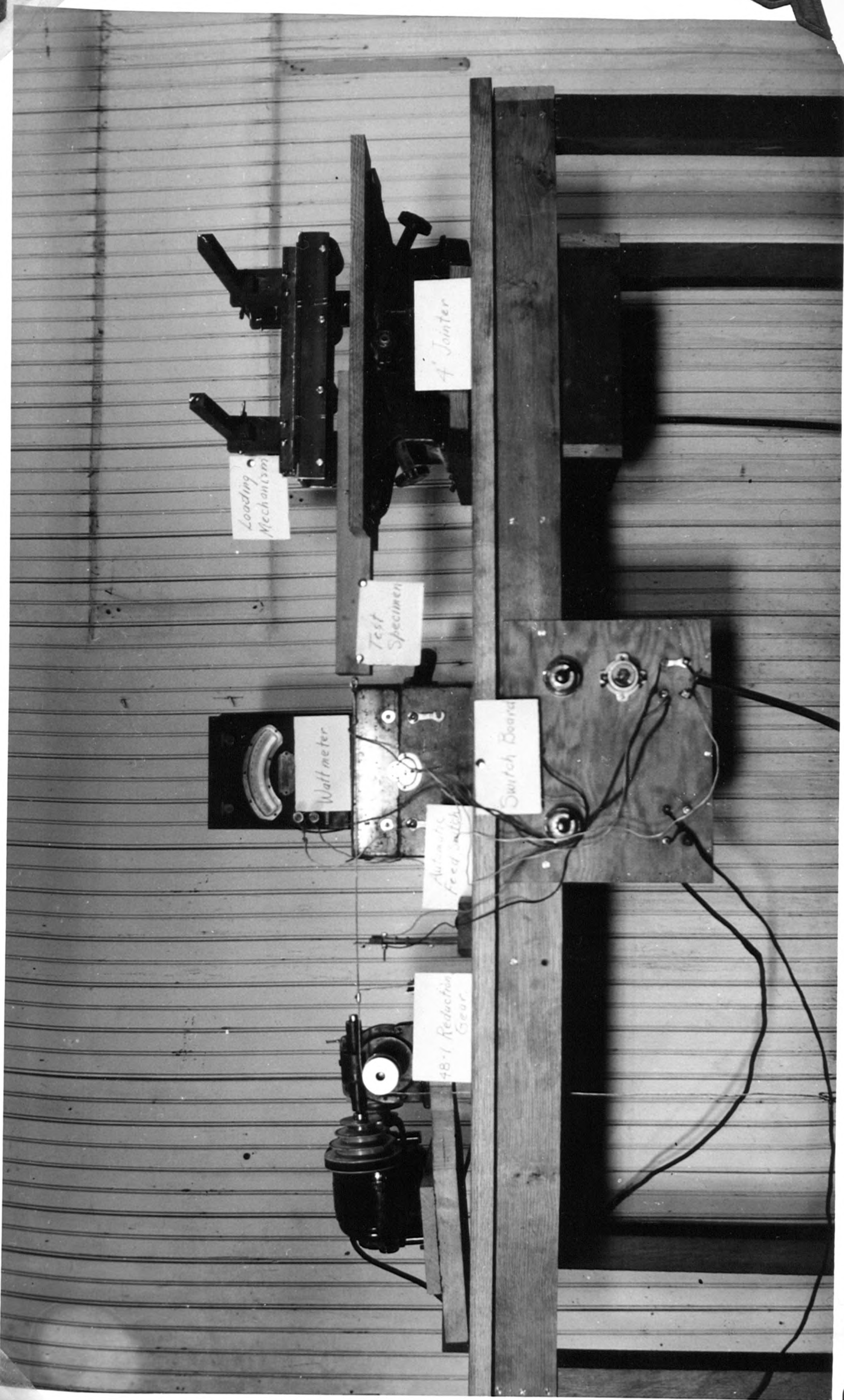

Figure 1 Photograph of Completed Equipment

Fig 1 Photograph of Complete Equipment

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INTRODUCTION

Wood has been in use for many centuries due probably to the ease with which it can be formed into desired shapes with relatively simple tools. During the last decades much advance has been made in the machinery and tools with which wood can be worked. The wood-using industries have developed to the point where they are second in importance to food-producing industries in respect to the number of plants and number of workers. One out of every seven plants is a wood-working plant and one out of every eight workers is employed by a wood-using industry.[1]

In spite of the importance of the wood-using industry there is relatively little known about the material used in fabricating the myriad articles which find their origin in the forests. To learn the extent to which research in wood has been neglected one has only to try to find such data as: forces exerted by wood in shrinking and swelling; heat, electrical, and sound conductivity of wood; machinability of wood and its related subject, the quality of surface produced by the various machining processes. These problems are becoming especially important due to the introduction of new tropical woods into our furniture and plywood markets.

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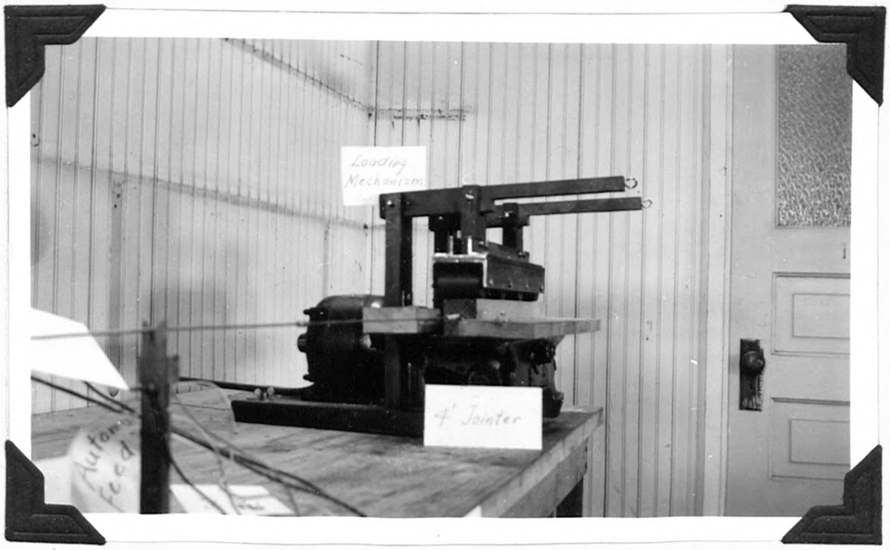
[1]1929 census figures.

If information on the machinability of wood could be placed into the hands of the manufacturers, it would eliminate the trial and error methods of manufacturing and, as a result, reduce costs of machining of wood.



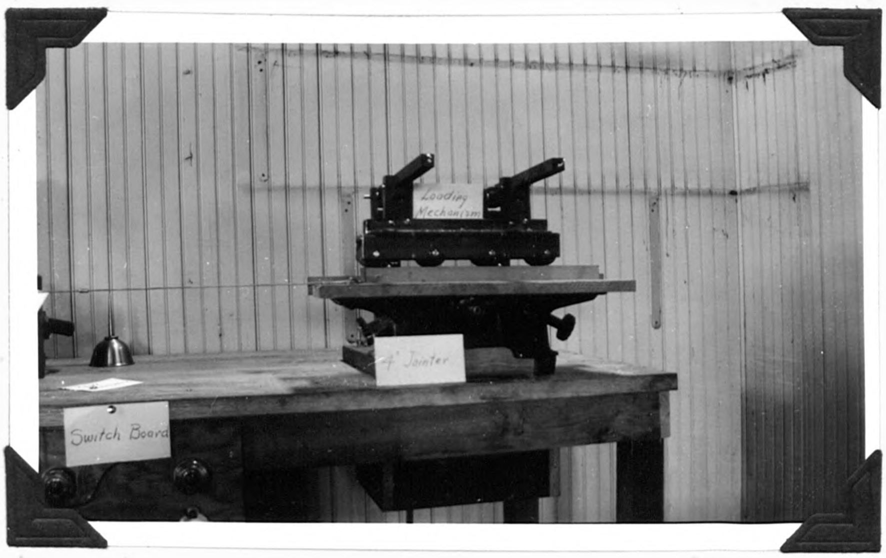


Figure 2 Photographs of Jointer and Loading Mechanism

Object

The object of this work is to devise a permanent method of determining the machinability and machining qualities of wood.

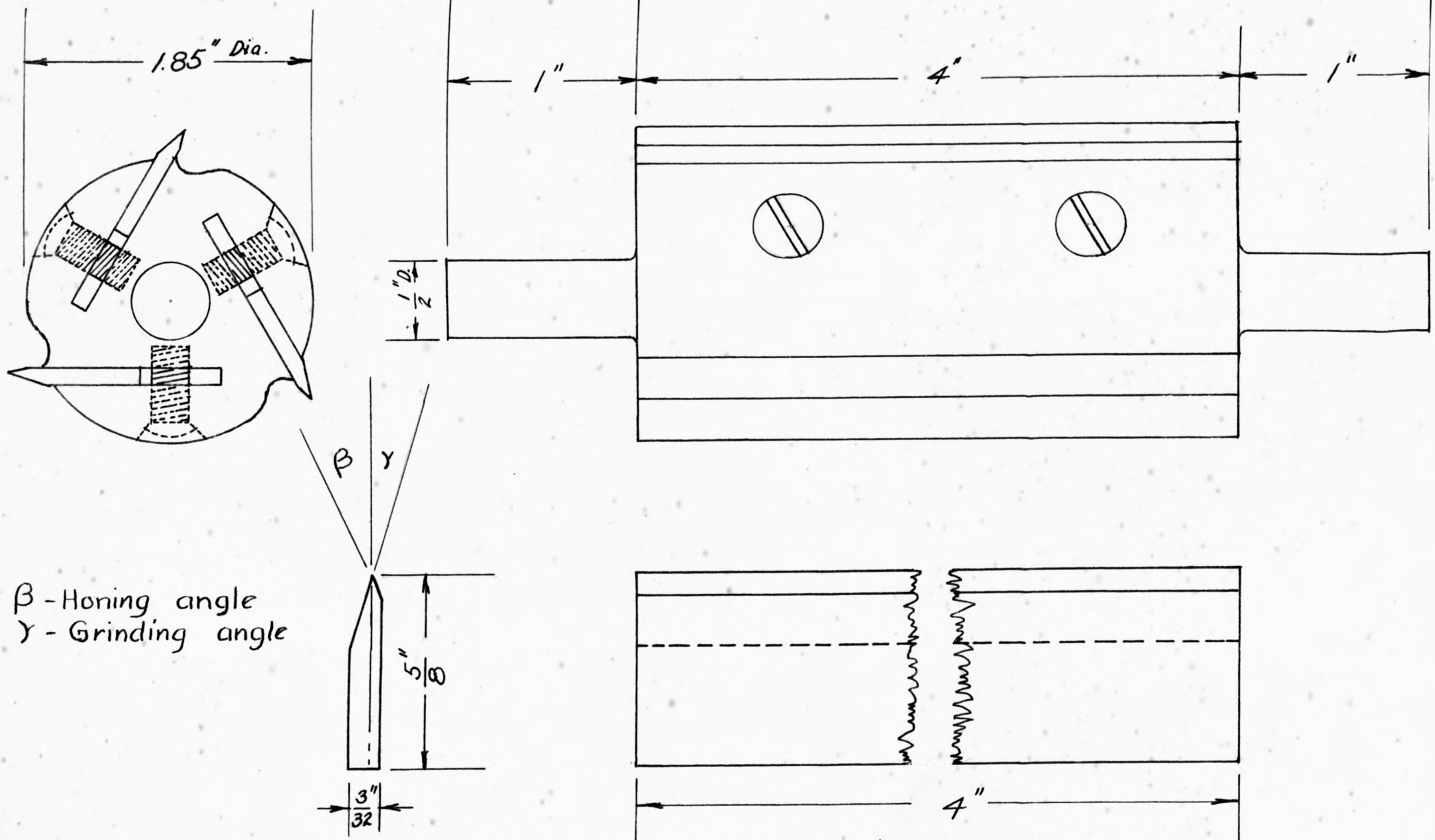
Procedure

Inasmuch as a large amount of wood is required to be jointed for gluing and other purposes where an exact joint is required, it is fitting that the study of machinability of wood be started by investigating the power required to joint the various species of wood.

Equipment

The machine that is used for this work is a four-inch bench type jointer, Figure 2, page 3. Due to the number of years the jointer has been in service it is not in the best condition for such exacting tests. It, however, serves for this preliminary work. The overall length of the table is 19 inches.

The cutting head is made of a solid cylinder of steel four inches in length and about one and five-eighths inches in diameter. Three knives four inches long, five-eighths inches in width, and three thirty-seconds in thickness are equally spaced on the periphery of the cutting head as shown in Figure 3, page 5. The cutting head is designed for an average speed of three thousand,



Detail of Cutting Knife 2" = 1"

Figure 3 Cutter Head of a 4" Jointer

four hundred revolutions per minute, and therefore there are ten thousand, three hundred, and fifty-six cuts taken from the wood every minute. The cutting head is fastened to the jointer frame by means of two bronze sleeve bearings one and one-quarter inches long. It is extremely difficult to align these bearings so as to minimize bearing power losses. These bearing losses could be almost eliminated by using ball bearings in place of sleeve bearings.

The cutting head is joined to the motor directly, through a flexible coupling. The direct drive is very important because it eliminates error that may be introduced through belt slippage. Power losses would also occur due to the friction of the belt on the pulleys, which would make the measurement of power consumption for the actual cutting of the wood difficult. The motor used to drive the cutter head is a single phase, 110 volt, $\frac{1}{4}$ horse power, alternating current motor which travels at the speed of 3450 revolutions per minute under full load. During the testing of various species of wood the motor is called upon to operate over a large range of loads, from zero load, when running idle, to a very heavy load, when cutting

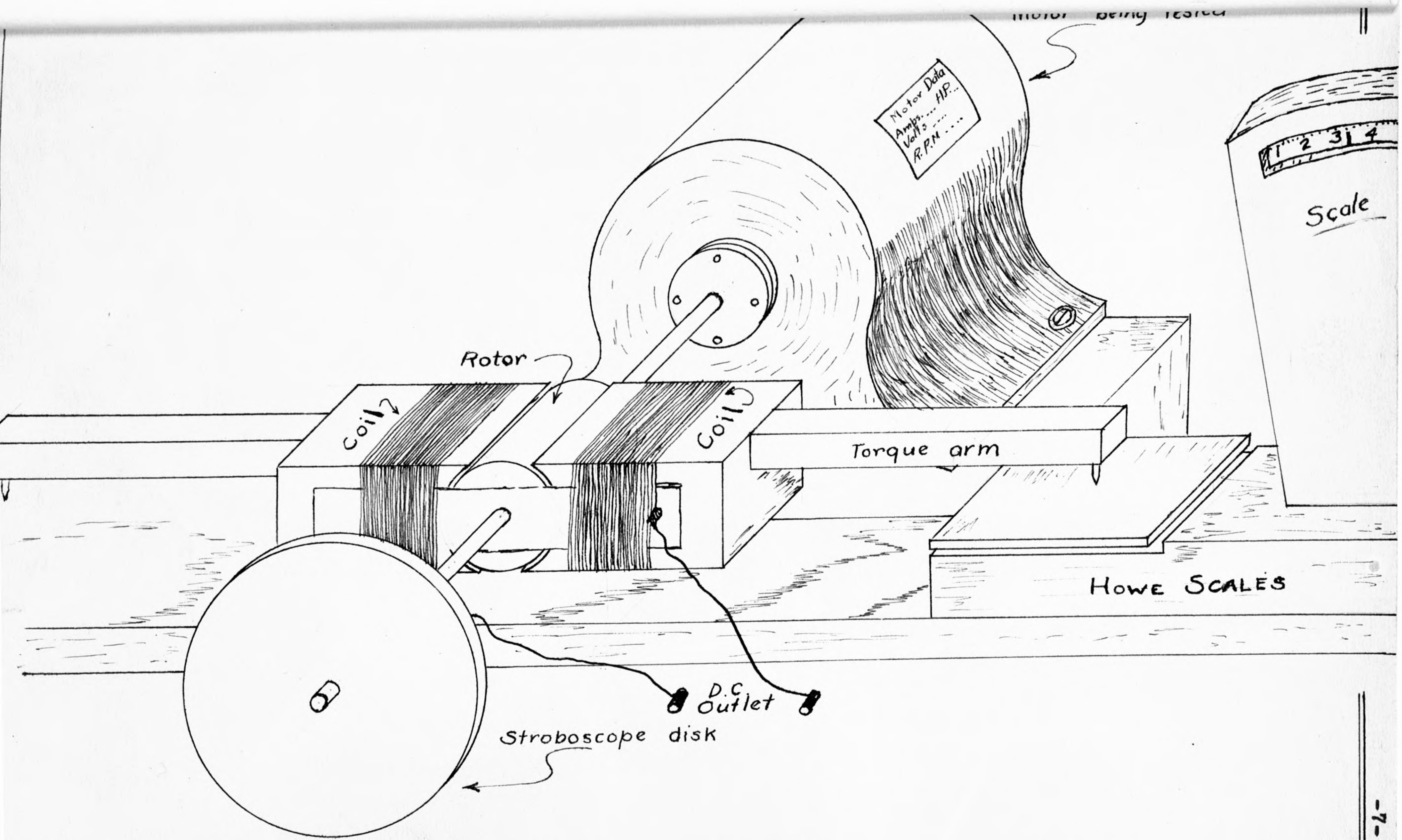


Figure 4 MOTOR EFFICIENCY TESTING EQUIPMENT

a dense species. In order to be able to account for power losses under these varying conditions, it was necessary to measure the efficiency of the motor from zero load to the maximum load that the motor will be called upon to carry. The apparatus that was used for the purpose of measuring the efficiency of the motor is shown in Figure 4, page 7. The method of testing the motor efficiency was as follows: the motor was clamped down on a solid stand. The motor shaft was coupled to the rotor of the prony brake by means of a flexible coupling. The rotor was free to rotate between the coils which are represented in Figure 4. The torque arms were fastened to the coils and are 1.05 feet long to facilitate the calculation of output horsepower. The torque arm rested on the weighing table of the scale. A stroboscope was used to measure the revolutions per minute of the motor. The stroboscope was used instead of a tachometer because it does not effect the speed of the motor since it is not attached to the motor in any way. However, if the stroboscope had not been available, a tachometer would not have introduced a very large error into the results.

The motor was then started and the only load

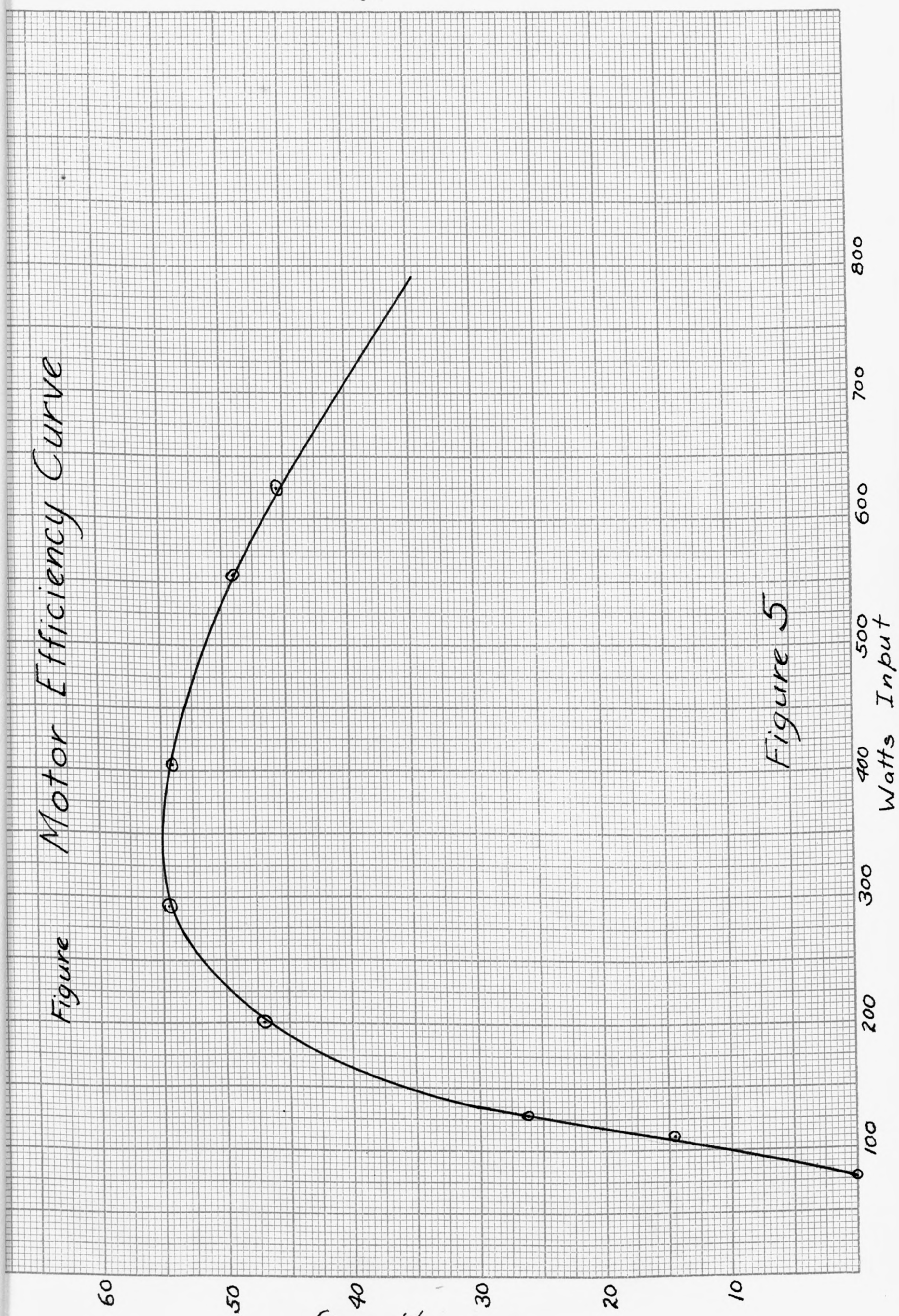

Motor Efficiency Curve
Figure
Figure 5
Watts Input
100
200
300
400
500
600
700
800
10
20
30
40
50
60

Table I Motor Efficiency Data

Wattmeter Reading Watts	Voltmeter Reading Volts	Revolutions per Minute	Load in Pounds	Corrected Load Tare = .04 lb	Length of Lever Arm	Input Horsepower	Output Horsepower	Percent Efficiency
110	110	3560	.070	.030	1.05 Ft.	.147	.0214	14.6
128	110	3550	.103	.063	1.05 "	.172	.0447	26.0
200	110	3510	.220	.180	1.05 "	.268	.1260	47.0
293	110	3460	.350	.310	1.05 "	.393	.2140	54.5
405	110	3380	.475	.435	1.05 "	.543	.2940	54.1
556	110	3250	.600	.560	1.05 "	.745	.3640	48.9
624	110	3180	.640	.600	1.05 "	.837	.3820	45.6

it was required to overcome was the friction of the rotor bearings. This gave the power input to the motor under no load conditions. The input power was measured by means of a wattmeter that was hooked in the motor circuit. The load was applied to the motor by passing a current through the coils on each side of the rotor. The electric current in the coils sets up an electric field between them and offers a resistance to the motion of the iron rotor. As the current that was passed through the coils was increased so was the resistance to rotation through the electric field increased. Wattmeter readings were taken as the load on the prony brake was increased. At each wattmeter reading a simultaneous reading on the scale and stroboscope was taken. These data are recorded as shown in Table 1, page 10.

The motor efficiency was computed by the following method. One horsepower is equal to 746 watts, and, therefore, we obtain the input horsepower by dividing the wattmeter readings by 746. The output horsepower is computed by the formula

$$\frac{\text{load in pounds x revolutions per minute}}{5000}$$

The efficiency of any machine is represented by the relation $\frac{\text{output}}{\text{input}} \times 100$. By dividing the output horse-

APPARATUS FOR APPLYING LOAD TO TEST SPECIMEN

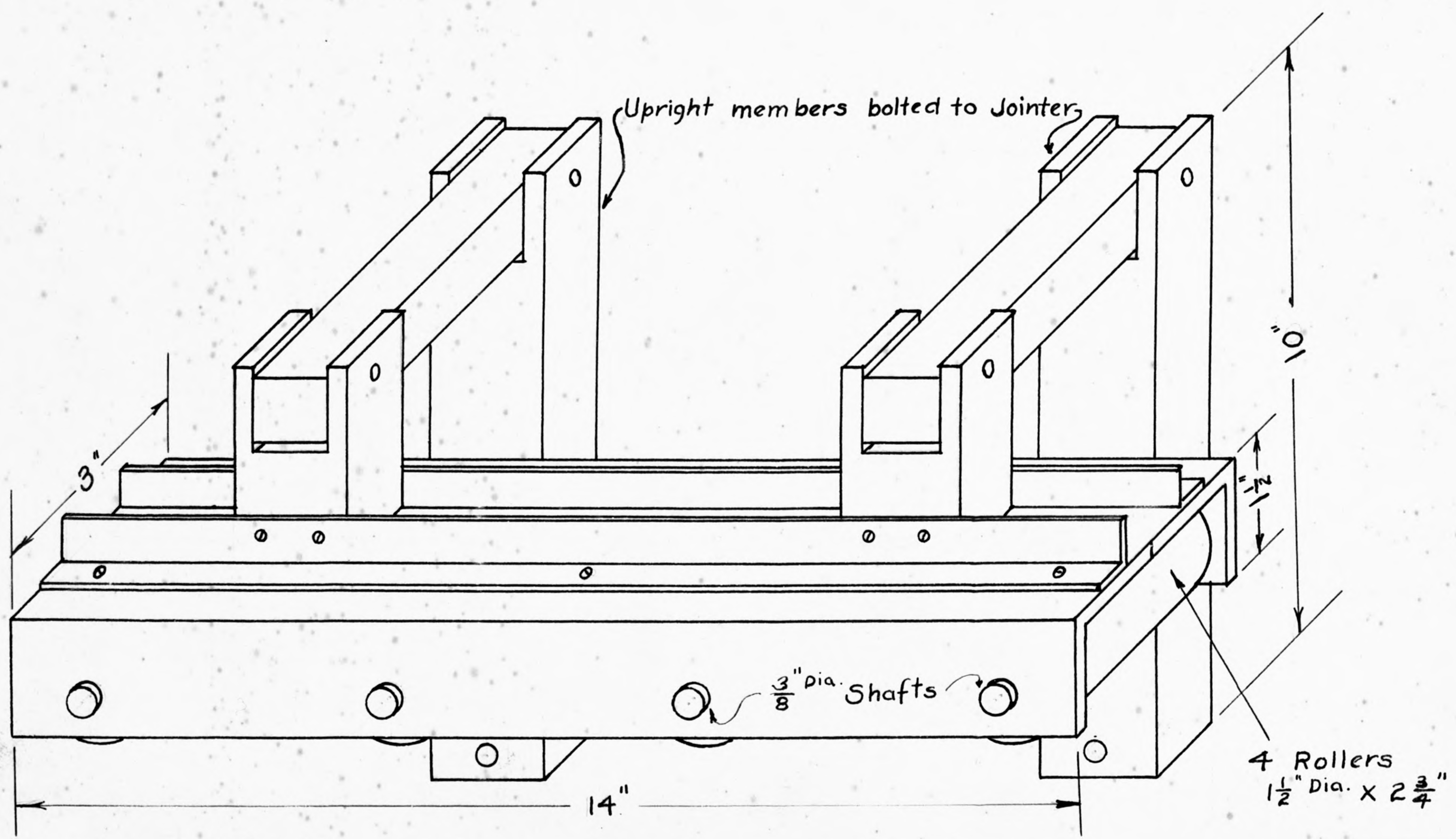


Figure 6

power by the corresponding input horsepower we arrive at the efficiency of the motor.. The efficiency of the motor varies with the load it is required to carry. On page 9 is shown a graph of the efficiency of the motor under varying loads. The method of applying this curve to the data taken in the actual testing of the different species will be shown on a subsequent page.

Loading Mechanism

When the jointer was selected for the machinability of wood it became apparent that some method had to be devised to hold the test piece against the bed of the jointer. At the beginning of the work the test piece was loaded by placing a bar of steel on top of it. This method proved unsatisfactory because the bar of steel vibrated off of the test specimen and also, due to the shortness of the tables on both sides of the cutter head, the test piece tended to tilt, thus raising it off of the cutter head. To overcome these difficulties the device as shown in Figure 6, page 12 was designed and built. The assembly of the loading device and jointer is shown in Figure 2, page 3. The loading mechanism consists of a set of four rollers made of dense tropical wood mounted in a frame of iron. The rollers are free to rotate on top of the test piece as it (the test specimen) is drawn over the knives of the jointer. It was found that the amount of load that was applied to the device had no effect on the power consumed in machining wood provided that it was sufficient to hold the test piece solidly against the table of the jointer. By the use of this loading device the readings taken on all the test specimens are constant because tilting of the test piece is entirely eliminated.

Feed Mechanism

Early in the work on machinability of wood it became apparent that some method of drawing the test piece across the knives at a definite rate of speed had to be devised. Inasmuch as there was only a limited amount of money available for work on this problem, it was necessary to set up a low-priced feed mechanism that would operate satisfactorily. This was accomplished by purchasing a low-priced ¼ horsepower 110 volt alternating current motor. The speed of the shaft of the motor was seventeen hundred and fifty revolutions per minute. If this motor

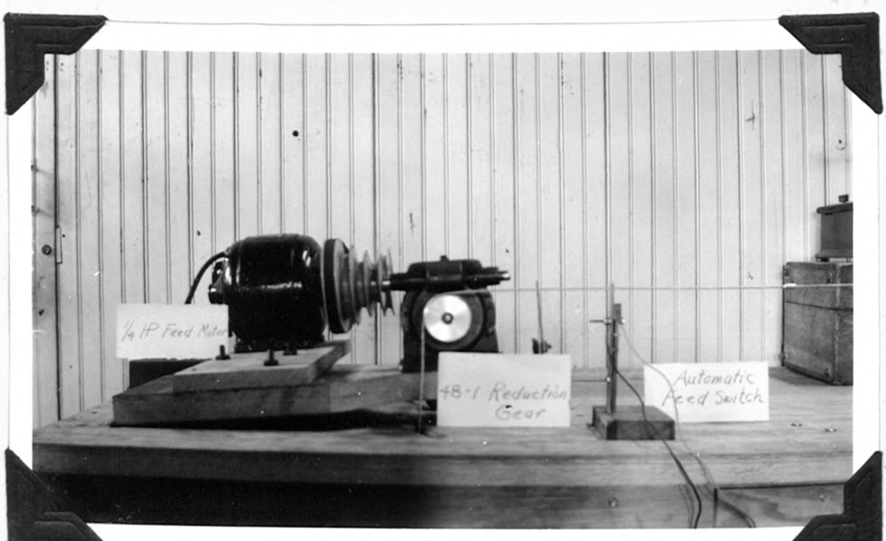


Figure 7 Photographs of Feed Mechanism and Automatic Switch

had been used with a one-inch pulley the speed of feed would have been four hundred and fifty-eight feet per minute. In commercial woodworking plants the feed used varies between twenty and thirty feet per minute. To meet these commercial requirements it was necessary to reduce the speed of the feed motor considerably. This reduction was accomplished by means of a pair of step pulleys connected with a "V" belt, and a forty-eight to one ratio reduction gear. This assembly is shown in Figure 7, page 15. By altering the position of the "V" belt on the four step pulleys it is possible to obtain speeds of feed of 7, 11, 15 and 21 feet per minute.

The test specimen is connected to the gear reduction pulley by means of a steel cable. The cable is attached to the test specimen by means of a screw eye. The other end of the cable is looped around twice on a pulley on the geared reduction mechanism, Figure 7, page 15. The end of the cable is weighted with a five-pound piece of steel to increase the friction on the pulley so that no slippage will occur. The feed assembly operates as follows: when the motor is started the cone pulley on the motor shaft

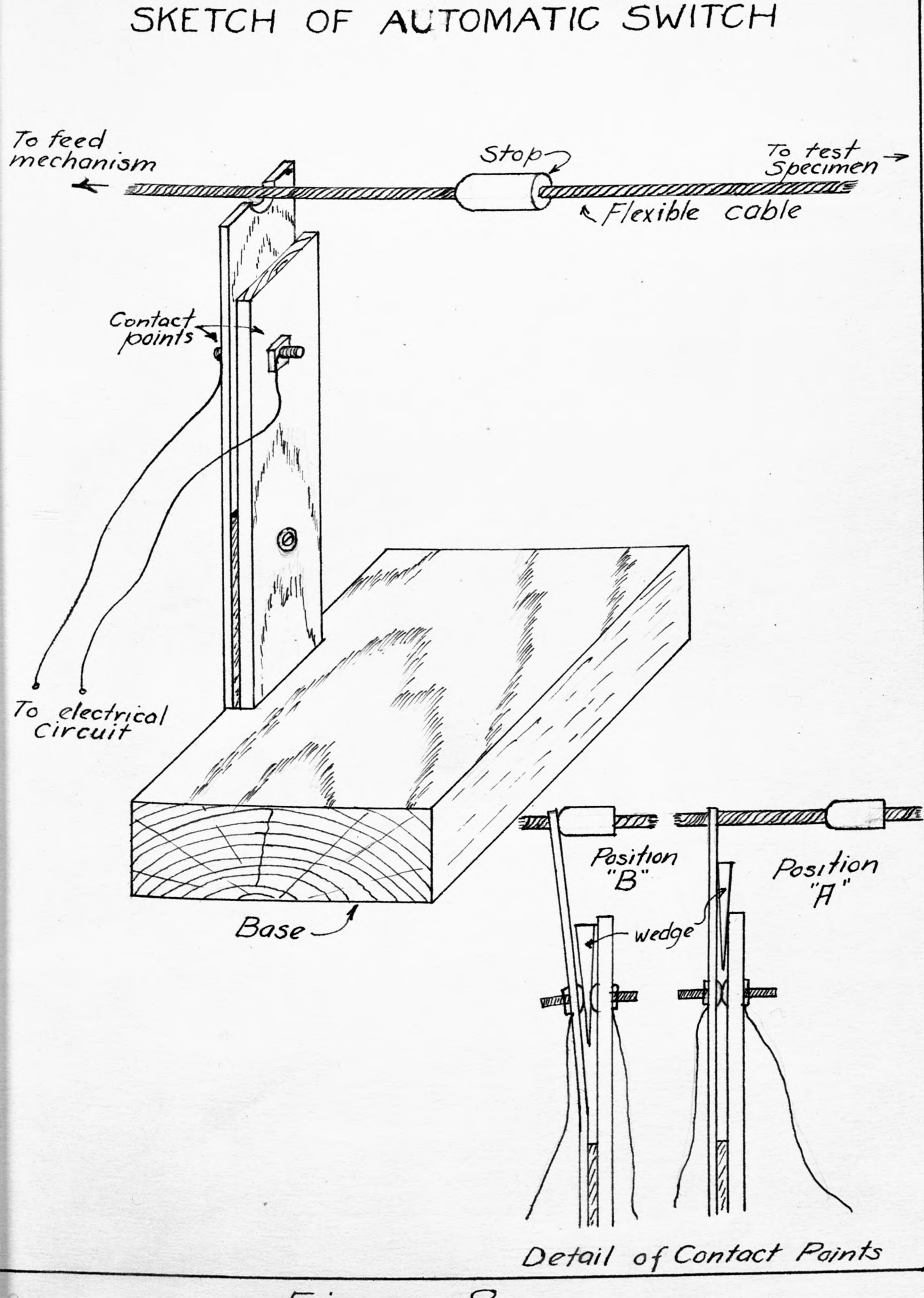

SKETCH OF AUTOMATIC SWITCH
To feed mechanism
Stop
To test Specimen
Flexible cable
Contact points
To electrical Circuit
Base
Position "B"
Position "A"
wedge
Detail of Contact Points

Figure 8

drives the cone pulley on the gear reduction. The power is transmitted through the gear reduction and thence to the two-inch feed pulley upon which is wound the steel cable. As the pulley revolves, it draws the cable which in turn draws the test specimen across the cutter head at a known rate of speed.

Automatic Switch

Between the feed mechanism and the jointer is located an automatically operating switch, see Figure 7, page 15, which turns the jointer and the feed motors off as soon as the test specimen has completely passed over the jointer cutter head. A detail sketch of the automatic switch is shown in Figure 8, page 17. The switch operates as follows: when a test is started the switch is in position "A" of figure 8. The contact points are together and the circuit is unbroken and the motors are operating. A "stop" is placed on the flexible cable and so adjusted that when the test specimen has passed over the cutter head it hits the longest upright prong of the switch and carries it back and breaks the contact as shown in position "B". As the prong is pushed back a wood wedge falls between the

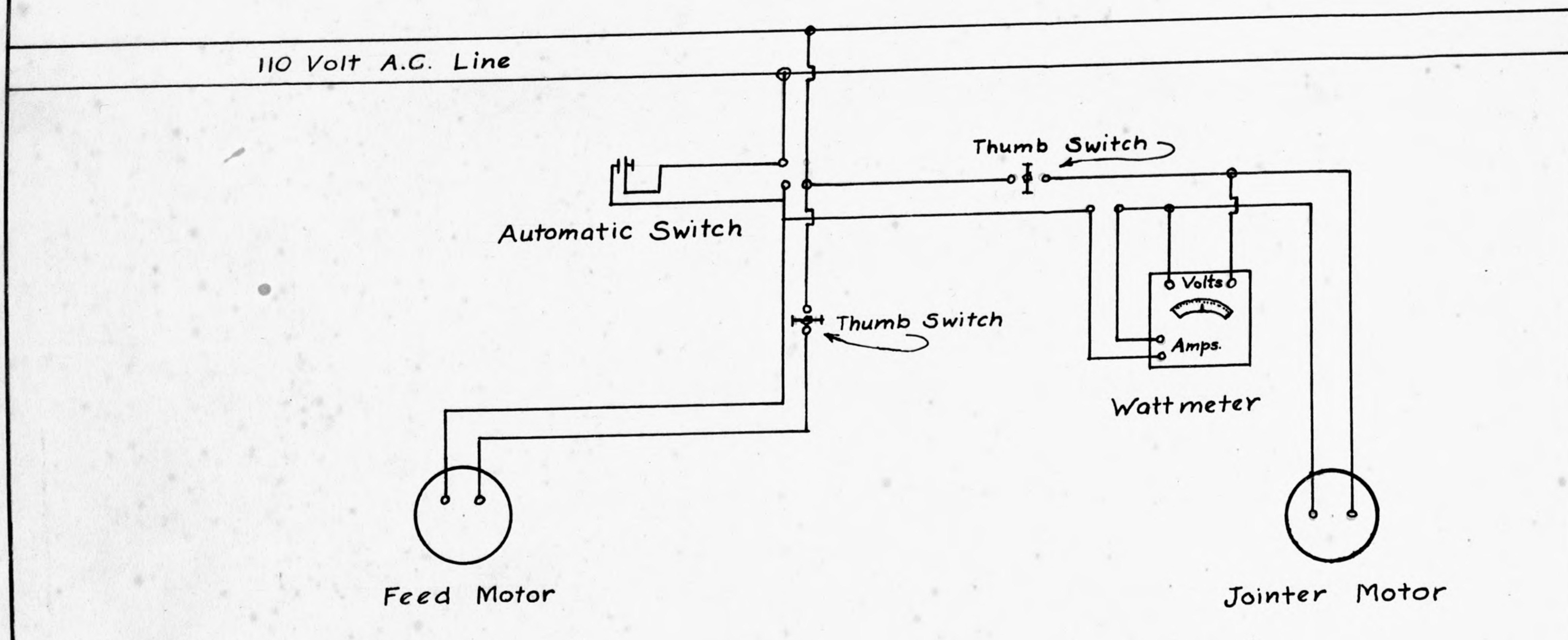
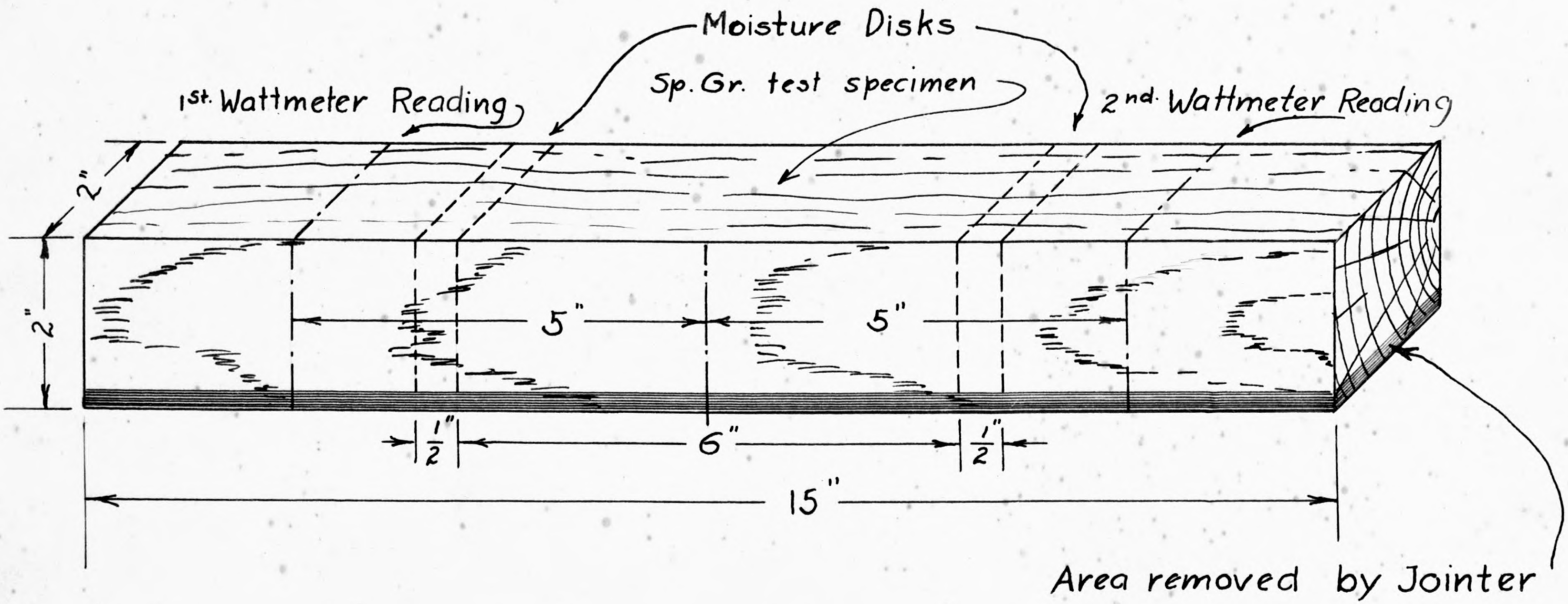


Figure 9 Circuit Diagram

contacts, breaking the circuit and thus stopping the motors. To start another test the wedge is removed and the metal points again come in contact with each other. By the use of the automatic switch the operator has only to take the wattmeter readings and is not distracted from it to stop the motors.

Wattmeter

In the description of the efficiency test in a previous paragraph, it was mentioned that the input power was measured by a wattmeter. As can be seen from Table 1, page 10, when the load on the prony brake was increased, the input watts to the motor increased. In the testing of the wood specimens the work of the cutter head in separating the wood particles can be compared to the prony brake. By using a wattmeter in the jointer motor circuit, we can accurately determine the power consumed in cutting the wood. Providing that we keep all other variable conditions constant, we can use the input power to the motor as a criterion of machinability of wood. Figure 9, page 19, shows a circuit diagram of the wattmeter. The wattmeter used is a 750 Watt 10 ampere range.



SPECIMEN FOR MACHINABILITY TEST

Figure 10

Table 2

Wood in Constant Temperature - Humidity Room

Native Woods

Sitka spruce	Red oak
Tulip poplar	Basswood
White oak	Red maple (soft)
Hickory	Douglas fir
Pecan	W. Yellow pine
White elm	Birch
Short leaf pine	Sugar pine
White ash	Western hemlock
Black cherry	Bald cypress
Hard maple	

Tropical Woods

Imbuia
Iroko - Chlorophora excelsa - Africa, W.
Imbuia (Phoebe porosa) Brazil
Macacahuba (Platymiscium Ulei Harms Brazil
" paraense
Massaranduba Mimusops Huberi Duche Brazil
Pau Amarello - Eucylophera paraensis Brazil
Pau Roxo (Peltogyne densiflora) Benth. Brazil
Sucupira (Bowdichia brasiliensis (Tul.) Duche Brazil
Cedar, White (Tabebuia longipes Baker) British Guiana
Duka (Tapirira guianensis Aubl.) British Guiana
Duka-Tapirira Marchandii Aubl. British Guiana
Greenheart - Ocotea Rodioei (Schomb.) Mez. British Guiana
Greenheart (Black var.) Ocotea Rodioei Schomb. Mez.
Kirikowa (Virola sp.) British Guiana
Kurokai - Protium Schomburgkianum British Guiana
Maho--Sterculia pruriens Aubl. Schum. British Guiana
Morabukea- Dimorphandra Gonggrijpii Kleinh. Br. Guiana
Purpleheart - Peltogyne pubescens Benth. British Guiana
Wallaba - Eperua falcata Aubl. British Guiana
Wallaba - Eperua coudata British (ined British Guiana
Mahogany - Swietienia macrophylla King Nicaragua
Bagtikan - Parashorea malaanonan Merr. - Philippine Islands
Mahogany - Swietenia macrophylla King Peru
Tanguile - Shorea polysperma Merr. - Philippine Islands
Algarrobo - Licania sp. - Venezuela
Apamate - Tecoma pentaphylla Juss. - Venezuela
Carbonera - Piptadenia pittieri Harms. - Venezuela
Flor Amarillo-Tecoma sp. - Venezuela
Gateabo - Astroneum graveolens - Venezuela
Guayabo - Mouriria sp. - Venezuela

Table 2 (Continued)

Pardillo - Cordia sp. - Venezuela
Roble - Platymiscium polystachium Benth. - Venezuela
Saqui-Saqui - Bombacopsis sp. - Venezuela
Tuque - Nectandra sp. - Venezuela
Trompillo - Guarea trichilioides - Venezuela
Vaquetero - Lucuma speciosa - Venezuela

Material to be Tested

Probably the most important items in running any type of wood test are to adopt a standard test piece, and to have it conditioned to a definite moisture content. By a standard test piece is meant an average representative piece of the species. The grain must be straight, and the piece must be free from defects such as knots, checks, pitch pockets, and decay. For these tests the moisture content of twelve and and one-half per cent (oven - dry basis) has been adopted because it is at about this moisture content that a great deal of the commercial machining is done. The test pieces that are available for this test have been collected and placed in the constant temperature room of the Chemical Engineering Department by Mr. Albert Tegge, Jr. A list of the specimens that are ready for use is shown in table 2, page 22. The size of the test piece that has been adopted for these preliminary tests is shown in Figure 10, page 21. The test pieces are fifteen inches long and two by two inches in cross section.

The tests are to be run by beginning with the lowest specific gravity and proceeding toward the higher specific gravity species, taking first the native species and then the tropical species that are available. This procedure is dictated by the writer's belief that the dulling of the knives is increased by the increase in specific gravity. In following this method much time will be saved during the early period of testing by not having to regrind the knives.

Procedure Used in Testing

Figure 1, page i, shows the complete set-up of equipment. Each piece of apparatus has been previously discussed and will be referred to according to the labels on Figure 1, page i. In pilot tests it was found that due to the condition of the jointer it was impossible to use commercial depths of cut or speeds of feed. The maximum cut that could be taken was one hundredth of an inch deep. The maximum feed that could be used was eight feet per minute. When these settings were made on the jointer and feed mechanism the apparatus was ready for the test specimen. The test specimens were taken from the constant temperature and humidity room to the laboratory in an oil cloth container so that the moisture content would not change before the tests were run. A screw eye was placed in one end of the test piece so that the feed cable could be hooked to it. The test specimen was then drawn back so that it was in front of the cutter head. Measurements to the accuracy of one hundredth of an inch were then taken on the test specimen at the points where the wattmeter readings were recorded. See Figure 10, page 21. The heights of the test blocks were recorded on the data card, page 28. The jointer motor was then started and the reading of the wattmeter was taken. This reading is recorded on the data card in the "Motor and Bearing Losses" column. The feed motor was then started and readings on the wattmeter were recorded as the points marked "Front Wattmeter Reading" and "Rear Wattmeter Reading" passed over the cutter head. When the automatic switch had turned off the motors, the test piece was drawn back and the procedure of testing was repeated until it had been done ten times. The height of the test piece was again measured and recorded on the data card. The first piece to be tested was saved to be later used as a control to reset the jointer if it went out of adjustment. The subsequent test pieces were cut up as indicated in Figure 10, page 21. The moisture disks used to determine the moisture content of the piece, and the specific gravity specimen, were handled in the manner indicated in the publication by Markwardt and Wilson, "Strength and Related Properties of Woods grown in the United States." For this work the specific gravity is based on a twelve and one-half per cent moisture content.

Test Piece No.______ Species ______

Specific Gr. ______ % M.C. ______

Feed - ft. per min. ________ Rings per in. _____

Height at Front	Height of rear
before test	------
after test -----	------

Average depth of cut -----

Front

Data Card

	Wattmeter reading during cut		Motor and Bearing Losses	Motor Losses from Curve	Watts Used in Cutting	Depth of Cut	Tangental or Radial Cut	Remarks
	Front	Rear						
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								

Rear

Sample Data Card

SPECIFIC GRAVITY AND VOLUMETRIC SHRINKAGE

(Ship. No.) (Stick No. (Lab. No.)

(Piece No.) (Mark) (Project No.)

Species .... Grade ....

Nominal size of specimen .... Sap ....% Rings .... S.W. ....%

	DATE	WEIGHT, GRAMS	MOISTURE, PER CENT	VOLUME DETERMINATION 1	2	Vol. C.C.	SPECIFIC GRAVITY	Weight Lbs. Per Cu. Ft.	Shrinkage, % Volume*
GREEN									
AIR DRY									
KILN DRY									
OVEN DRY									

1 Wt. of Vessel, Water and Displacement of Specimen.
2 Weight of Vessel and Water.

*Based on Original Volume.

Remarks ....

....

.... (Over)

Sample Specific Gravity Card

Results of Tests on Sitka Spruce & Ponderosa Pine

Test Species and Number	Width of Piece (inches)	Moisture Content in Percent (oven-dry)	Specific Gravity on 12.5 % Moisture content basis	Average Wattmeter Reading (Watts)	Jointer Bearing Losses (Watts)	Motor Losses from Efficiency Curve (Watts)	Total Losses (Watts)	Watts used in Cutting Wood	Depth of Cut in (Inches)
Sitka Spruce (Picea sitchensis) 1-1	2.02	13.06	.419	147.6	13.0	95.35	108.35	39.25	.011
Sitka spruce (Picea sitchensis) 1-2	2.02	13.06	.419	148.2	15.0	95.5	110.5	37.7	.011
Sitka spruce (Picea sitchensis) 1-3	2.01	12.6	.419	165.0	12.0	99.0	111.0	54.0	.013
Ponderosa Pine (P. ponderosa) 70-1	2.01	12.5	.48	168.0	16.0	99.5	115.5	52.5	.012
Ponderosa pine (P. ponderosa) 70-3	2.01	(Control)		172.0	18.4	99.6	118.0	54.0	.012
Ponderosa pine (P. ponderosa) 70-6	2.01	12.4	.48	170.0	21.0	99.4	120.4	49.6	.012

Table 3

Results

Due to the large amount of time consumed in setting up the equipment for testing the machinability of wood, it was possible to run only enough tests to indicate whether or not the equipment operated satisfactorily. The results on the two species that had been run for this purpose are shown on Table 3, page 30. The average wattmeter reading was arrived at by taking the average of all the wattmeter readings. The jointer bearing losses were determined by subtracting from the motor and bearing losses, as shown on the data card, page 28, the power required to drive the motor when it is not connected to the jointer. This power required is constant throughout the test at a value of 75 watts. The motor losses at the varying loads is determined by the use of the motor efficiency curve, Figure 5, page 9. The input power, as shown by the wattmeter, is multiplied by the efficiency of the motor at that point, giving the amount of power lost in driving the motor. The remainder of the power was actually consumed in removing the cut from the test specimen and overcoming frictional losses. The difference between the total power losses and the average wattmeter reading gives the watts of power actually used in cutting the wood.

Conclusions

All indications from the very few tests that were run show that the apparatus as it is set up is an excellent method of determining the machinability of wood. The wattmeter shows different values with even a very small change in the proportion of springwood to summerwood. For this reason it was decided that radial surfaces should be used in subsequent tests because more uniform results are obtained. Due to the fact that the jointer had been used for many years for ordinary shop work and had been misused on many occasions, it would not stay in adjustment. If any further tests are to be run with this equipment, it is the writer's opinion that the work and the time would be wasted unless a new precision jointer could replace the one used in this preliminary work. Another improvement that the writer can suggest is the use of a recording wattmeter in place of the indicating type used in this work. The recording meter would give the continuous reading of power consumed from one end of the test piece to the other, and, as a result, a more exact average reading could be arrived at.

In order to use the power consumed as a measure of machinability, it is imperative that all other conditions of the test be kept constant. Due to the idiosyncrasies of the jointer used, it was impossible to keep the depth of cut constant. As a result, the species tested can not be compared purely on the basis of power consumed in cutting them, inasmuch as more wood was removed from one than from the other. With a new jointer, the depth of cut could be kept constant and the various species could be compared on the power consumed basis.

In this preliminary work only the surface of the machinability of wood has been touched. It brought to light innumerable problems that remain to be investigated.

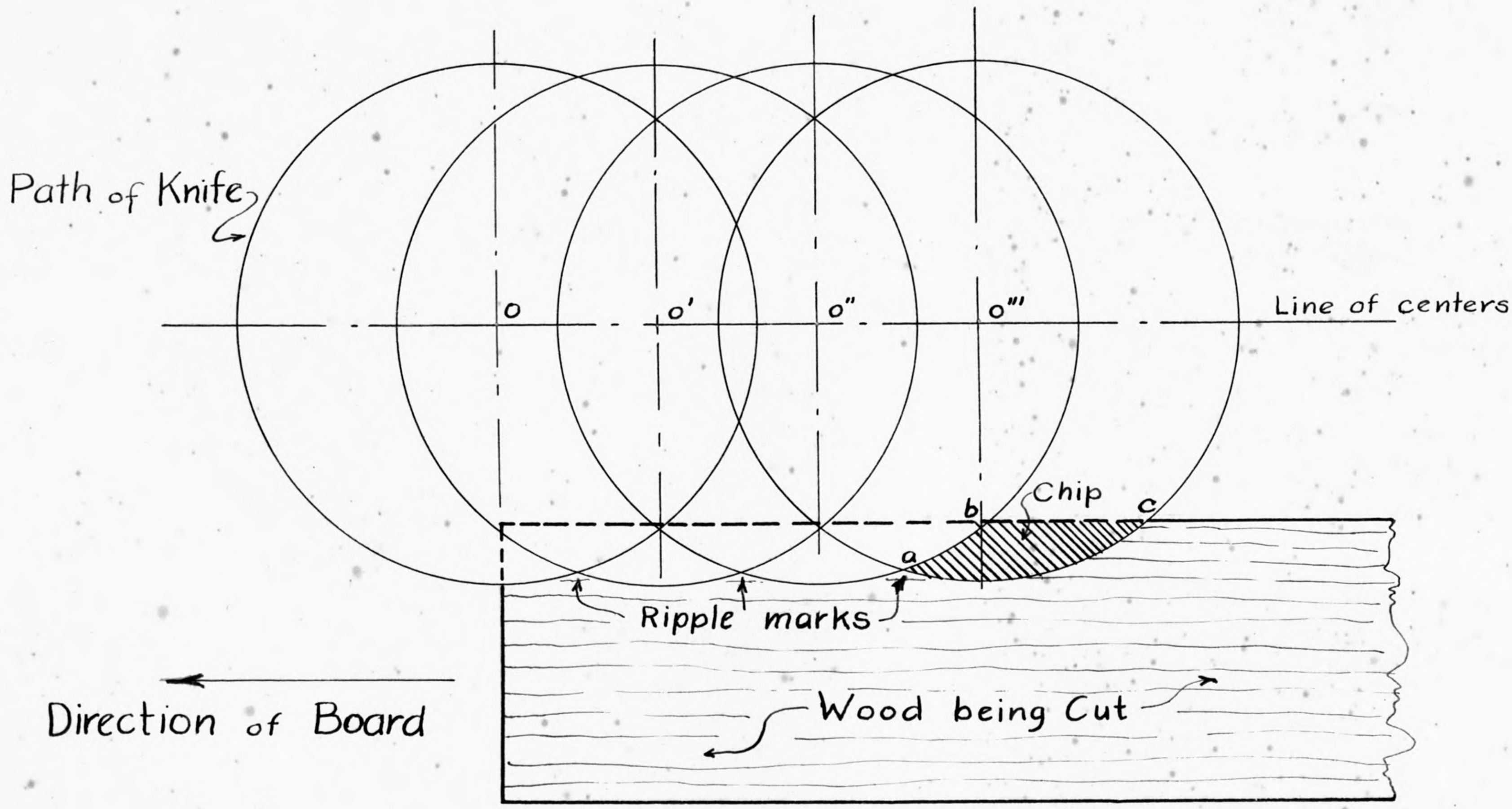


DIAGRAM SHOWING RIPPLE MARKS & SHAPE of CHIPS

Figure 11

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