INVESTIGATION OF THE POWER REQUIREMENTS OF MARBLE FINISHING MILLS AND MACHINE SHOPS IN TENN.

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I

Introduction.

The results of this investigation should be of interest to anyone engaged in the two industries under discussion. The discourse is intended to show conditions as they actually exist in the plants now in operation. The plants visited should be typical of their kind in any of their respective cities.

The power requirements are reduced to several units. These units form a basis for the comparison of the plants of a similar kind throughout the state. This report is intended to show why that some plants require more power in proportion to the amount of work done than others doing the same kind of work. The writer also intends to show how changes could be made to reduce this power consumption.

The primary object of this work is an investigation of the operating conditions and the power requirements of the marble finishing mills and the machine shops of the state of Tennessee. It is not the object of this report to introduce any new scheme of factory management but simply to offer suggestions as to how the operating conditions in the several plants visited could be improved. The different units to which the power consumption was reduced will be explained later in the report.

The writer, not being a man of very wide experience, is not trying to dictate to any of his superiors but is merely offering a few suggestions which to his mind should be improvements over the conditions now prevailing. Due acknowledgment is made of the ideas suggested by the similar works of Mr. O. R. Eichenberger and of Mr. W. B. Lincoln. These two works have been of great help in making this investigation and also in writing this report.

II

General Survey of the Field.

It has scarcely been twenty years since the manufacturing industries began to develop the various systems of scientific management. During this period, however, many great advancements have been made. The exponents of the various systems of management realized from the beginning that units were needed by means of which the different plants of the same industry might be compared as to efficiency. Most of these units up to this time have been based on costs. Cost may be a very important factor in manufacturing, but this does not necessarily mean that it should enter into the comparative units.

It was with this idea in mind that Mr. Lincoln made a survey - similar to this - of the knitting and furniture mills of Tennessee.

It seems that operators have just begun to realize that unless they improve their operating conditions they will sooner or later face bankruptcy due to the constantly increasing cost of coal. The recent general business depression helped to bring them to this viewpoint. As time goes on there will be greater and greater need for improvement and investigations of this character will furnish valuable aid in pointing out weaknesses in existing plants and in determining what can be accomplished in a really good plant. In most of the manufacturing establishments in operation now there is plenty of room for improvements.

III

Purpose of the Investigation.

The purposes of this investigation were:

1. To study the operating conditions in the marble finishing mills and the machine shops of the State of Tennessee.

2. To determine whether or not the power consumption might be reduced to some unit which could be used for comparisons between plants.

3. To determine the effect of variations in operating conditions on such a unit.

4. To determine the most satisfactory unit for making comparisons.

The operating conditions in the marble mills of Tennessee are, on the whole, very good. Since a routing system here is of very great importance due to the weight of the marble slabs, good men were usually employed to designt he plants. In consequence of this all of the plants were, usually, very carefully designed.

The investigation also brought out the fact that the operations in the machine shops varied from the very worst to the very best. It was found that the operating conditions were always worse in the poorly planned plants. There is a psychological effect which the surroundings have on workers which is clearly reflected in the amount of work turned out per man. The best arranged plants seemed in every case to have the best lot of workmen. In the well arranged plants the workmen seemed to go about their work with more willingness than in the poorly arranged ones.

IV

General Theory.

No technical knowledge is necessary for a complete understanding of the methods used in this investigation. The total power consumption was secured and reduced to the following units:

1. The horse power per direct laborer. By direct laborer is meant any man that is engaged directly in the making of the product. This includes machine operators and skilled hand labor.
2. The horse power per employee. This number includes everybody employed in the plant.
3. The horse power per machine operator.
4. The horse power per machine in use.
5. The horse power per machine installed.

Of course it would be possible to measure the input to each individual machine either by measuring the input to the motor, if driven by an individual motor, or by means of a transmission dynamometer if driven from a line-shaft. This method would be practically impossible in a plant because it would interfere with the operation and the owners would not permit such interference. This method would also require a great amount of time. The information derived from such an investigation would be of great value to an engineer in designing a plant, but it would usually be supplied by the manufacturer of the machines.

In the case of the marble mills a division was made between the power consumption of the saws and the finishing mill. Also in several instances the power required to drive the line-shaft was measured. No other divisions were made.

In arriving at conclusions, the five units were compared and the one showing the greatest correlation accepted.

V

Description of Method and Apparatus Used.

The power consumption in the steam driven plants required two instruments, viz., an indicator and a speed counter. A Trill Outside Spring Indicator with a "Faultless" reducing wheel was used in conjunction with a Van Sicklen Elgin Tachometer. Indicator cards were taken over periods of ten hours in most of the plants. In several instances cards were taken, after all the machinery had been shut off, to determine the power necessary to drive the line-shaft. This figure in some plants amounted to quite a large amount.

The only apparatus used in determining the power consumption in mills driven by electrical power was the meters installed by the power company. The readings usually were taken to cover a period of ten hours. Since in all cases except one the sawmills ran all night, it was possible to get the power taken by them by taking a reading in the afternoon after the shutting down of the finishing mill and another in the morning before the finishing mill started up again.

A close examination of the operating conditions was made in each plant. A complete list of machinery was taken in each plant and a note made as to whether each machine was or was not in operation. All of this data is given in tables one and four of the appendix. The data was also reduced to the units explained in Chap. IV. These results are shown in tables two and five of the appendix.

The above method of attacking the problem was used because it seemed to be the only practical and at the same time inexpensive method which could be used. A more detailed investigation would also have taken more time.

There were no great sources of error in this method. There was very little danger of error in securing the power consumption. The only other possible error would have been in securing a list of the machines or of the number of workmen. Such errors, while possible, are not apt to occur. No allowance was made for the size of the piston rod in securing the indicated horse power. This , however, could hardly be called an error since a correction is made for this only in very accurate calculations. Another source of error in the measurements of the power in the steam driven plants was in the fact that the indicator cord did not always travel in a line parallel to the guides. In other cases the cord would always strike some part of the engine when the piston got nearly to the head end of the cylinder. These errors are, however, just the kind that would be expected in actual engineering work.

About the only difficulty which was encountered in the investigation was in persuading the managers that we only wanted a little information and that no mischief to them was intended. Most of them, however, when they found out that no harm was meant, helped us in every way that they could and seemed really glad to do so.

VI.

OBSERVATIONS.

1. Tennessee Producers Marble Co.

The Tennessee Producers Marble Company is located in Knoxville, Tennessee. The plant now in use was erected in 1915. Before 1915, the company operated in a two-story wooden structure. This building was destroyed by fire.

The new buildings are of standard factory design. The trusses are about twenty feet apart. The sidewalls are made of bricks for about five feet at the base, and the rest of the wall is made of steel sash windows. This applies particularly to the finishing mill. The saw mill has higher walls and less window space. This large amount of window space almost eliminates artificial lighting except during the short winter days in the finishing mill and at night in the saw mill. The finishing mill has a very good artificial lighting system. Large flood lights are suspended from the roof in the central aisle of the building and smaller lights are used for the individual machines. The saw mill lamps are suspended about ten feet from the roof. The natural lighting is excellent. The artificial lighting could be improved.

The machinery is well arranged for safety. The motors are high. The belts are well above the workers' heads and any dangerous drives are encased. Chemical extinguishers are used as a protection against fire. However, with the types of buildings used there is very little danger from fire.

Plate I shows that the factory has been well designed to take care of any expansion in the future. There is plenty of room to add more factory space to either the finishing shop or the sawmill. One 90' extension has already been added to the original sawmill building. In addition to this an examination of plate I shows that the plant is well equipped for transportation. The raw material is brought in on either the Southern or L. & N. railways. It is unloaded and moved by means of two overhead electric cranes. These cranes carry the blocks of marble to the saw trucks and then after it is sawed move it to the finishing mill. Narrow gauge railway is used to carry the material from under the crane-way into the shop. The finishing mill is equipped with three hand cranes which move on a track which runs the full length of the shop. The material in process moves in direct lines from one end of the shop to the other. In the farther end of the shop is the crating department. The storage spaces are marked on plate I.

At the time of inspection practically all of the machinery was in operation. There were no machines in the plant which were not in good running condition, nor were there any which were never used. The plant is completely motorized. A list of the motors and their sizes will be found in Chapter VII. All the power used is purchased from the Knoxville Power and Light Co. As explained in a previous chapter, the power required was measured by taking meter readings over a period of ten hours. The power data is also shown in Chapter VII.

Group drives are used exclusively in this plant. The rub beds are driven in groups of two and are connected by means of a cone clutch so that either of them may be used separately. The polishing machines are driven in groups of three machines each. Some of the larger machines have individual drives. This applies to the coping machine and other machines of a similar kind which require a very large amount of power. The saw mill is divided into four groups. Two groups have four saws each and two have six.

It was not possible without interfering with the operation of the plant to get the power required to drive the line-shafting. The power used in driving the shafting must be small, however, because all of the bearings are in excellent condition and are well oiled. There is in the plant about 450 feet of line-shafting. The maximum length of any section is about 60 feet. With short sections this way there is less likelihood of the shaft bearings being out of alignment than with long lengths of shafting.

The workmen found in this plant are about the average found in this industry. They are secured by direct application at the plant. The only skilled laborers employed are the men who do the carving. There has been very little trouble with labor and very little is to be expected.

All of the buildings are heated by steam. The steam is furnished by a 125 H. P. Dallas Boiler operating under five pounds pressure. The boiler is located between the pump house and saw mill on the banks of Second Creek. The setting is very low, and as a result the ash pit is usually full of water almost up to the grate bars and very poor service is secured. Plans are now under way for the improvement of the heating system.

Water is of vital importance in a marble mill. As will be seen in plate I, the water for this plant is pumped from Second Creek. Two centrifugal pumps are installed to do this pumping. Either pump has a capacity of 500 gallons per minute. Either of the pumps may be driven by the same motor. The waste water is discharged into the same creek.

2. The Knoxville Marble Co.

The Knoxville Marble Company is located on the Island Home Pike. The company is engaged in the production of all classes of finished marble goods. The plant has been in operation for several years.

The main building of this plant is patterned, in shape, after the modern steel factory structure. However, it is made of wood. The sidewalls and trusses are of wood. For this reason the building is far from fire-proof.

The artificial light here is supplied by a D. C. Generator, which also runs the motor for the coal conveyor . No artificial light is necessary in summer for the day shift. The lights are all attached to drop cords suspended from the ceiling. No shades are used. The artificial lighting could be improved by the use of flood lights with individual lights for the machines.

The weakest point in the interdepartmental transportation lies at the door between the mill and shop. The only way by which material can be transferred from the derrick to the cranes is by hand. A great saving of labor could be effected by putting a short spur of narrow gauge railway through this door.

The routing system is direct throughout the plant. The blocks of marble are unloaded and placed on the saw carriages by means of derricks. The material is taken from the sawmill into the finishing mill by hand. The material is moved within the finishing mill itself by means of overhead cranes. These are shown in Plate II. This sketch also shows the loading platform.

The dangerous features usually encountered in factories are taken care of automatically in marble mills. The machines are made in such a way that there is little danger from the drives. The drives are usually higher than a man's head. Those drives that are dangerous are taken care of by screen shields. The aisles are kept open. Scraps of material are not allowed to collect on the floor, most of which is swept every day.

The buildings, with the exception of the boiler room which is made of brick, are all made of wood and are, as stated before, far from fire-proof and are a very poor risk for an insurance company. The danger of fire is also increased by the workmen's allowing greasy clothes and waste to collect and pile up in the corners. The fire protection is very good. Chemical extinguishers are used, and also there is on a neighboring hill a storage tank which gives about 100 feet of head for fire fighting purposes. Special pipes and hose are provided for this system.

The main building is not very well arranged for expansion. A reference to Plate II will show that the finishing mill could probably be increased in size, but it would be very difficult for the sawmill to be expanded and still use the same system of transmitting power. The power used by the sawmill and finishing mill is all transmitted by one long line shaft. The driving pulley is at one end of this shaft.

At the time of this inspection the plant was operating about 80% of its machinery. The only machines seldom, if ever, used are the hoisting engine and derrick across the railway from the main plant. This derrick when used can only be used to handle material about the yard.

The power for this plant is furnished by an 18" x 36" Hardie-Tynes Engine. This engine was manufactured in Birmingham, Ala. The engine is rated at 150 H. P. by its owners. At the time of the visit to this plant the engine was carrying a load of 198 H. P. and a 60 K. W. generator which was ordinarily used was not connected. The engine really is not so much overloaded but is underrated by the operators. An engine of this size running at the rate of 93 R. P. M. ought to develop 250 H. P. The fact that the engine gave such good cards and seemed to be in such good shape is proof enough that it is not greatly overloaded. The engineer is above the average in intelligence and takes a great deal of pride in his work.

The power plant also contains a direct connected Sullivan Air Compressor. No arrangements could be made for indicating this compressor and in the calculations found in this report the power consumption was estimated by means of information furnished by the manufacturers. In addition to the above mentioned equipment there were two hoisting engines one of which was not used for months at a time, and the other not more than five hours per day. The average power consumption of the two was estimated. These two engines took steam from the boilers, and due to the fact that they were quite a distance away from the boilers and were connected to them by uninsulated pipes, were not very economical in the amount of steam that they took per I. H. P. hour.

The exhaust steam from the main engine was passed through a feed water heater and then discharged into the air. The exhaust steam from the hoisting engines and the air compressor was discharged directly into the air. The feed water temperature is supposed to be 210° F. but was nearer 200° F.

The building is heated by means of live steam with special pressure valves. By an addition to their radiation surface this company could use exhaust steam for heating purposes and thus make a considerable saving in their fuel bill. Another means of effecting a considerable saving would be to insulate their steam pipes. The pipes were perfectly bare. It is a well known fact that the losses from bare steam pipes are very great.

All of the steam for the plant is furnished by two Walsh and Weidner Boilers of the H. R. T. type. The capacity of each of them is 125 H. P. operating under a pressure of 125 pounds. The boilers are hand fired. They have natural draft produced by two steel stacks. When examined there were several small cracks in the settings of these boilers. Gauges were located in the engine room so that the engineer was able to supervise the work of the fireman very closely.

There was in this plant about 300 feet of line-shafting. The indicator card taken with only the line-shaft running showed that the engine and line-shaft together required about 56 H. P. Allowing, probably, half of this for the engine, it would seem that the shaft was in good running order. Observations made later verified this conclusion. All the bearings were well oiled and were in perfect alignment.

The workmen are secured by direct application at the plant. These men require very little special training. The majority of them have always been residents of Knoxville.

The plant has three sources of water supply - a well, the city mains, and the Tennessee River. The water used in the finishing mill and sawmill is usually taken from the river. The boilers are fed by a Riely No. 9 steam pump. The mills are supplied by a No. 10 Riely with a No. 9 for reserve. All of the pumps are operated from the main boilers. The estimated power consumption of the pumps supplying the mill is given with the rest of the power data in Chapter VII.

3. Meade Marble Co.

The Meade Marble Company is located on the Island Home pike and is about two miles out of Knoxville. The layout of the plant is shown in Plate III. The office building is a frame structure. The two main buildings are of standard factory design with corrugated steel side walls and metal sash windows. The boiler room is of brick.

The artificial lighting of the plant is good. It is furnished by electric lamps suspended from the ceiling and by individual lights for the separate machines. The natural lighting could be improved. This would be an easy matter for all that would be necessary would be to add a few more windows. There is ample space for them in the sidewalls of the buildings.

The plant was planned with the idea of expansion in mind. The saw mill or the finishing mill could either be expanded without difficulty.

All loading and unloading of material and all handling of material about the yard was done by means of derricks driven by hoisting engines. The material is moved in the finishing mill by means of hand operated derricks. Electric cranes are much less expensive for handling material than these derricks. This company is planning the installation of electric cranes in the near future. The routing system is direct throughout the plant. This is almost an unfailing characteristic of marble mills that the routing system is direct. If it were not direct, the extra or useless movement of materials would soon decrease the profits to a very small figure.

As a protection against fire chemical fire extinguishers are used. Most of the machines have individual drives and in this manner eliminate the problem of dangerous drives. All the necessary safety devices are to be found in this plant.

The power plant contained the following machinery: An 18" x 36" Corliss valve engine commonly supplies all the power. There is also a Buckeye Balanced Valve Engine installed in the plant to be used in case of emergency. Ordinarily the connecting rod is disconnected and the flywheels used as a counter shaft between the Corliss engine and an alternating current generator. This generator is an Allis-Chalmers, three-phase, 240 volt machine. It furnishes the power for the shop. A 125 volt direct current generator is also installed for lighting purposes. There is another small engine, 6" x 8", of the slide valve type which can be used to drive this generator in case of an emergency.

The saws are driven by a line shaft which is belt driven from the engine. All of the other machinery, except the derrick which is operated by the hoisting engine, is driven by electricity furnished by the Allis-Chalmers generator. The power consumption of the saws and also of the line shafting were secured at this plant.

There was no way of indicating the hoisting engine. The power consumption had to be estimated.

There were two boilers in this plant. They were manufactured by the Lombard Iron Works, of Augusta, Ga. They were of the H. R. T. type. They were hand fired and used only natural draft. The settings were examined and found to be in good condition. The exhaust from the engine was passed through a feed water heater and then into the air.

A steam driven air compressor was installed, but had not been used for several months.

Water was secured for the mill and boilers from a near-by creek. For some unknown reason the water was first pumped into a muddy pond. This mud was giving some trouble from foaming. Water of this kind when taken into a boiler continuously for a very long period forms a hard scale which is liable to cause a great deal of trouble.

The buildings were all heated by means of stoves.

This plant is the smallest of the marble mills which were visited in connection with this investigation. The plant seemed to be working to capacity as at the time of the writer's visit to it 80% of the installed machinery was in operation. There were two or three very wasteful machines installed in the power plant, but they were only used in case of an emergency.

There seemed to be quite a lot of work ahead from the appearance of the storage space for raw material.

4. The Appalachian Marble Co.

The Appalachian Marble Company is one of the oldest of its kind in the city of Knoxville and has probably the largest plant in that city. It is one of the Lonsdale group of mills. The company has two mills, one of which is very old and is somewhat jumbled in appearance, and the other is a new mill and is designed along the latest scientific lines. At the time of the inspection the new mill was not equipped to perform all the operations that were necessary in the manufacture of marble wares. The operations which it could not do were still performed solely by the old mill. For this reason both mills are treated as one in this report.

The arrangement of both plants is shown in Plate IV. The new plant was constructed within the last year, and is modern in every detail. The old plant consists of a bunch of old frame structures connected in every conceivable way.

In the new plant both the natural and artificial lighting are excellent. In the old plant the artificial light is very good, but the natural light is poor.

The new plant is well arranged for expansion. It could expand in three directions with a very small cost. The old plant could expand, but it would be very expensive and the extra space probably would not be very effective in bringing up the production in proportion to the extra space occupied. It seems to be the plan of the company to abandon this plant in a very few years.

In both plants electric cranes are used for loading and unloading purposes. These cranes place the marble blocks on the saw carriages. The interdepartmental transportation is taken care of in a rather peculiar way. The material is moved by means of a two-wheeled cart pulled by a horse. This method has given very good satisfaction. In the old plant the routing is not exactly direct, but in the new plant it is. Taking into consideration the age and shape of the old plant, it seems that the routing system has been kept in about as good a shape as it is possible for it to have been.

In the old plant there are a great many belts. All the dangerous drives are encased. The aisles are kept fairly free from obstructions. In the new plant group and individual drives are used so that there are not so many belts. For this and several other reasons very few safety devices are necessary.

No precaution against fire had been taken at the time of this investigation, but they were to be installed later. There is really very little danger of fire in this building. The old building, however, is in more danger of fire, and more precautions have been taken. An automatic sprinkling system is installed, and in some parts chemical fire extinguishers are also used.

This plant is completely motorized. The power is secured from the Knoxville Power and Light Company. A list of the motors and the other power data will be found in chapter VII of this report.

The heat for the buildings is furnished by stoves.

The water used in the sawing and finishing work was pumped from the creek, which flows by the mill, by means of a centrifugal pump driven by a motor. Part of the water used in the old plant came from the city mains. The company was prohibited from discharging its water into the creek because of the location of the Tennessee Producers Marble Company just a few hundred yards below on the same creek.

Despite the fact that this company had one of the most poorly constructed plants of the group visited, it was doing the largest business of any of the group. At the time of the visit over 90% of the installed machinery was in operation.

5. The Gray-Knox Marble Co.

The Gray-Knox Marble Company is located near the crossing of the Louisville and Nashville and the Southern Railways. This plant has been in operation for several years. This can be seen by reference to Plate V. Many additions have been made to the plant, in a very disorderly way too, it seems, by reference to the layout, in the last few years. Considering the fact that the plant is as old as it is, the conditions are very good. Most of the buildings are in a good state of repairs while others need repairs very badly.

The routing system has been very well taken care of in the expansion of the plant. Very little back tracking is done with the goods in the process of manufacture. Both the Louisville and Nashville and the Southern Railways have spur tracks from which material may be unloaded by means of the electric cranes. The cranes carry the raw material to the saws and then to the finishing mill. After the material is in the finishing mill it is moved about by hand cranes. Part of the moving in the shops is also done by hand. This plant is really a combination of two plants which were formerly operated by two different companies. This accounts for some of the peculiar arrangements. The two parallel craneways side by side are an example of these peculiar arrangements.

The natural light could not be said to be wholly poor nor wholly bad since it is good in some of the buildings and bad in others. The arrangement of some of the buildings is such as to make good natural lighting an impossibility. The artificial light is fair. It is furnished in the usual way by means of lamps suspended from the ceiling. Only a few of the machines have individual lights.

The necessary safety devices are found in this plant. The protection against fire is very good. It would be difficult to expand this plant. It does not, however, need to expand as it has in operation only a very small per cent of its installed machinery. By simply putting this machinery in operation the capacity of the plant would be nearly doubled.

Electric power is used almost completely in this plant. It is secured from two sources: the Knoxville Power and Light Company, and the generating plant belonging to the company. The power for the latter plant is furnished by a 16" x 30" Corliss engine manufactured by the Filer and Stowell Company, of Milwaukee. This engine is connected by belt to a Westinghouse 100 Kv. a, 240 volt, three-phase alternator which operates at 900 R. P. M.

A Northern Electric 25 K. W. 125 volt, direct current generator is also driven by the engine to supply power for the cranes. Several of the saws are belt connected to the engine. This engine was in fair condition. An examination of the cards showed that the valves were slightly out of adjustment. The valves were adjusted while the investigation was being made. At the time of the visit to this plant the maximum load on the engine was 144 H. P.

The steam was furnished by two Walsh and Weidner 250 H. P. Boilers of the H. R. T. type. Only one of the boilers was in use. Both of them were equipped with standard steel settings.

Each of the boilers had a steel stack. The setting was in good condition. The boilers were hand fired, and only natural draft was used. The boiler feed was supplied by an independent pump. The water used by the mills was secured from a nearby creek. The temperature of the feed water was about 195° F. An injector was kept connected up for use in case of an emergency.

This was the only plant visited where the exhaust steam was used for any other purpose than for heating feed water. The steam was passed from the feed water heater into the steam heating system. Heat was supplied for all the plant. The water for the mills was pumped from the creek by a motor-driven centrifugal pump. The boiler also supplies steam to a small air compressor. This compressor is seldom used.

6. The Candora Marble Co.

The Candora Marble Company is a plant of the Vestal Group. The plant has been in operation for several years, yet today it is one of the most up-to-date marble mills in Knoxville.

The main building is of standard factory design. It has steel trusses and brick side walls. The walls are stuccoed. This gives the plant a very pleasing appearance. The offices are made of marble and are in a separate building. There are two or three other small buildings all of which are well constructed.

The natural lighting is very good in that part of the mill where the finishing work is done. The part of the mill where the saws are located is not so light because the cover over the loading platform keeps out the light. The artificial light is only fair. The general illumination is secured in the usual way. There are, however, very few individual lights. The individual lights are not, however, needed so very bad.

This plant has an excellent system of transportation. The routing is direct throughout the plant. The marble is brought to the front end of the building on a standard gauge spur track. It is unloaded from the cars by means of an electric crane which travels then the full length of the building to the back end and for quite a distance further. The raw material is stored in the space covered by this crane. The finished material is taken to the loading platform on a narrow gauge railway.

All the necessary precautions are taken for safety. The motors are above the workers' heads. The switches and dangerous drives are enclosed. The aisles are kept open. There is no precaution taken against fire, but it is almost unnecessary.

The plant is well arranged to take care of expansion. The main building could be extended in either direction with very little trouble.

Most of the machines were in use at the time of the visit to this plant. All the machines were in running condition. Several new machines were being installed. There were no expensive idle machines in the plant.

The plant is run entirely by means of motors. The power is secured from the Knoxville Power and Light Company. A list of motors is given with the power data in Chapter VII. Both the group and individual drive systems were used. The saws were arranged in groups of four. The sub beds were in groups of two.

The line-shafting was in excellent condition. The boxes were well lubricated. Due to the group drive system, the shafting was in short lengths. The power used by the shafting could not be obtained in this plant.

The workmen at this plant are secured by direct application. The turnover is not large. The men employed in this plant seemed to be above the average. Very little soldiering was noticed here.

The water for this plant is taken from a nearby pond which is fed by springs. The water is drawn from the pond by means of a motor-driven centrifugal pump. There are two pumps installed. Each of them is of sufficient capacity to furnish the plant at full capacity. The capacity was not secured for this report.

The buildings are steam heated. The steam is furnished by a 50 H. P. boiler of the H. R. T. type. It operates under a pressure of 30 pounds. This boiler is not in very good condition. Some trouble is experienced in supplying enough heat for the buildings in cold weather.

The derrick used in storing the raw material is operated by an American hoisting engine with a vertical fire-tube boiler. The coal consumption for this boiler averages about one ton per month.

This plant seemed to be operating at full capacity when the visit was made.

7. The Andres Stone and Marble Co.

The Andres Stone and Marble Company owns a plant located in Vestal, a suburb of Knoxville, Tennessee.

This company is engaged in the finishing of marble. The plant differs from most of the others in Knoxville in the fact that only the worst grades of marble are sent to it. The best grades are sent to another mill, owned by the same company, located in Milwaukee.

The building is of standard factory design. It has corrugated steel side walls.

The natural light in the plant is fair. The sidewalls are made up largely of steel sash windows. The artificial lighting is not so good. The question of artificial illumination does not need the same consideration here as it does in the other plants due to the fact that this plant operates only in daytime.

The routing system is very good. The marble is unloaded from the cars by means of an overhead crane and stored as shown in the layout which is shown in Plate VII. The same crane is used to load and unload the saw carriages and to carry the sawed marble to the finishing machines. The arrangement of the machines is rather poor and necessitates the use of short spurs of narrow gauge track and also quite a good deal of moving by hand.

The plant is entirely motor driven. Some of the machines are driven by individual motors, and others have group drives. Both alternating and direct currents are used.

The safety precautions are few. The floor is littered with supplies and waste material. Very little is done to keep things safe and neat. The only safety devices are those required by law. Fire precautions were hardly necessary and none were used.

Ample room is provided for expansion. There is enough room in the plant, as it stands, to place machinery to increase the output by 25%.

About half of the machinery was running at the time of the inspection.

The line-shafts were in short lengths due to the group drives. The boxes were all well lubricated.

The workmen in this plant seemed to be below the average. They seemed to take great pleasure in loafing on the job. The foreman did not seem to object seriously to this practice.

As was stated above, both direct and alternating currents are used. The alternating current is secured from the Knoxville Power and Light Company. The direct current is generated by the power plant which is located in a brick building near the mill and belongs to the company. This power is generated by a Sprague 150 K. W., 240 volt generator. The greater part of the load on this unit is the crane load. This load varies greatly in just a few seconds of time. This fluctuating load is very hard on the engine and generator. The engineer of this plant is above the average and kept the unit in fairly good operating condition.

Steam was supplied by means of a 135 H. P. Haynes boiler. This boiler was of the H. R. T. type. It was fired by hand and used natural draft only. A small vertical boiler was also installed. It was used only while the other boiler was being cleaned. The feed water heater was made by the Milwaukee Reliance Boiler Works. The feed water temperature was about 195° F. The exhaust steam was discharged into the air after passing through the heater. This was the only plant visited in the investigation in which a complete record was kept of the power consumption and cost. All of the coal was weighed as it was conveyed to the boiler. Daily and weekly records were kept of all supplies used in generating the power and the amount of power generated.

8. The Layne and Bowler Company.

The manufacturing plant of this company is located on Chelsea Avenue in North Memphis. The company has three manufacturing plants the other two of which are in Houston, Texas, and Los Angeles, California, respectively. The company is engaged in the manufacture of turbine pumps and well screens for railroad, mining, and irrigation service.

At the time that the writer visited the Memphis plant the principal output of the plant seemed to be well screens and turbine pump cases. Supposedly the impellers for the pumps were being made in one of the other factories.

The buildings are principally of corrugated iron and sheet steel with steel frames. They are all in first class condition at the present time. This plant is a very good example of one that has been well laid out along scientific lines. The buildings which make up the factory proper are all only one story high. The general layout of the plant is given in plate VIII.This plant was one of the best visited by the writer in making this investigation.

At the time of the writer's visit to this plant there was a very low percentage of the machinery in operation. This was due to a lull in business. The machines were all in good repair and could have been put in operation on very short notice.

The workmen employed by this company seemed to be very much above the average in intelligence. They all seemed very well contented and were turning out a high grade of work.

The machine shop was the only part of the plant that was in full operation when the writer visited the plant. This shop, especially, was laid out on a scientific plan. It contained the usual machines found in a machine shop and in addition some machines of the production type which were especially designed for the class of work which the company does.

In addition to the work in their factories the company maintains in the field a force for the installation of the equipment produced. In fact the superintendent remarked that the actual production of the equipment in their shops was a very small portion of their work. The company seems to do business very much in the same way that the water wheel companies do, i. e. they build the pump to suit the conditions under which it is to operate. Before they agree to make an installation one of their engineers is sent to make a survey of the conditions and factors affecting its operation. This company claims the distinction of being the largest in the world engaged in this specific line of work.

The plant is an example of a completely motor driven one. The power is obtained from the local public service company. The motors were of the three-phase induction type and like most of motors in the other plants visited were manufactured mainly by the Westinghouse Electric Company and the General Electric Company. All of the power was measured by one meter. In addition to this meter, however, there was another in the testing plant which measured the power consumption for testing purposes. It might be mentioned here also that every pump, when it is completed, must be tested in this plant and must measure up to specifications. As usual, with a plant using induction motors for power, the ratio of the power used to the capacity of the motors was very low.

Individual drive was furnished for a great many of the machines and group drive for the rest of them. Of course, no attempt was made to get the power consumption of the different shops since this would have been practically impossible.

The lighting of the shops was as nearly perfect as could have been obtained. The side walls were largely made up of steel sash windows. These, of course, admitted a great deal of light. In addition, there was also a row of windows up near the top of the roof on the north slope. The buildings were heated by stoves in the winter. The factory was splendidly equipped as viewed from a sanitary aspect. Toilets and washrooms were provided. Protection from fire was had by an automatic sprinkling system. The safety devices were all good. All belts were covered and every precaution was taken to prevent the men's being injured in any way. The interdepartmental transportation was taken care of by means of narrow gauge railways. These tracks are shown on the sketch of the plant. The plant had good shipping facilities, being on the belt line. An electric crane was used for unloading purposes. This crane was required to handle a great deal of pipe.

9. The Chickasaw Iron Works.

The plant of the Chickasaw Iron Works is located in Memphis, Tennessee, at the corner of Winchester Avenue and Second Street. This puts the plant just a few blocks north of the main business part of town. The plant is engaged in general machine shop and foundry work.

The building which houses the plant is made of brick and is very old. The plant has the appearance of one which has been expanded with very little care simply by putting in new machines just wherever there was room for them. About the only good point that could be mentioned is the fact that the plant seemed to be working right up to capacity even in the supposedly dull times in which the writer visited it. Everything was crowded. The tool room and engine room were all in one. There were very few machines which were not in use. Everything seemed to go right along in spite of the disorderly arrangement of the plant. The writer thinks that it would be much better if the machine shop could all be in one enclosure and the tool room kept separate from the engine room. At the time of the writer's visit the plant was operating eighty-two percent of all machines installed. The plant was operating on a nine hour per day schedule with five hours on Saturday. The workmen employed in this shop were about of average skill and energy. Negroes were used largely to do the simpler manual labor.

All of the power used by the plant is furnished by 12" x 18" Atlas Engine. This engine is of the simple slide valve type well known for their steam using abilities. As shown by the cards from this engine it takes steam practically the full length of the stroke. The engine is governed by throttling and the different heights of cards for different loads is shown in the cards.

Connected to this engine was an air compressor made by the Chicago Pneumatic Tool Company. This compressor is one of the type that compresses until the pressure reaches a certain maximum and then instead of forcing the air into the tank a valve is opened which lets it go from the cylinder into the atmosphere very much the same as the action of the gas engine with the hit-and-miss type of governing. In taking cards from the engine the writer had to be careful that he took both ends while the air compressor was compressing air into the tank or the card would be very much higher on one end than on the other. This was probably the only type of compressor that could have been run belted to the engine as this one was, as the pressure of the air did not have anything to do with the governing of the engine which drove the compressor. The engine was stuck away in a corner which was very poorly illuminated. There was an indicator on the engine and according to the superintendent some cards had been taken lately. The engine was set about as good as it could be, and was giving as good service as could be expected from this type.

The machinery connected to the engine was driven through a very complex system of shafts. It was very difficult to trace out just how some of them were belted to the initial line shaft. It was really a very complex system and the writer did not take much pains to investigate it. The lack of proper illumination would account in some degree for the appearance of some of the machines, but most of it could be attributed to age.

The natural light in this plant was very poor for most of the departments. One factor which helped to make this worse was the great number of belts which were used as noted above. The day on which the writer visited the plant all the artificial lights were burning. This was a dark day, however, but these lights would be needed all the time even on the brightest of days. The power for artificial lighting was obtained from the city.

There are very few safety devices to be found in this plant. All the belts were uncovered. The passage ways, however, were kept open as indeed they almost had to be. There were no chemical fire extinguishers or sprinkling system for fire protection. All the water which the plant used was pumped from a well, but by merely opening a valve the pressure from the city mains could be turned on. As an additional safety precaution against a shortage of water, two storage tanks were kept filled. The pump for the well was operated by steam and was one of the crudest which the author has ever seen. It, like the engine, is also noted for its ability to use large amounts of steam.

The boiler equipment of this plant was one 75 horse power boiler of the H. R. T. type. The setting seemed to be in fairly good shape. There was a sort of pit in which the boiler was set. In front of the boiler there was just room enough for the fireman, who was a negro, to work. The job was rendered particularly difficult by this arrangement as the coal was at a much higher level than the furnace doors. The boiler was manufactured in the plant. The steam pipes were bare. This along with the types of engines used resulted in a very high water rate per indicated horse power hour.

The foundry of this plant was very dark. The storage room for patterns and also the pattern shop was on the second floor. In the foundry proper were two derricks which were used in handling the ladles. The cupola was situated so that it was charged in one room and the outlet for the molten metal was in the foundry itself. This company seemed to have a pretty good reputation for turning out good castings. At the time of the writer's visit they were making all the castings for the other plant visited in Memphis.

From a sanitary aspect the plant was very well fixed. Toilets and wash rooms were provided. This plant appears to be one of the kind in which everything goes off properly even though the equipment isnot of the best. This is probably due to good management.

10. Nashville Machine and Supply Co.

The Nashville Machine and Supply Company is located near the center of the city of Nashville not far from the Cumberland River. The company has a well equipped machine shop and can handle most any kind of general repair work. In addition to this a stock of supplies is kept on hand and sold to small manufacturing plants in and near the city of Nashville.

The company occupies a two story brick building. The lower floor of this building contains a machine shop, forge shop, boiler room, supply room, and offices. The second floor is used for storage, woodworking, electrical repair work, and also for a brass foundry. The building is rather old and is in a poor condition of repair. The building is very closely shut in and for this reason artificial light must be used at practically all times during the day. The machines which operate most of the time are equipped with special lights. There is plenty of room for improvement in the artificial light as well as the natural.

The plant is not on a railroad. All material which is transported to and from the plant must be hauled by trucks. The movement of material within the shop is all by hand.

Very little has been done to make the building attractive or safe. The aisles are filled with supplies of all descriptions. Some of the dangerous drives are encased while others are not. The building is protected from fire by means of an automatic sprinkling system. This was probably done in order to get a lower insurance rate.

There is practically no arrangement whatever for expansion. The only way for the plant to expand would be to buy one of the adjoining buildings. At the time of this investigation the buildings which were being used were very crowded. Of all the installed machinery, seventy-five per cent was in operation.

The machinery is ordinarily driven by means of a steam engine through a line shaft. At the time of the inspection a slide valve engine was installed, but was not belted to the shaft and was not in operation. The engine was a 10" x 12" Chandler and Taylor engine manufactured in Indianapolis, Ind. The steam was furnished by a 75 H. P. boiler of the H. R. T. type. This boiler was hand fired. The entire power generating plant was in a poor condition of repairs and at the time of the visit to this plant was not in operation.

When the steam plant is not in operation the power is furnished by a 40 H. P. three-phase induction motor. The power is secured from the Nashville Railway and Light Co. No comparison of the cost of power under the two systems could be secured.

The workmen employed in this plant seemed very well contented with the existing conditions. Very little soldiering was noticed during the whole of the writer's stay at the plant. They seemed very inquisitive and wanted to know all about what information was desired, and were ready enough to impart any that they knew anything about.

The main line shafts were in good condition and also the counter shafts. The amount of power required to drive the shafting could not be secured.

11. The Englert Machine Works.

The Englert Machine Works are located in Nashville, Tennessee, not far from the Cumberland River. The company does general repair work and manufactures ornamental designs in metal.

The plant is housed in one large building which is only one story in height.

The natural light of this plant is rather poor. There are windows on only one side of the building. In addition to these windows there is a sky light in the roof. Some artificial light is necessary at all times of the day. The side walls are of brick and have no windows. The roof is supported by wood columns. There is a sky light in the roof. The individual lights for the machines were especially good.

This plant, like the one just preceding it, is not on a railroad. All transportation to and from the plant must be by trucks. All handling of material within the shop is done by hand as there are no cranes or similar devices.

There is a tendency, in this plant, for the workmen to leave things where they used them. This causes the shop to have a very bad appearance. A few safety devices were installed, such as screens for belt drives. There was no protection against fire.

This plant like the one just preceding it in this report has practically no arrangement for expansion. The only way in which its floor area could be increased would be to add another story which would be used for storage, or to purchase one of the adjoining buildings. The plant was not running to capacity at the time of this investigation.

This plant is another example of a completely motorized plant. All of the machinery is driven by motors on the group drive system. The power is secured from the Nashville Railway and Light Company.

The line shafting was in good condition. All of the bearings were well aligned and well lubricated.

This was the only machine shop visited in which the oxy-acetylene welding outfit was equipped with an acetylene generator. This generator was a money saver for the company as a large amount of welding was being done.

The workmen here were about the average of intelligence found in machine shops.

12. The Jones Machine and Foundry Co.

The Jones Machine and Foundry Company is located in Chattanooga, Tennessee. This plant is divided into two parts. In one section the general machine work is done, and in the other the grinding and foundry work.

Each part of the plant occupies one single story building. These buildings, although rather old, are in a good state of repair. One of the buildings, as stated above, houses the machine shop. This building also contains the store rooms and offices. The grinding department and foundry are in another building.

This plant is not like the Nashville plants in that it is not crowded on every side by other buildings. The natural light in the plant is very good. There are windows in all of the walls. No artificial light is necessary during the day except in very cloudy weather. All of the light is furnished by lamps suspended with drop cords from the ceiling.

This plant is located near a spur track of the Nashville, Chattanooga, and St. Louis Railway. Raw material can be brought in on this road. However, most of the material for the machine shop is handled by motor trucks. A hand operated derrick is used for loading and unloading heavy work. The machinery is arranged in the plant so that all unnecessary handling of material is avoided.

The shop is kept in good condition. All of the tools and supplies were kept in their proper places. All necessary safety devices were installed. Nearly all of the belt drives were enclosed.

Chemical fire extinguishers were the only precaution which was taken against fire.

The plant could be expanded very easily. The buildings now in use are very crowded.

This plant, like many of the other machine shops, is completely motorized. The group drive system was used almost entirely. The motors were all of the three-phase induction type. The power was secured from the local public service company. A list of the motors will be found with the power data in Chapter VII.

Two line-shafts were used. These shafts seemed to be in good alignment and were running in good shape.

In the grinding department all of the machines had individual drives.

The foundry was a well arranged department. All the moulding was done by hand.

In addition to their general machine work, this company specialized in producing rock drills.

Employees were secured by direct application at the shop. The plant did not give employment to a very large number of men. There was practically no labor turnover. The men employed at this plant were better workers than the average found in machine shops.

The buildings were heated by means of stoves.

13. The Fulton Co.

The Fulton Company is located in Knoxville, Tennessee, near the intersection of the Louisville and Nashville Railway and the Kingston Pike. The company is engaged in the manufacture of many articles, practically all of which were invented by Mr. Fulton who is now at the head of the company. Most of the articles manufactured are used in steam fitting work.

The plant of this company is composed of several large buildings. The layout of this plant is shown in Plate XIII. The buildings are all frame structures with outside walls stuccoed. This gives the entire plant a very clean appearance. The buildings are of various heights, depending on the use to which they are to be put. The tallest building has three stories.

This plant, as mentioned previously, is on the Louisville and Nashville Railway. Most of the finished products are shipped on this road, and practically all of the raw material comes in over it.

The loading and unloading of material is done by cranes provided for this purpose. The coal is conveyed to its place in the storage bin near the boiler room through an underground tunnel.

The whole plant shows very careful planning. The white walls of the building help to make natural lighting better. Both the natural and the artificial lighting are excellent. The large number of windows makes the natural light as good as it is. Very little artificial light is used during the day. The artificial lighting system shows a great deal of careful planning. In some of the buildings mercury arcs are used for general illimination and incandescent lights for the separate machines. In others, only indirect lighting is used.

In this plant the routing system is excellent. There was very little unnecessary moving of materials, with one exception. This exception was in the corrugating department. Between each process in the manufacture of the sylphons the material had to be annealed. The machines were arranged just backward to what they should have been for the best routing system. The foreman of this department realized this defect, and it was later found out by the writer that a change was made which should save the company a considerable amount of money. In moving parts from one department to another small carts which were moved by hand were used. This system seemed to be giving satisfaction, but a saving could probably be made by the use of some sort of mechanical conveyor. Most of the parts could easily be handled in this way.

The shops were all provided with separate tool rooms. The tools are let out on checks. This helps to keep the shop free of tools and other apparatus which would collect on the floor and hinder transportation. The floor space is plentiful. Wide aisles are used and are kept free of tools and material. The drives are all arranged so that they are not dangerous.

The inspecting department is organized separate from the production department. This helps to prevent faulty apparatus from leaving the plant to lower the standard of quality which the company proposes to keep up.

An automatic sprinkling system which is fed by a separate tank of water is used as a protection against fire. This arrangement is made still better by the fact that the tank is kept full of water at all times, thus insuring a good supply of water in case that fire should break out. This plant could easily be expanded. Before it will be necessary to expand, however, the production could be increased quite considerably in the buildings in use at the present time.

The plant is completely motorized. The power is secured from the Knoxville Power and Light Company. Both group and individual drives were used. Individual drives were used on the large machines. On account of the strict regulations of this company a list of motors could not be obtained.

The shafting is kept in good condition. One man was employed whose duty it was to inspect the shafting and belting each day.

The workmen in this plant are above the average to be found in most shops. This is accounted for by the fact that they were working on piece work. This system always encourages the worker to do his best. The workmen are secured largely by application. Some of the more skilled men are secured through employment bureaus and other agencies.

This plant is operated under real scientific management. Organization charts are worked out and must be followed both by the executives and the workmen. This system has shown itself to be a complete success in this plant.

The company also carries on a research department. This is regarded as a very important department as it is from here that the ideas come which may later be commercialized and make money for the company.

14. The Ty-Sa-Man Machine Works.

The Ty-Sa-Man Machine Works are located in Knoxville, Tennessee. The work of this company might be divided into three classes: general repair work, structural steel work, and the manufacture of milling machinery.

The plant occupies one large two story building and two smaller buildings. The first floor of the main building is made of brick and the second story is framed. The other two buildings are framed structures.

The first floor of the main building contains the machine shop, wood shop, and offices. The second floor is used for storage. The drafting room is also located on this floor. The forge shop, boiler, and a small steam engine which drives the coal conveyor are all located in one of the other buildings, and the structural steel department in the other. The plant is located on the Southern Railway. A derrick is used for loadingand unloading by hand and no mechanical devices are used in this plant for handling material, with this exception and that a coal conveyor is used to bring the coal from the cars up to the boiler room where it is placed in a storage bin.

The machines are so arranged that the routing is as direct as possible. A routing system is not such an important consideration in a plant of this type.

The natural light in this plant is good. The machines are most all placed in rows near the windows. The artificial light is fair. The general illumination is good, but some of the machines which are used constantly should be furnished with more light. Some of these machines are used at night.

The shops are kept in good condition. All the aisles are kept open. The buildings are in a very good state of repair. All necessary safety devices are installed, but there is no precaution taken against fire. There is ample room for this company to expand. At the time of this investigation it was running at full capacity and had orders on hand for three months of work.

This plant is another example of a completely motorized one. The power is secured from the Knoxville Power and Light Company. A list of the motors is given in Chapter VII together with the rest of the power data.

The tendency in this plant seems to be to use as few motors as possible. One long line-shaft drives most of the machinery. This shaft was well aligned and was in good condition. A gas engine is also installed for power purposes, but is rarely used. When the writer was at this plant it hadn't been used for several months. It is only kept for emergencies.

The workmen are secured by direct application at the plant.

All of the buildings are heated by steam from a 5 H P. boiler of the H. R. T. type. The boiler and heating system were in fair condition.

VII

Calculations and Power Data.

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1. Marble Mills.

No difficult calculations are involved in arriving at the results of this investigation. However, in order to make the tables in the appendix clear, an explanation of the calculations will be given.

Table I gives the classification of the machines installed in the marble mills. The table is self-explanatory. Two columns A and B were given for each plant. The two columns were then added and next the sum of both columns together was found. These results were used in calculating Table II.

In the latter part of this chapter the power requirements are given for the various plants. The methods used in securing the power requirements of the various plants have already been explained, but a brief summary will be given here. The electric power was found by taking meter readings over a certain period of time thus determining the consumption. In the steam plants the indicated horse power was determined. All that was necessary to determine this horse power was the speed of the engine, the bore and stroke, and the indicator cards for determining the mean effective pressure in the cylinder. The indicated horse power was then calculated by the formula:

$$I.\ H.P = \frac{PLAN}{33000}$$

An explanation of the results shown in Table II is necessary. From Table I the number of machines in use and the number in the plant are transferred to Table II. The part of the table down through the horse power consumption needs no explanation. The horse power of the saws was determined in every case except one. The reduction of the horse power consumption to the different units needs no explanation as it is just simple division. Tables 3A, 3B, and 3C show these results graphically. These tables should be of more value to the reader, as they are in graphical form, than a mere table of figures.

2. Machine Shops.

The same procedure was followed in recording the results of the investigation in the machine shops as in the marble finishing mill work. Table IV shows a classified list of machinery for the machine shops as Table I does for the marble mills. Table V gives the results in tabular form as in Table II. In Tables 6A, 6B, and 6C the same thing is shown for the machine shops as is shown in 3A, 3B, and 3C for the marble mills.

1. Tennessee Producers Marble Co.

Power data.

Size of Motors	Number	Total H.P.
3	2	6
5	3	15
8	1	8
15	1	15
20	3	60
25	11	275
30	2	60
35	1	35
50	1	50
60	1	60
75	2	150
Total	28	734

Total electrical power used 2860 K.W.H. (10 hours)

Average load on motors 384 H.P.

Ratio of average load on motors to rated capacity $\frac{384}{734} = 52.2\%$

Electrical power used in saw mill 1900 K.W.H.(13 hrs.)

Average load on motors 196 H.P.

Ratio of average load on motors to rated capacity $\frac{196}{260} = 75.3\%$

2. The Knoxville Marble Co.

Power data

Total mill.

M.E.P.	I.H.P.	
40	166.5	
36.2	151.0	
34.5	144.0	
35.0	150.0	
42.0	181.0	
39.0	171.0	
42.5	183.0	
43.2	186.0	
46.0	198.0	(Maximum)
42.5	183.0	
37.0	158.0	
34.0	146.0	
Average Load	168.0	

Line Shaft Only

13.5	58.0
13.0	56.0
13.0	56.0
13.0	56.0
Average Load	56.5

The Knoxville Marble Co.

Power data (con'd)

Sawmill Only

M.E.P.	I.H.P.
27.0	116.0
27.0	116.0
26.0	112.0
25.0	107.5
32.0	137.5
27.0	116.0
29.0	125.0
28.0	120.0
27.5	118.0
Average Load	118.5

Load on Air Compressor (Estimated)	50 H.P.
Load on Hoistings Engines (Estimated)	10
Total load for mill	168.0
Total Load on Boilers	228

Engine:

Bore	18"
Stroke	36"
R.P.M.	93
I.H.P.	M.E.P. x 4.3

3. Meade Marble Co.

Power data

Total Mill in Operation.

M.E.P.	I.H.P.
33	111
40	134
43	144
34.5	116
31.2	105
35.5	118
34.0	114
32.5	109
41.0	137.5
35.0	117
38.5	129
35.0	117
35.5	118
36.5	123
38.0	127
Average Load	121.3

Engine:

Bore	18"
Stroke	36"
R.P.M.	80
I.H.P.	M.E.P. x 3.36

Meade Marble Co.

Power data (con'd)

Sawmill Only

M.E.P.	I.H.P.
23.0	77
25.5	85
25.5	85
25.5	85
Average Load	83

Following motors were driven by power generated at the plant:

Size of Motor	Number	Total H.P.
25	3	75
7.5	2	15
5.0	5	25
2.0	1	2
Total	11	117

4. Appalachian Marble Co.

Power data.

Size of Motor	Number	Total H.P.
60	1	60
50	11	550
25	7	175
10	7	70
7.5	11	82.5
5	5	25
75	4	300
40	1	40
35	1	35
2	7	14
20	2	40
Total	57	1391.5

Total electrical power used 2020 K.W.H. (10 hours)

Average load 272 H.P.

Ratio of average load to rated
capacity of motors $\frac{272}{1391.5} = 19.5\%$

5. The Gray-Knox Marble Co.

Power data.

Saws and Finishing Mill

M.E.P.	I.H.P.
35	117
38	127
35.5	119
35	117
33	111
40	134
38.5	129
36.5	123
43	144
34.5	116
31.2	105
35.5	118
34	114
32.5	109
41	137.5

Sawmill only

$24\frac{1}{2}$	82
$25\frac{1}{2}$	85
$25\frac{1}{2}$	85
23	77

5. The Gray-Knox Marble Co.

Power data (con'd)

Size of Motor	Number	Total H.P.
75	1	75
50	1	50
35	4	140
25	11	275
20	1	20
15	3	45
5	10	50
Total	31	655

Total electrical power secured from
Knox. Power and Light Co 660 K.W.H. (7½ hours)

Average load on motors 118 H.P.

Note: City power was used only when the power plant was loaded to more than capacity.

Total power consumption of plant 239 H.P.

6. The Candora Marble Co.

Power data.

Size of Motors	Number	Total H.P.
10	3	30
7.5	6	45
50	2	100
75	2	150
5	8	40
1.5	3	4.5
30	2	60
40	1	40
2	1	2
35	3	105
15	1	15
25	1	25
3	2	6
Total	35	622.5

Total electrical power used by plant	1620 K.W.H.
Total H.P.	246
Ratio of average load on motors to rated capacity	$\frac{246}{622.5}$ = 39.5%
Power used by Sawmill	147 K.W.H. (13 hours)
Average H.P. for Sawmill	151
Ratio of average load on motor to rated capacity	$\frac{151}{250}$ = 60.5%

7. Andres Stone Marble Co.

Power data

Whole Mill

M.E.P.	I.H.P.
31.5	138
26.5	116
28.5	125
34.5	151
35	153
30.5	133
29.5	129
32.5	142
28	122
28	122
31	136
28.5	125
27.5	120
Average load	131.7

Andres Stone and Marble Co

Power date (con'd)

Size of Motor	Number	Total H.P.
75	1	75
60	2	120
50	1	50
20	2	40
10	2	20
5	3	15
2	1	2
Total	12	322

The power for the above motors is furnished by the company's power plant.

Size of Motor	Number	Total H.P.
60	2	120
20	1	20
10	2	20
Total	5	140

Total power from Knox. Power & Light Co.	170 K.W.H. (7 hours)
Average load	32.6
Ratio of average load to capacity of motors	$\frac{32.6}{140} = 23.3\%$
Total power consumption of plant	164.3 H.P.

8. Layne and Bowler Co.

Power Calculations.

Size of Motor	Number	Total H.P.
25	2	50
35	2	70
15	1	15
10	3	30
5	11	55
7.5	1	7.5
2	1	2
50	1	50
Total	22	279.5

Total electrical power used 422 K.W.H. (10 hours)

Average load 56.5 H.P.

Ratio of average load to rated capacity $\frac{56.5}{279.5} = 20.2\%$

9. The Chickasaw Iron Works.

Power Calculations

M.E.P.	I.H.P.
36	44
33.5	41.5
34	42
33	41
23	29
35	43
29	36
34	42
Average load	39.8

Engine:

Bore	12"
Stroke	18"
R.P.M.	120
I.H.P.	1.24 x M.E.P.

10. Nashville Machine and Supply Company

Power Calculations.

Size of Motor	Number	Total H.P.
40 h.p.	1	40

Total Electrical Power Used 245 K.W.H. (10 Hours)

Average load on motor 32.8 H.P.

Ratio of average load on motor
to rated capacity $\frac{32.8}{40.0} = 82.0\%$

11. The Englert Machine Works.

Power data.

Size of Motor	Number	Total H.P.
10	1	10
7	1	7
2	1	2
Total	3	19

Total electrical power used 103 K.W.H. (10 hrs.)

Average load on motors 13.8 H.P.

Ratio of average load on motors to rated capacity $\frac{13.8}{19.0} = 72.5\%$

12. Jones Machine Co.

Power Calculations.

Size of Motor	Number	Total H.P.
5 H.P.	2	10
10	2	20
15	1	15
7.5	1	7.5
0.25	1	0.25
Total	7	52.75

Total Electrical Power Used 280 K.W.H. (10 hrs.)

Average Load 37.5 H.P.

Ratio of average load on motors to rated horse power $\frac{37.5}{52.75} = 71.0\%$

13. The Fulton Co.

Power Data.

The Fulton Company has 1000 horse power of electric motors installed. These motors vary in size from one half horse power to fifty horse power. The average is approximately 7.5 horse power.

Due to strict regulations of the company a list could not be secured.

Total electrical power used	2039 K.W.H. (10 hrs.)
Average load	272 H.P.

Ratio of average load on motors to rated capacity - $\frac{272}{1000} = 27.2\%$

14. Ty-Sa-Man Machine Works.

Power Calculations.

Motor size	Number	Total H.P.
25 H.P.	2	50
7.5	1	7.5
Total	3	57.5

Total electrical power used 98 K.W.H. (7.5 hours)

Average load on motors 17.6 H.P.

Ratio of average load on motors
to rated capacity $\frac{17.6}{57.5} = 30.6\%$

VIII

Conclusions.

-

1. Marble Finishing Mills.

A careful examination of the results shown in this report revealed the following conclusions:

1st. The power requirements of marble mills can be reduced to certain definite units which may be used for comparison. The three units which give the closest correlation are: the horse power per machine installed, the horse power per machine in use, and the horse power per employee. The results obtained by the use of these three units are shown graphically in Tables 3A, 3B, and 3C. An examination of these tables will give the reader a good idea of their usefulness.

2nd. The operating conditions affect the units mentioned above to a very large extent. Take, for instance, the unit on which Table 3A is based, the horse power per machine installed. With this unit the Meade Marble Company shows the greatest percentage of variation from the average. This is explained by the fact that this company uses smaller machines and consequently more time for the work than does any of the others. The Knoxville Marble Company, the Gray-Knox Marble Company, and the Andres Stone and Marble Company show the largest amount of power per machine in use. This is due to the fact that the majority of the work at these plants is on the saws and sub beds, machines which use a large amount of power. Table 3C shows the horse power per employee. No distinct relation was obtained with this unit, but it should be valuable to use in connection with other units.

3rd. The unit which could best be used in making comparisons is the horse power per machine in use. This unit is given preference over the horse power per machine installed because it is more apt to adjust itself to varying conditions.

2. Machine Shops.

A careful examination of the results shown in this report revealed the following conclusions:

1st. That the horse power requirements of the plants visited could not be reduced to any satisfactory unit comparison. In connection with the above conclusion, the writer would like to state that he believes the relation would exist if the companies were engaged in the same work. No two plants, however, which were visited in connection with this investigation were engaged in exactly the same class of iron work. The power requirements of the machine shops were reduced to the same units as for the marble mills. The results are shown graphically in Tables 6A, 6B, and 6C.

IX

Bibliography

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Ingersoll-Rand Company - Catalogue

Sullivan Machinery Company - Catalogue

Investigation of the condition and power requirements of Furniture and Hosiery Mills in Tennessee - W.B. Lincoln

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X

Appendix

This chapter is merely put in this report as a sort of supplement to the main body. The plates will be found which show the layout of the various plants visited. The tables of data presented herein are the results of the calculations made in Chapter VII. The results are shown in graphical form in many instances much clearer than a mere table of figures could show them. This is one of the principal objects which the writer had in mind when he placed this chapter in his report.

TABDE 1

Equipment of Marble Finishing Mills.

Name of Machine	1		2		3		4		5		6		7	
	A	B	A	B	A	B	A	B	A	B	A	B	A	B
Saw Gangs	20	0	11	0	8	0	23	5	8	3	11	1	9	4
Sand Pumps	5	0	4	0	2	0	9	0	4	0	3	0	3	0
Water Pumps	1	1	1	1	1	0	3	0	1	1	2	0	1	0
Carborundum Mach.	2	0	1	0	1	0	2	0	1	3	2	0	0	0
Diamond Saw	0	0	0	0	1	0	0	0	0	3	0	0	0	0
Copeing Machine	0	1	0	1	0	1	2	0	0	0	0	1	0	1
Planer	1	0	0	1	1	1	1	0	[illegible]	5	1	0	0	1
Air Compressor	1	0	1	0	1	1	1	1	1	2	1	1	1	0
Polishing Mach.	3	3	4	0	2	2	12	0	2	5	6	0	0	5
Rub Beds	8	0	3	1	3	1	10	0	4	4	6	0	2	1
Wood Saws	2	0	2	0	1	0	1	0	1	1	1	0	1	0
Lathe	1	0	0	1	1	0	1	0	1	2	0	1	0	0
Pneumatic Tools	8	10	0	1	8	0	18	0	4	0	6	0	2	0
Crusher	1	0	0	0	0	0	1	0	0	1	0	0	0	0
Cranes	2	0	0	0	0	0	1	0	[illegible]	[illegible]	1	0	1	0
Hoists	0	0	1	1	1	0	0	0	0	0	0	1	0	0

-LEGEND-

A-Machines in use.

B-Machines not in use.

1-Tenn. Producers Mar. Co.

2-Knoxville Marble Co.

3-Meade Marble Co.

4-Appalachian Mar. Co.

5-Gray-Knox Marble Co.

6-Condora Marble Co.

7-Andres Stone & Mar. Co.

TABLE 2

	1	2	3	4	5	6	7
Machines Idle	15	7	6	6	32	4	12
Machines in Use	55	28	31	36	28	40	20
Total Mach. in Plant	70	35	37	92	60	44	32
% of Mach. in Use	78.5	80	83.5	93	47	91	62
No. Common Laborers	43	17	15	40	17	33	9
No. Mach. Operators	32	7	8	80	29	22	15
No. in Office & Foremen	11	6	4	20	8	16	6
No. Skilled Laborers	11	17	4	30	20	34	1
No. Direct Labor	43	24	12	110	49	56	16
No. Indirect Labor	54	23	19	60	25	49	15
Total no. Employees	97	47	31	170	74	105	31
Average H.P. of Plant	348	228	144	415	239	246	164
Average H.P. of Saws	196	118	79	262	82	151	---
H.P./Direct Laborer	8.10	9.5	11.9	3.8	4.9	4.4	10.2
H.P./Employee	3.6	4.8	4.6	2.4	3.2	2.3	5.3
H.P./Mach. Operator	10.9	31.6	17.9	5.2	8.2	11.2	10.9
H.P./Mach. in Use	6.3	8.1	4.6	4.8	8.5	6.2	8.2
H.P./Mach. Installed	5.0	6.5	3.8	4.5	7.5	5.6	5.1

-LEGEND-

1-Tenn. Producers Mar. Co.

2-Knoxville Marble Co.

3-Meade Marble Co.

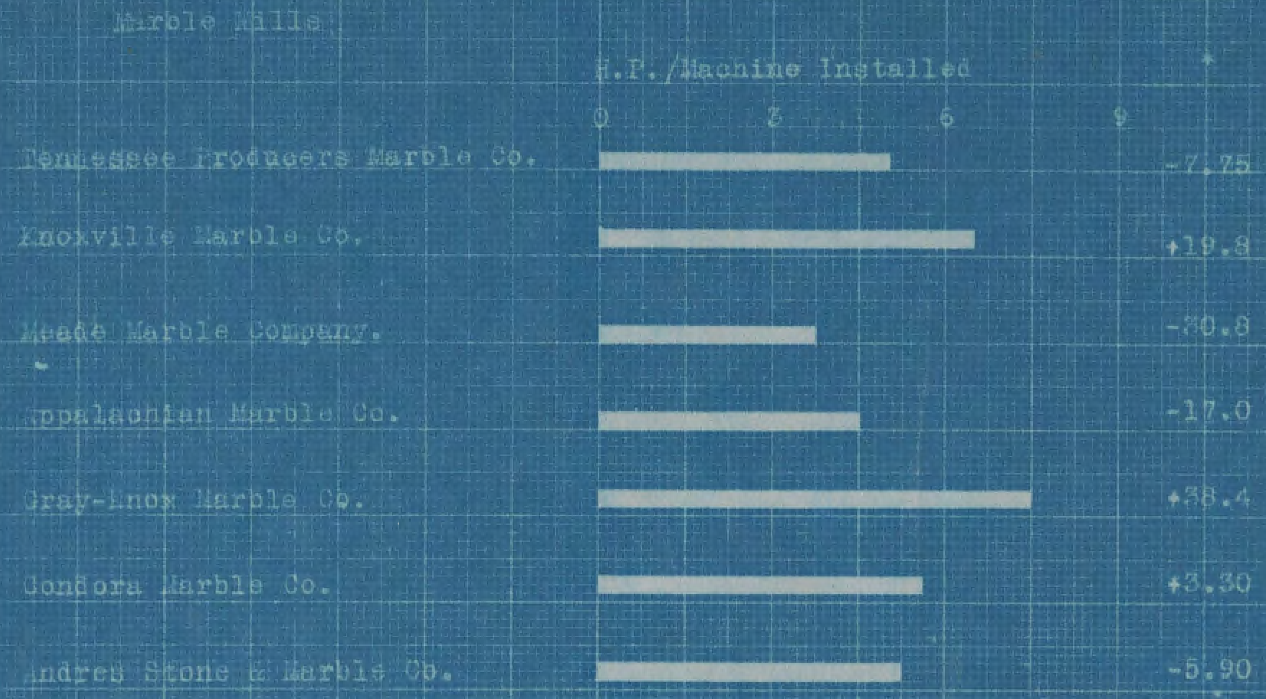
4-Appalachian Mar. Co.

5-Gray Knox Marble Co.

6-Condora Marble Co.

7-Andres Stone & Mar. Co.

TABLE 3A



* This column gives the percent of variation from the average.

TABLE 33

This column gives the percent of variation from the average.

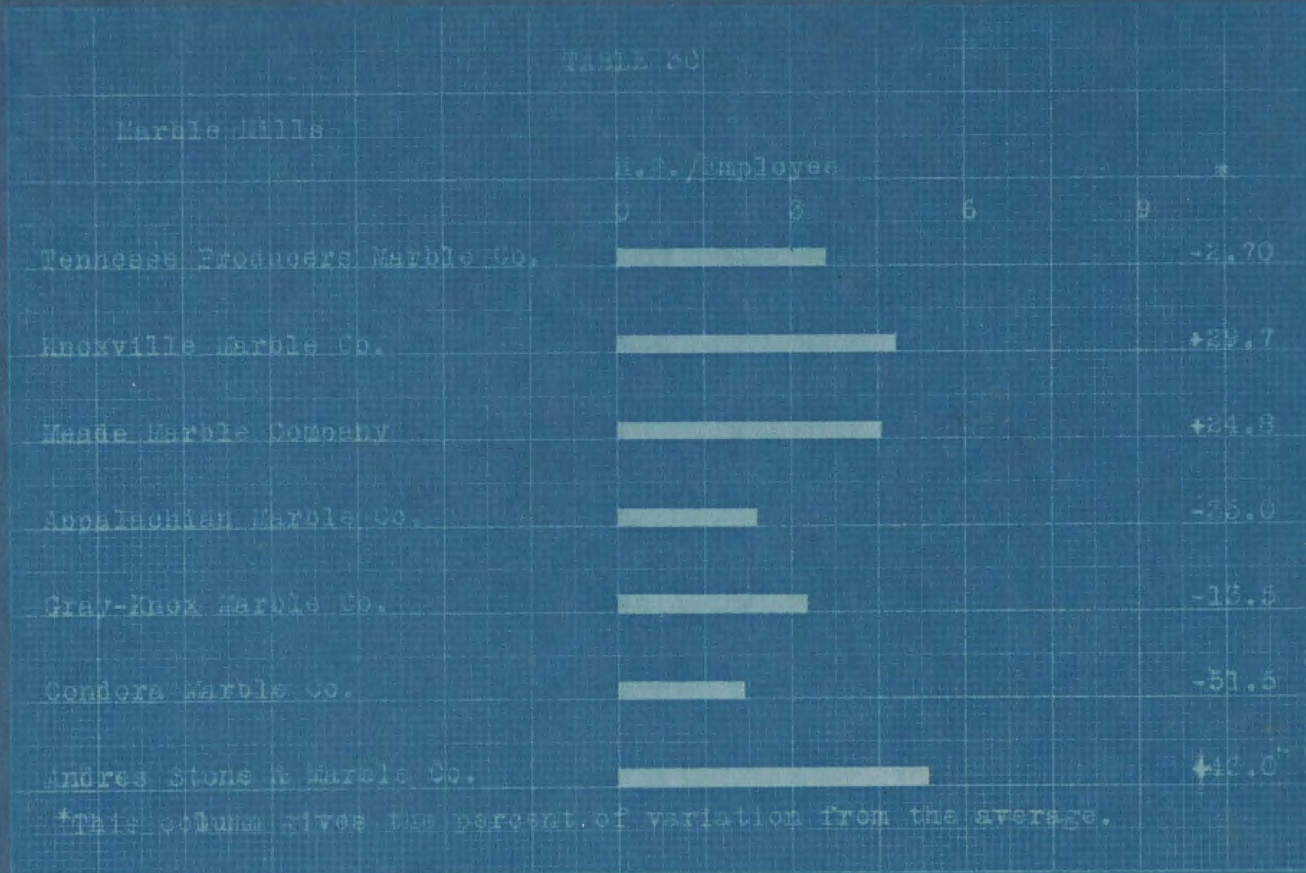


TABLE 30
Marble Mills
H.P./Employee
0
3
6
9
*
Tennesse Producers Marble Co.
-2.70
Knoxville Marble Co.
+29.7
Meade Marble Company
+24.8
Appalachian Marble Co.
-35.0
Gray-Knox Marble Co.
-13.5
Condora Marble Co.
-51.5
Andres Stone & Marble Co.
+45.0
*This column gives the percent of variation from the average.

TABLE IV

Equipment of Machine shops

Name of Machine	1		2		3		4		5		6		7	
	A	B	A	B	A	B	A	B	A	B	A	B	A	B
Turret Lathe	5	-	-	-	-	-	-	-	-	-	15	30	-	-
Lathe	10	2	6	1	6	3	4	1	2	3	12	9	6	2
Bolt Machine	1	-	1	-	-	-	-	-	-	-	-	-	-	-
Tool Grinder	6	2	1	1	5	4	1	-	1	-	5	8	1	1
Sensitive Drill	-	4	4	-	-	-	-	-	1	-	5	4	-	-
Power Saw	1	1	1	-	1	-	2	-	1	-	1	1	1	1
Buffing Wheel	-	-	-	-	1	-	-	-	-	-	4	6	-	-
Pulley Lathe	-	1	-	-	1	-	-	-	-	-	-	-	-	-
Boring Mill	2	-	1	1	-	-	-	-	-	-	-	-	-	-
Pipe Threader	1	1	-	-	3	1	-	1	-	1	-	-	2	-
Shaper	-	1	1	-	1	1	1	-	-	3	-	-	1	-
Vertical Drill	-	-	-	-	3	-	1	1	1	-	3	2	1	2
Cupola	1	2	-	-	-	-	-	-	1	-	-	2	-	-
Shearing Mach.	-	2	-	-	2	-	1	-	-	-	4	7	1	-
Steam & Trip Ham.	1	3	2	-	-	1	-	-	1	-	-	-	1	-
Sheet Metal Punch	-	5	1	-	2	-	2	-	-	-	-	-	1	-
Pit Roller	1	-	-	-	-	-	-	-	-	-	-	-	-	-
Band Saw	1	-	1	-	1	-	-	-	1	-	-	-	1	-
Wood Lathe	2	-	2	-	2	-	1	-	-	-	-	1	-	-
Wood Planer	-	-	1	-	-	-	-	-	-	-	-	-	-	-
Joiner	1	-	1	-	-	-	-	-	-	-	-	1	-	-
Cutoff Saw	-	-	-	-	1	-	-	-	-	-	-	-	1	-
Air Compressor	2	-	-	1	-	-	-	-	1	-	-	2	1	1
Water Pump	1	-	1	1	1	-	-	-	-	-	-	-	-	-
Forges	2	1	2	1	1	1	1	2	2	-	1	-	1	-
Blower	1	-	1	-	1	-	-	-	1	-	2	-	1	-
Crane	1	1	-	-	-	-	-	-	-	-	-	-	-	-
Milling Machine	-	-	1	-	-	-	1	-	1	-	7	3	2	-
Grinder	-	-	1	1	-	-	-	-	2	-	-	-	1	2
Keyway Machine	-	-	1	-	1	-	-	-	-	-	-	-	-	1
Radial Drill	-	-	1	-	1	1	-	-	-	-	-	-	1	-
Derrick	-	-	2	-	1	-	-	-	1	-	-	-	1	-
Gear Generator	-	-	-	-	1	1	-	-	-	-	-	-	-	-
Corrugating Machine	-	-	-	-	-	-	-	-	-	-	21	16	-	1
Wood Drill	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Grind Stone	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Gas Furnace	-	-	-	-	-	-	-	-	-	-	3	3	-	-
Stamping Machine	-	-	-	-	-	-	-	-	-	-	17	-	-	-
Crimping Machine	-	-	-	-	-	-	-	-	-	-	2	-	-	-
Moulding Machine	-	-	-	-	-	-	-	-	-	-	10	3	-	-
Brass Furnace	-	-	-	-	-	-	-	-	-	-	4	7	-	-
Core Oven	-	-	-	-	-	-	-	-	-	-	3	3	-	-
Die Casting Mach.	-	-	-	-	-	-	-	-	-	-	-	2	-	-
Furnaces	-	-	-	-	-	-	-	-	-	-	1	4	-	-
Trimming Press	-	-	-	-	-	-	-	-	-	-	1	1	-	-
Special Milling M.	-	-	-	-	-	-	-	-	-	-	-	1	-	-
Plating Tanks	-	-	-	-	-	-	-	-	-	-	5	-	-	-
Test Tables	-	-	-	-	-	-	-	-	-	-	2	-	-	-

LEGEND

A-Machines in use.
B-Machines not in use.
1-Payne & Bowler Co.
2-Chickasaw Iron Works.
3-Nashville Mach. & Sup. Co.
4-Englert Machine Co.
5-Jones Machine & Foundry Co.
6-The Fulton Co.
7-Ty-Sa-Man Machine Works.

TABLE V

	1	2	3	4	5	6	7
Machines Idle	27	6	13	5	7	116	15
Machines in use	40	33	37	15	17	126	27
Tatal Mach. in Plant	67	39	50	20	24	242	42
% of Mach. in use	59	85	74	75	71	52	64
No. Common Laborers	12	30	10	3	4	69	6
No. Mach. Operators	24	31	7	9	8	73	16
Office and Foremen	21	4	7	3	2	45	6
Skilled Labor	39	4	6	4	3	141	4
Direct Labor	63	35	13	13	11	214	20
Indirect Labor	33	34	17	6	6	114	12
Total Employees	96	69	30	19	17	328	32
Average H.P. of Plant	56.5	39.8	32.8	13.8	37.5	272	17.6
H.P./Direct Labor	0.90	1.14	2.53	1.06	3.39	1.27	0.88
H.P./Employee	0.60	0.58	1.09	0.73	2.20	0.83	0.55
H.P./Mach. Operator	2.35	1.28	4.70	1.53	4.70	3.72	1.10
H.P./Mach. in use	1.40	1.20	0.90	0.92	1.61	2.16	0.65
H.P./Mach. Installed	0.85	1.02	0.66	0.69	1.15	1.20	0.42

-LEGEND-

1-Layne & Bowler Co.

2-Chickasaw Iron Works.

3-Nashville Mach. & Supply Co.

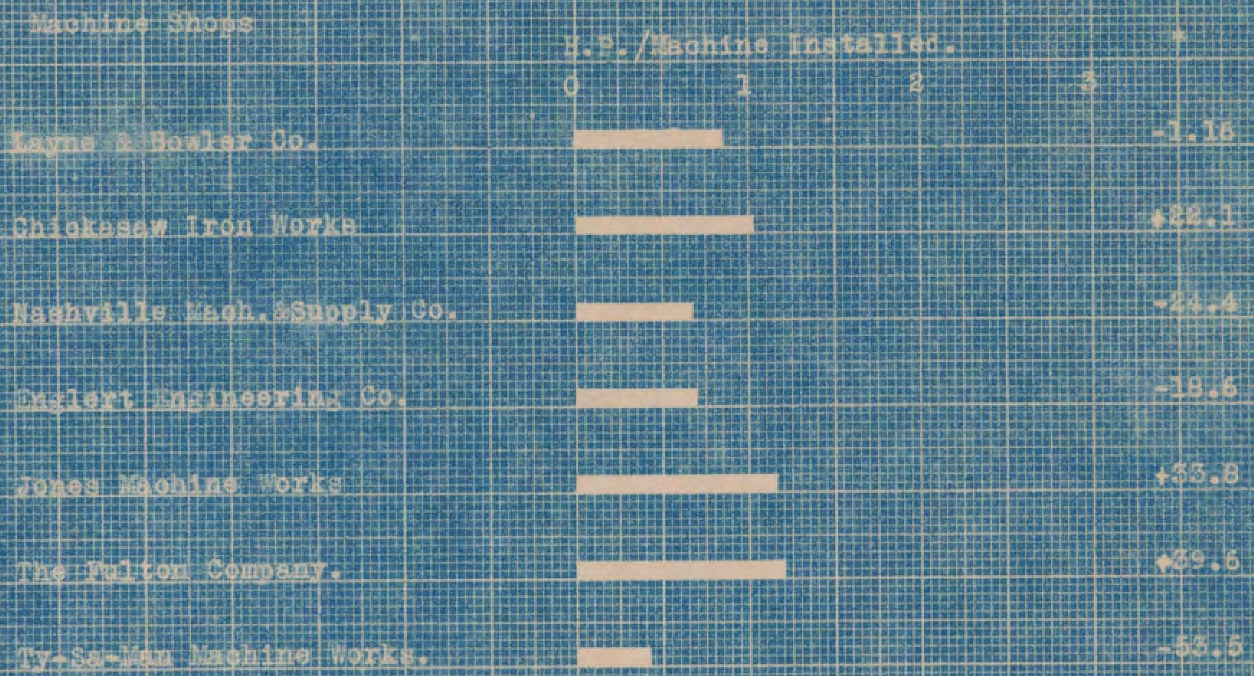
4-Englert Engineering Co.

5-Jones Machine Works.

6-The Fulton Co.

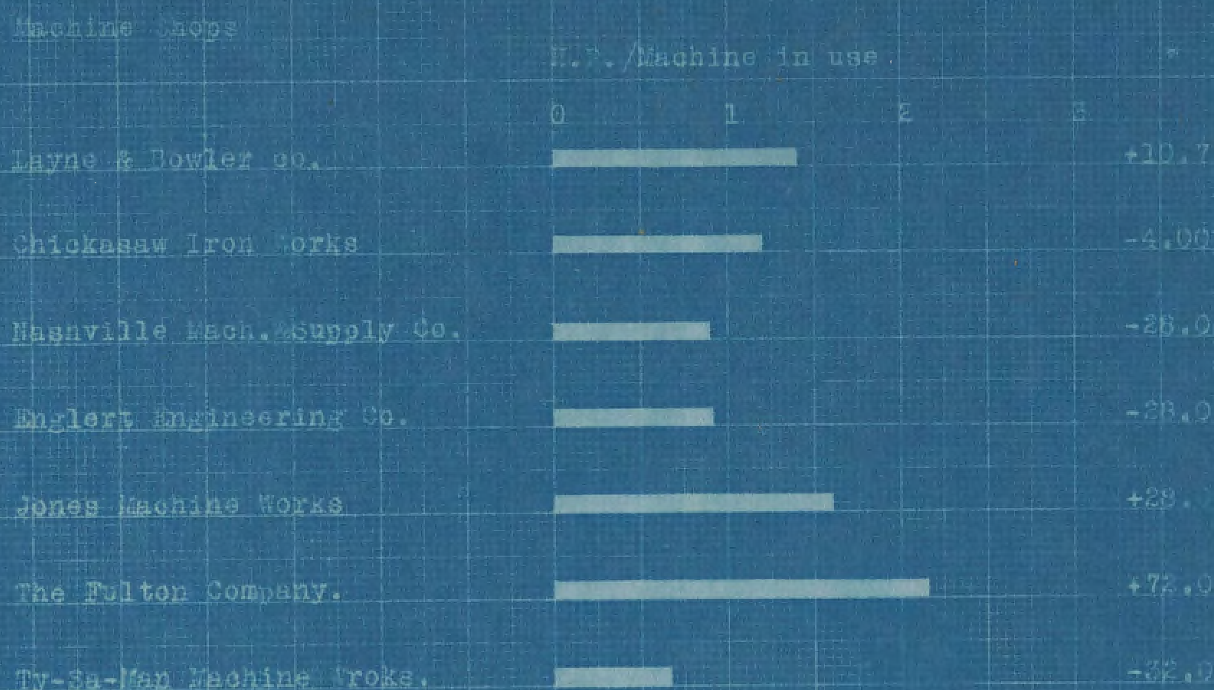
7-Ty-Sa-Man Machine Works.

TABLE 6A



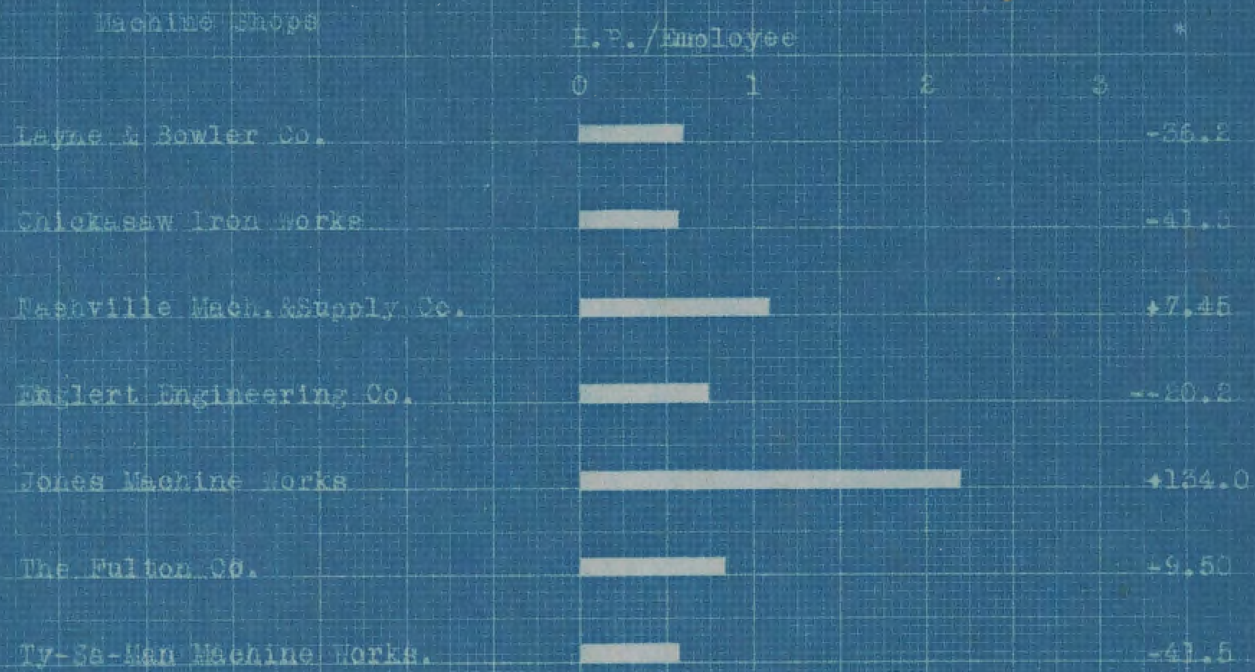
* This column gives the percent of variation from the average.

TABLE 63



* This column gives the percent of variation from the average.

TABLE 6C



* This column gives the percent of variation from the average.

KEY

Abbreviations used on sketches of marble mills

R-----Storage of Raw Material.

P-----Storage of Goods in Process.

F-----Storage of Finished Goods,

S-----Finishing Mill.

M-----Saw Mill.

L-----Storage of Lumber.

D-----Storage of Sand.

C-----Storage of Coal.

O-----Office.

E-----Engine Room.

B-----Boiler Room.

K-----Loading Platform.

H-----Hoisting Engine.

⊗ ---Derrick.

N-----Pumping Station.

—— – ——Line Shaft.

Narrow Gauge Railway.

Crane Track.

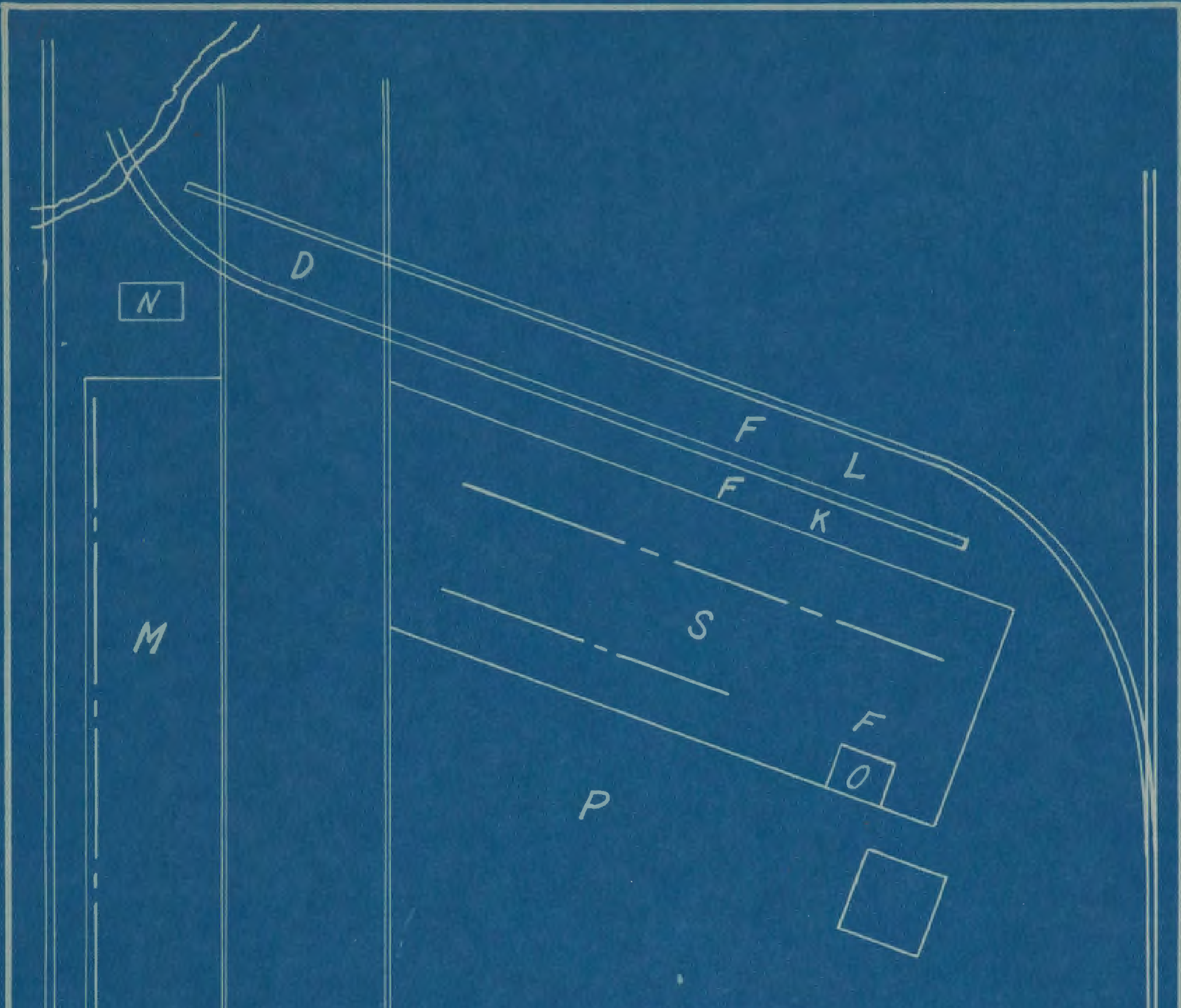


PLATE I

PLAN OF THE TENN. PRODUCERS MARBLE CO.

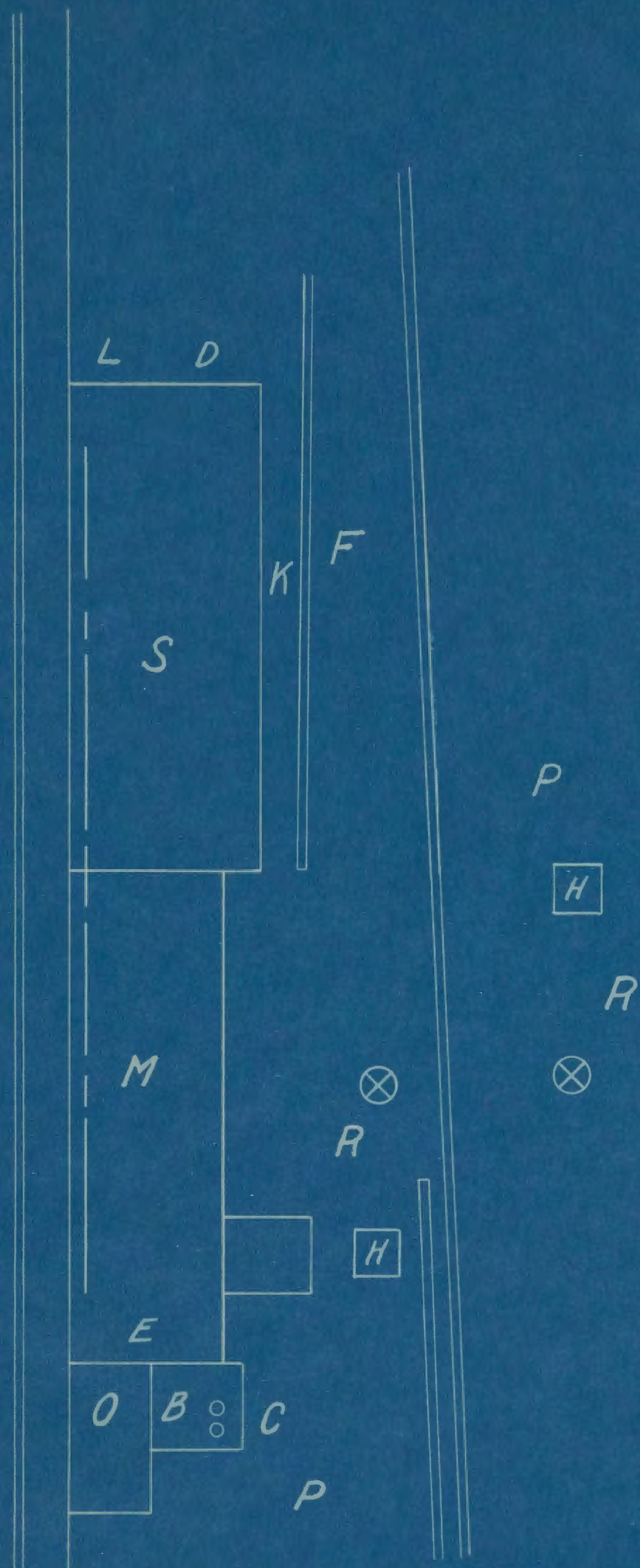


PLATE II

PLAN OF THE KNOXVILLE MARBLE CO.

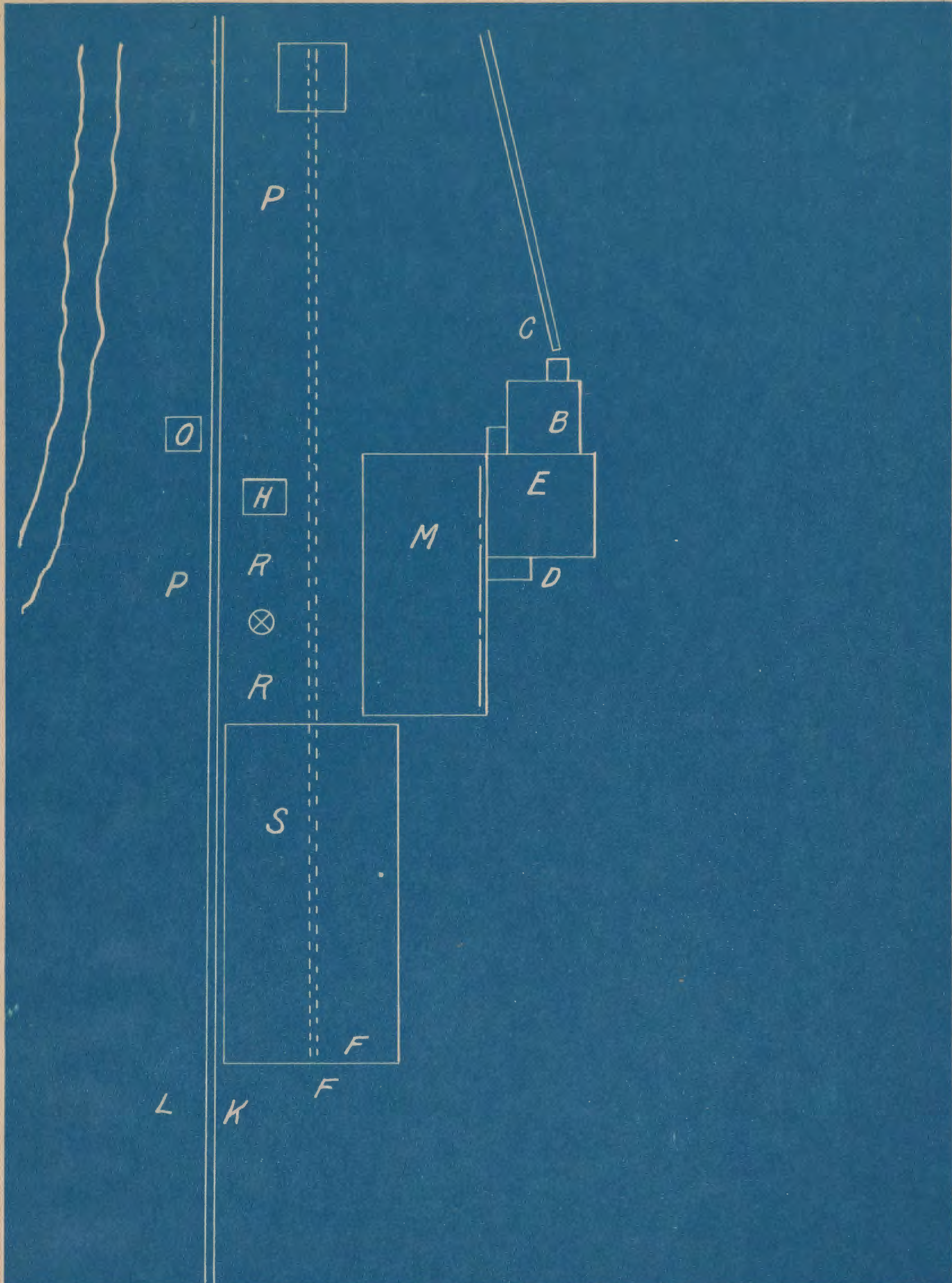


PLATE III

PLAN OF THE MEADE MARBLE CO.

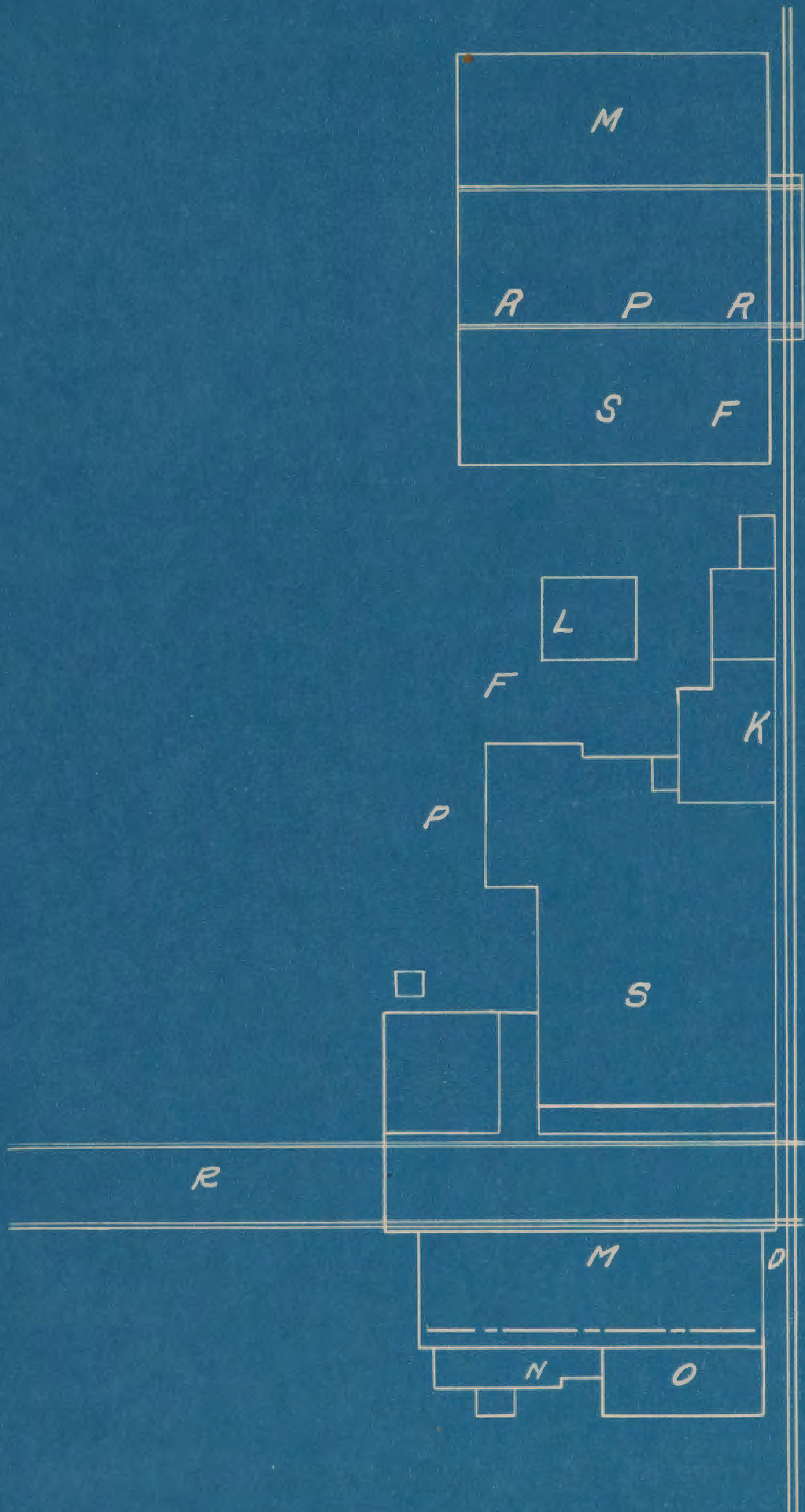


PLATE IV
PLAN OF THE APPALACHIAN MARBLE CO.

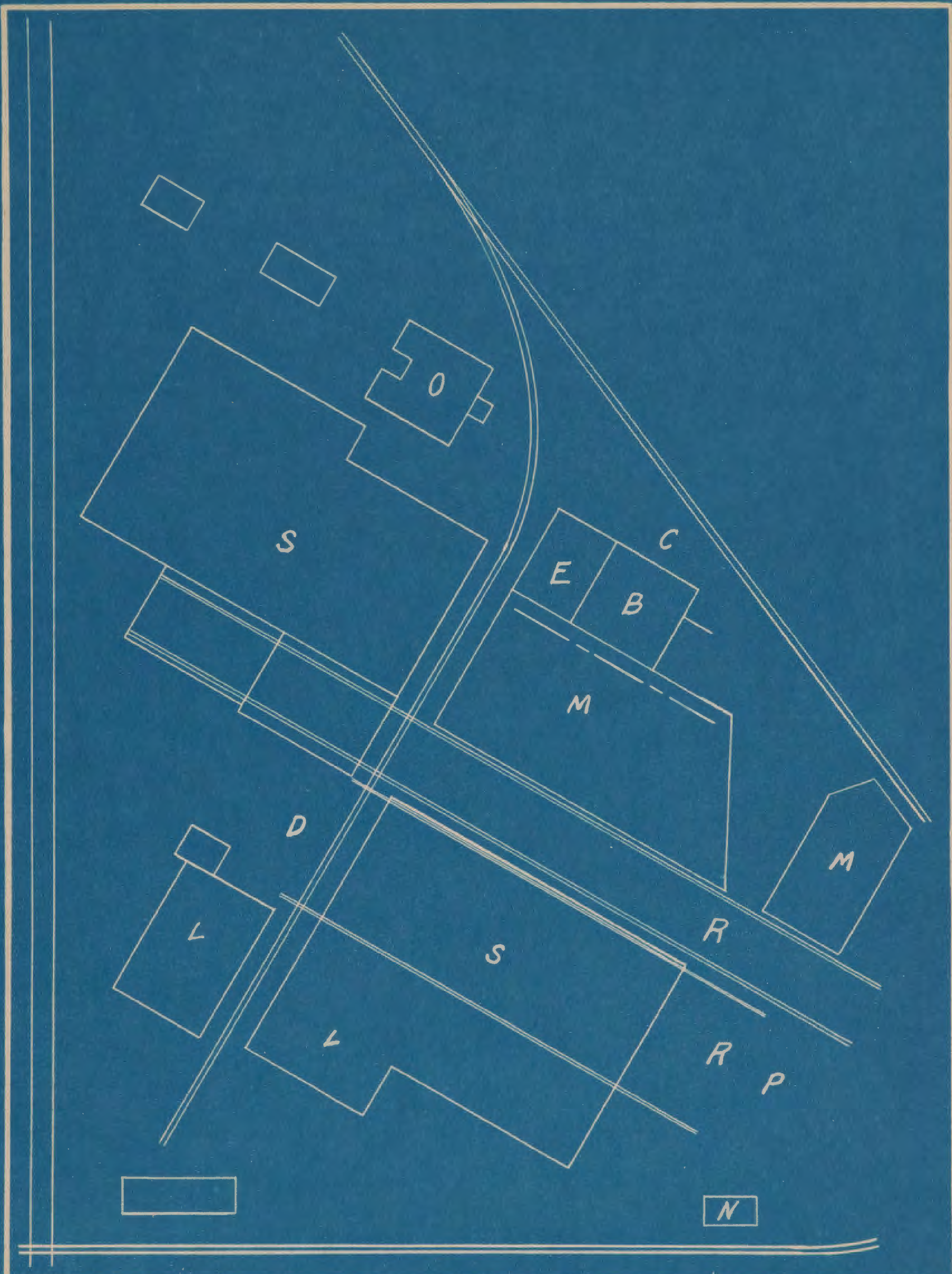


PLATE V

PLAN OF THE GRAY-KNOX MARBLE COMPANY

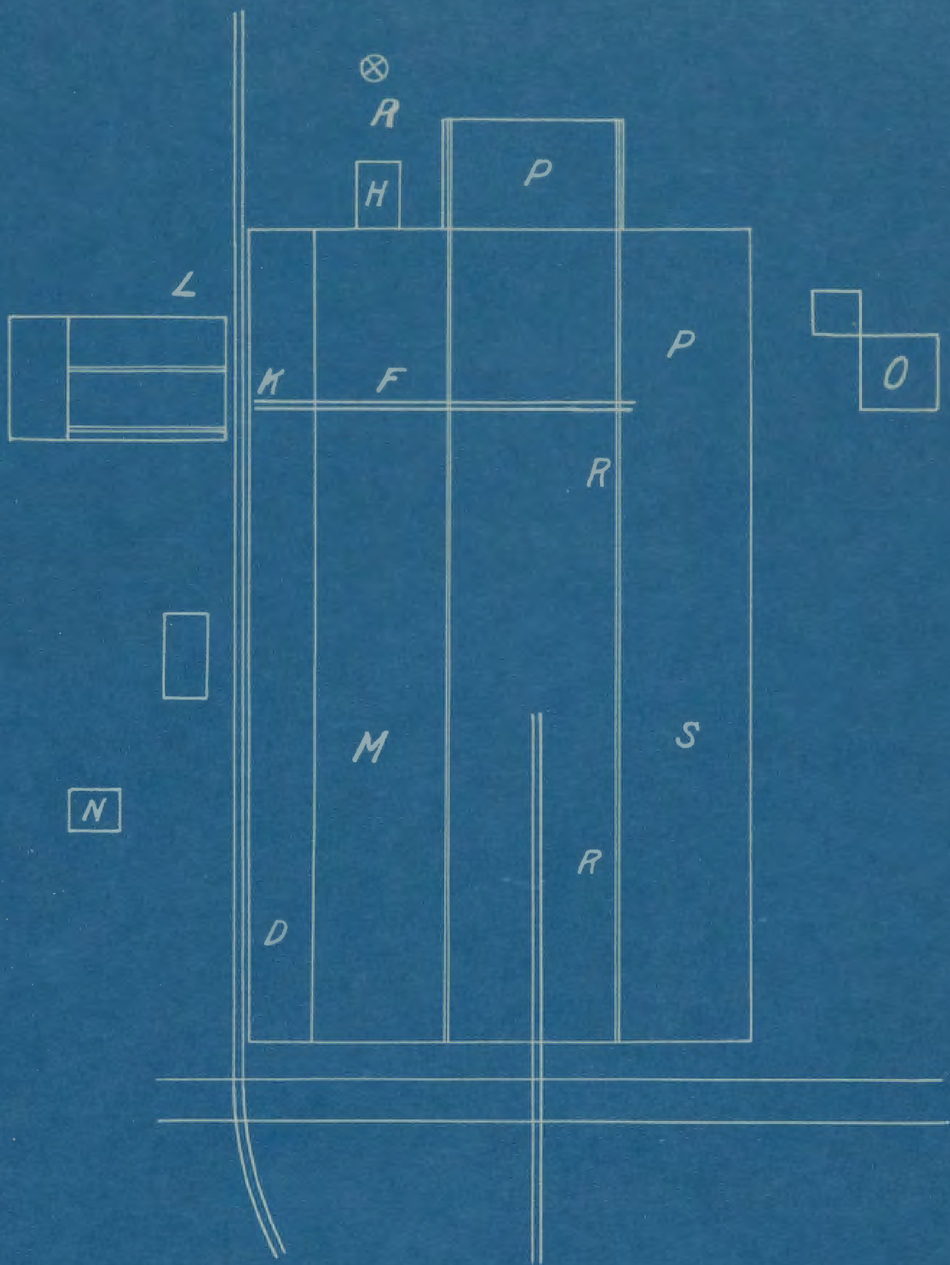


PLATE VI

PLAN OF THE CONDORA MARBLE COMPANY

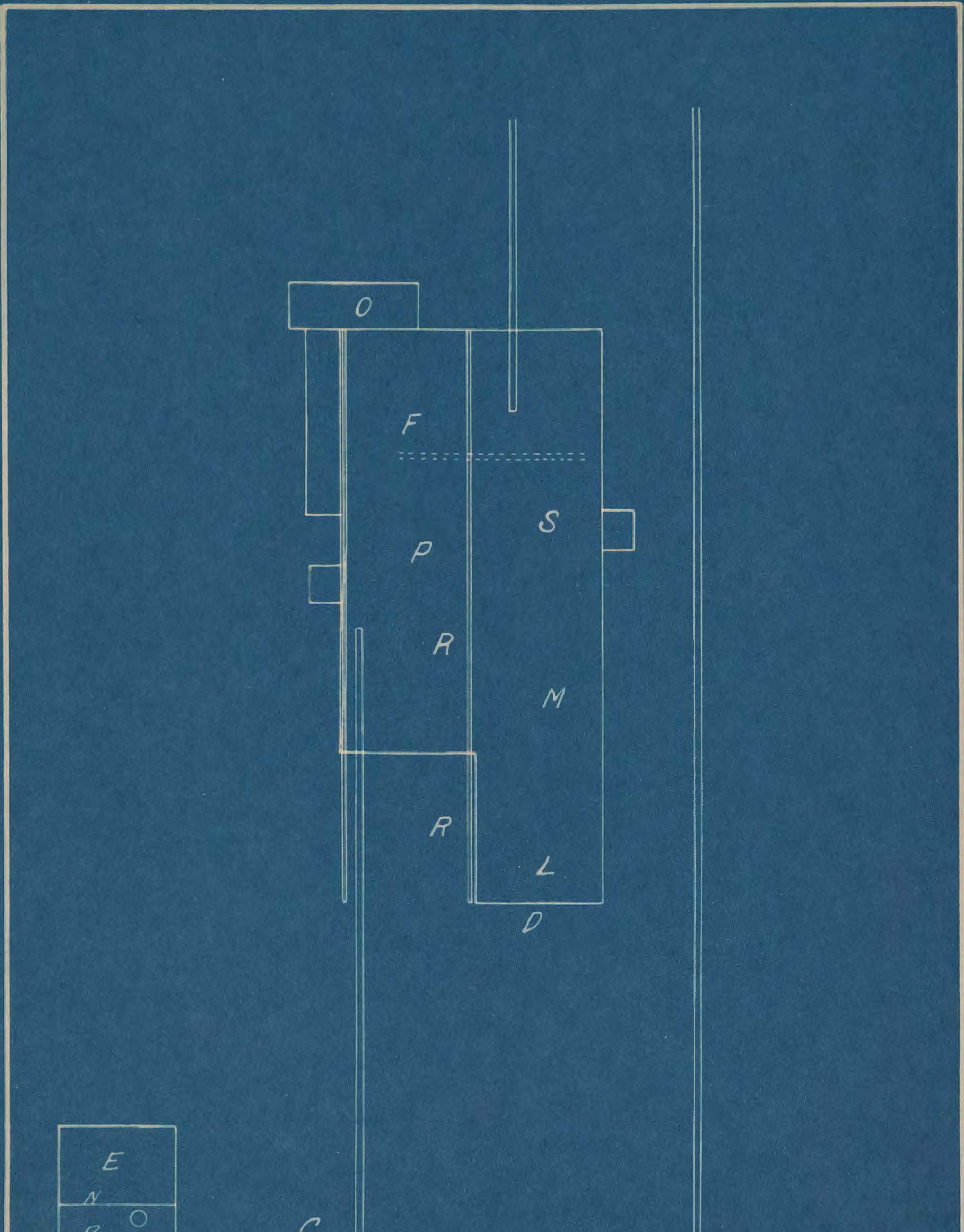


PLATE VII

PLAN OF THE ANDRES STONE-MARBLE CO.

KEY.

Abbreviations used on sketches of machine shops.

R-----Storage of Raw Material.

P-----Storage of Goods in Porcess.

F-----Storage of finished Goods.

S-----Location of Machines.

C-----Storage of Coal.

O-----Office.

E-----Engine Room.

B-----Boiler Room.

K-----Loading Platform.

⊕ ---Derrick.

———Line Shaft.

═════Narrow Gauge Railway.

≡≡≡≡Crane Track.

D-----Drafting Room.

M-----Foundry.

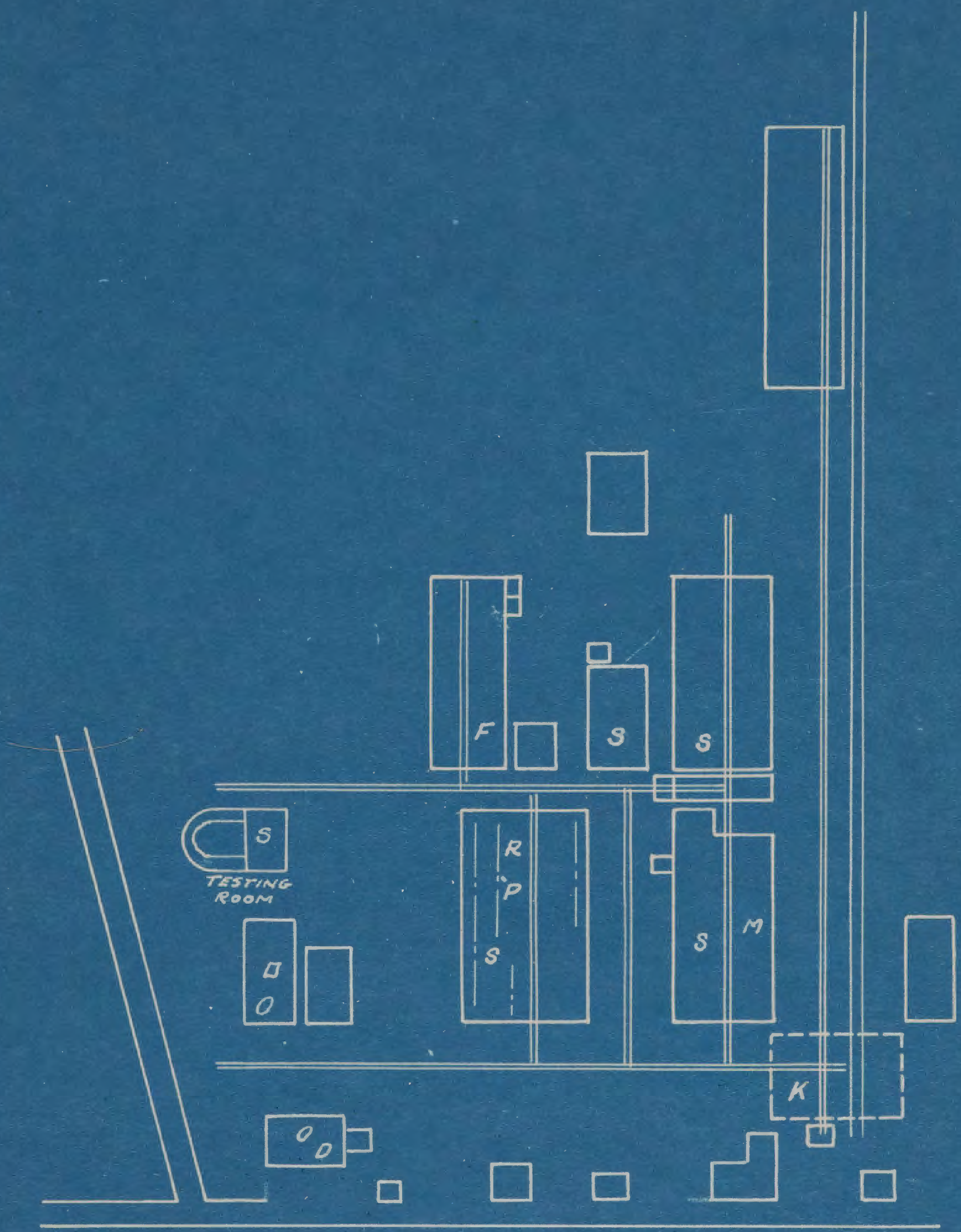


PLATE VIII

PLAN OF THE LAYNE-BOWLER CO.

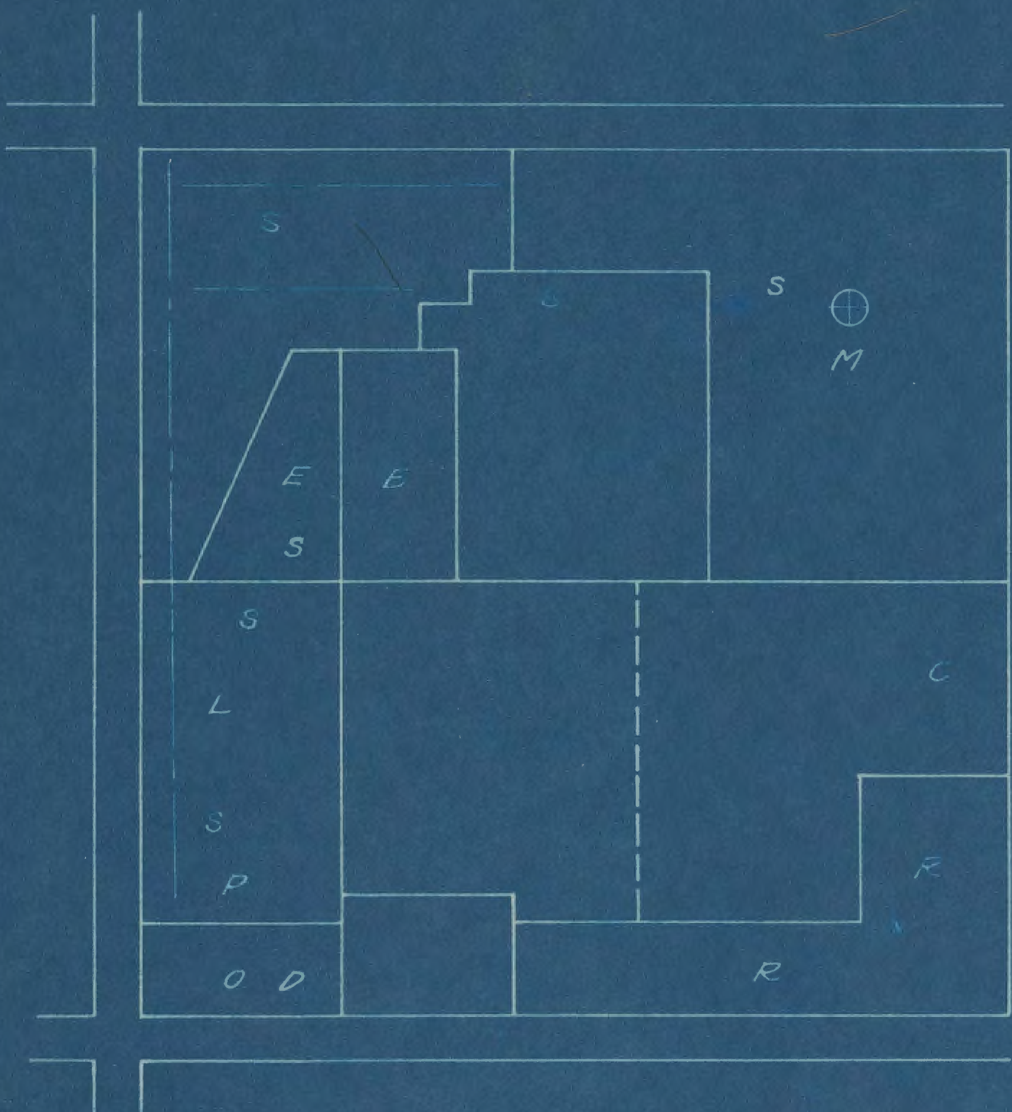


PLATE IX

PLAN OF THE CHICKASAW IRON WORKS

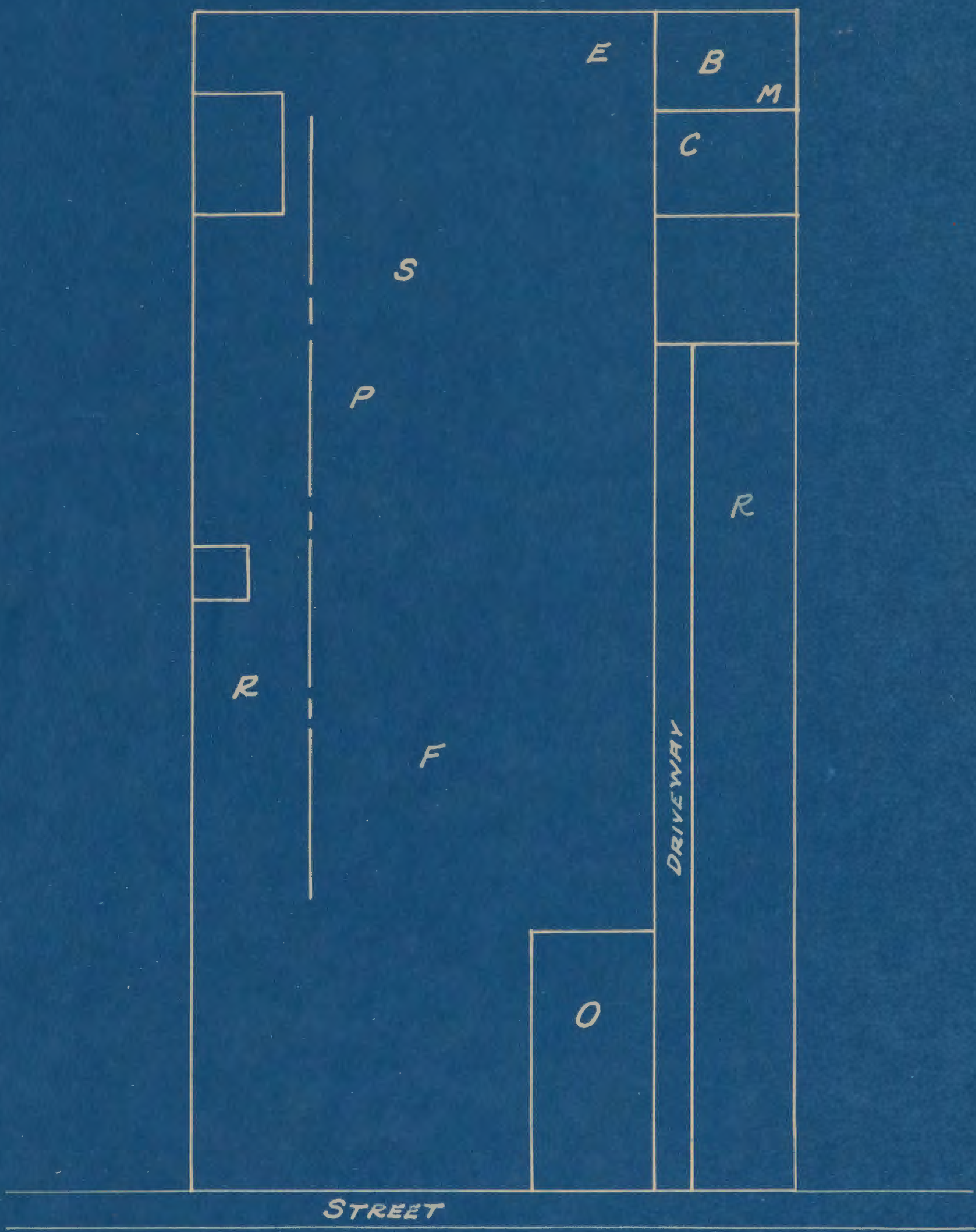


PLATE X

PLAN OF THE NASHVILLE MACH. AND SUPPLY CO.

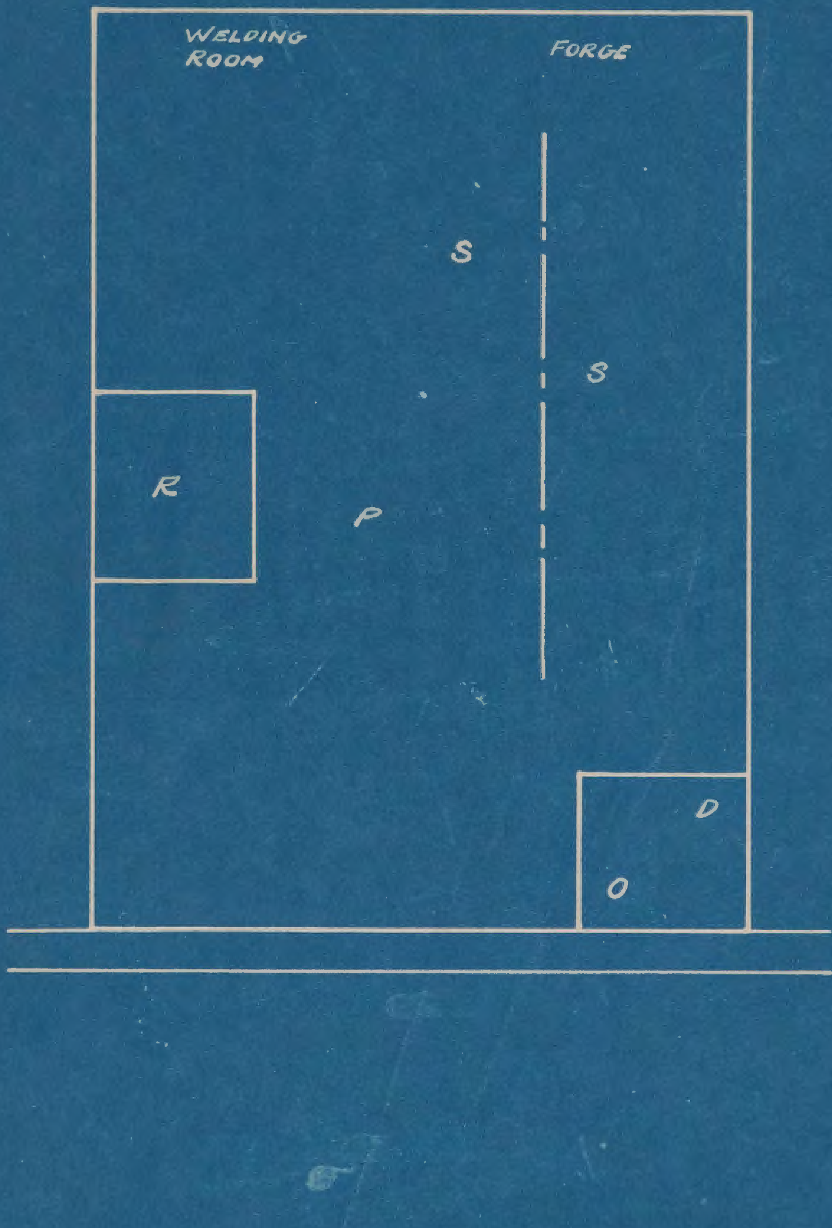


PLATE XI

PLAN OF THE ENGLERT ENGINEERING CO.

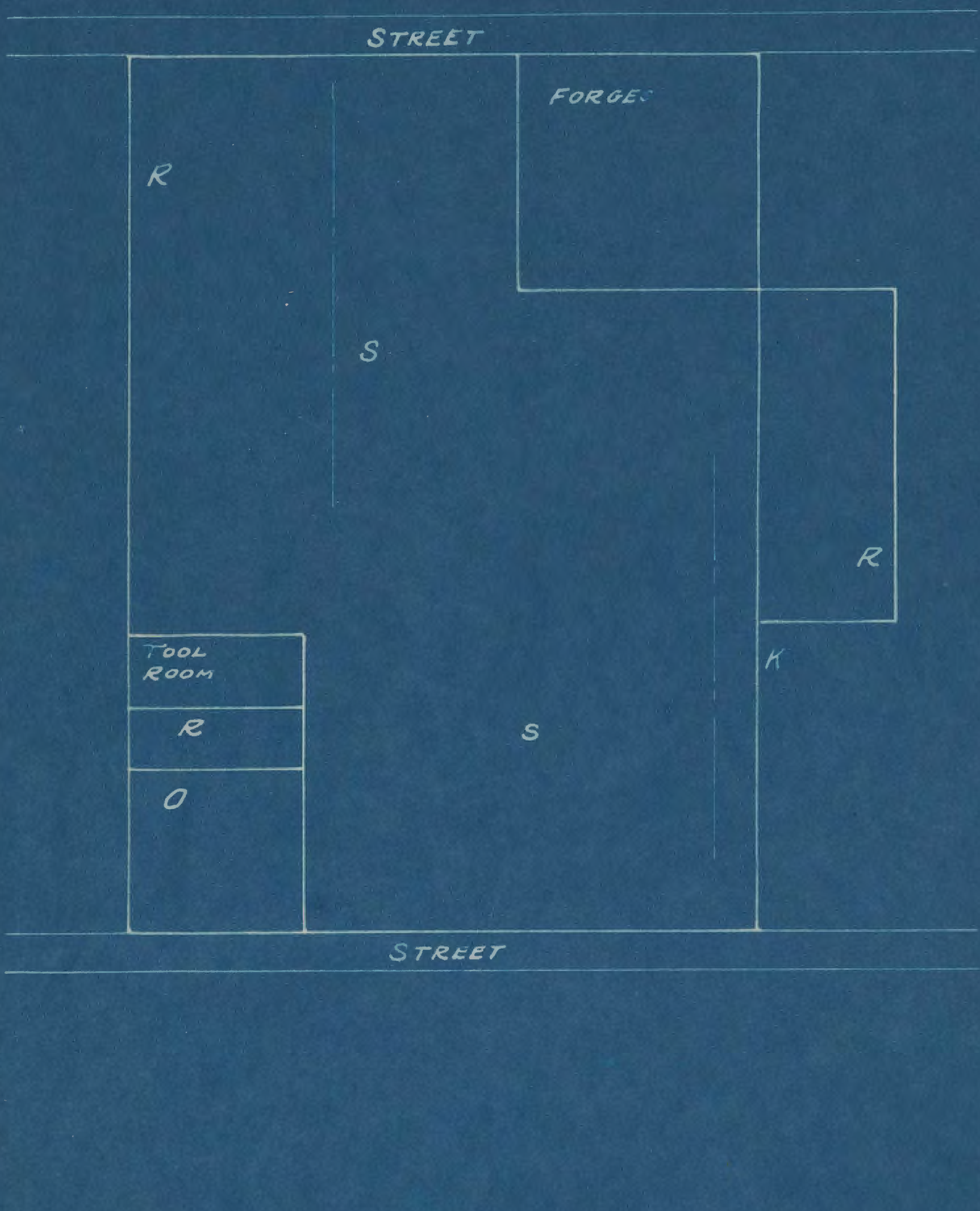


PLATE XII

PLAN OF THE JONES MACHINE CO.

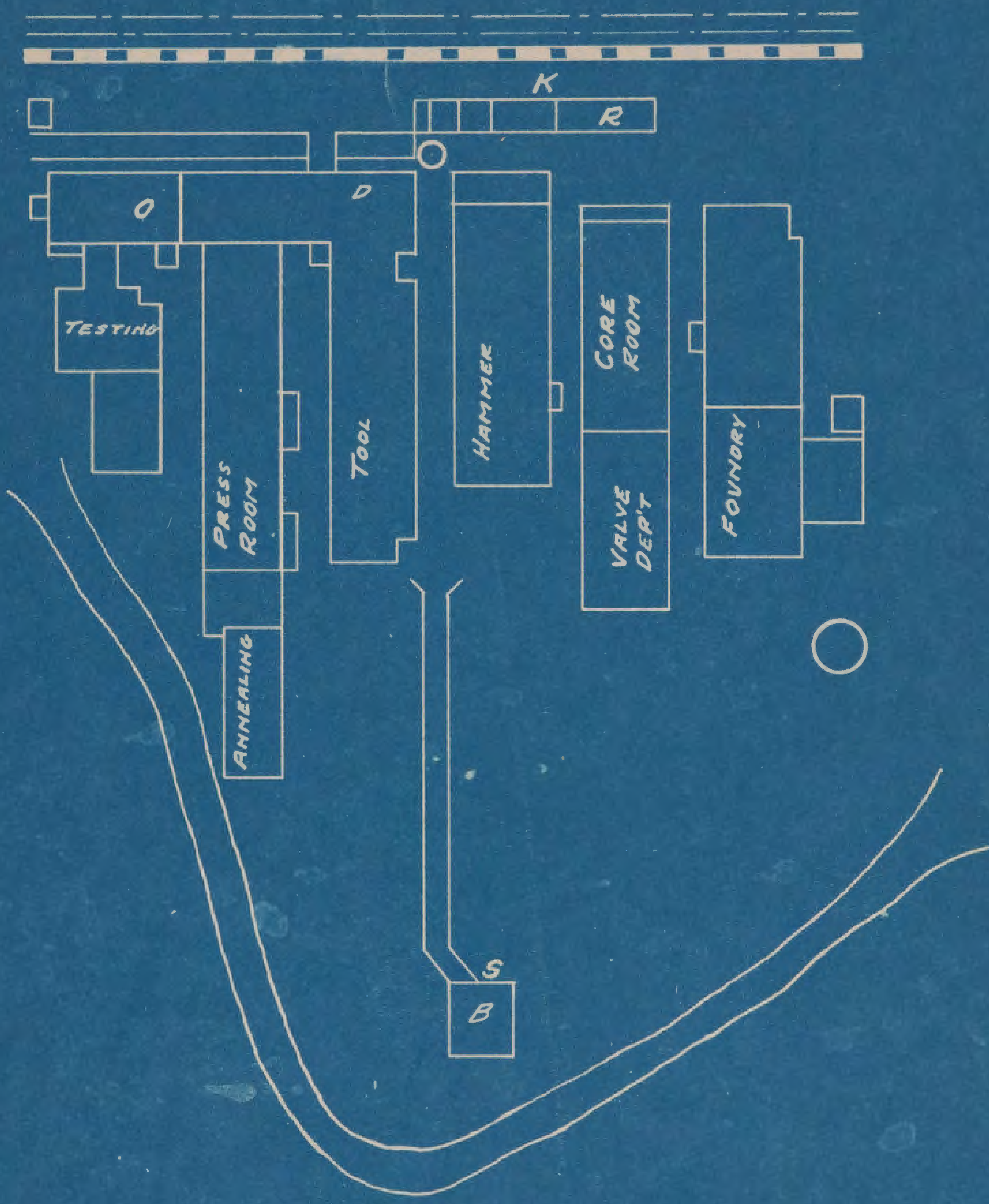


PLATE XIII

PLAN OF THE FULTON CO.

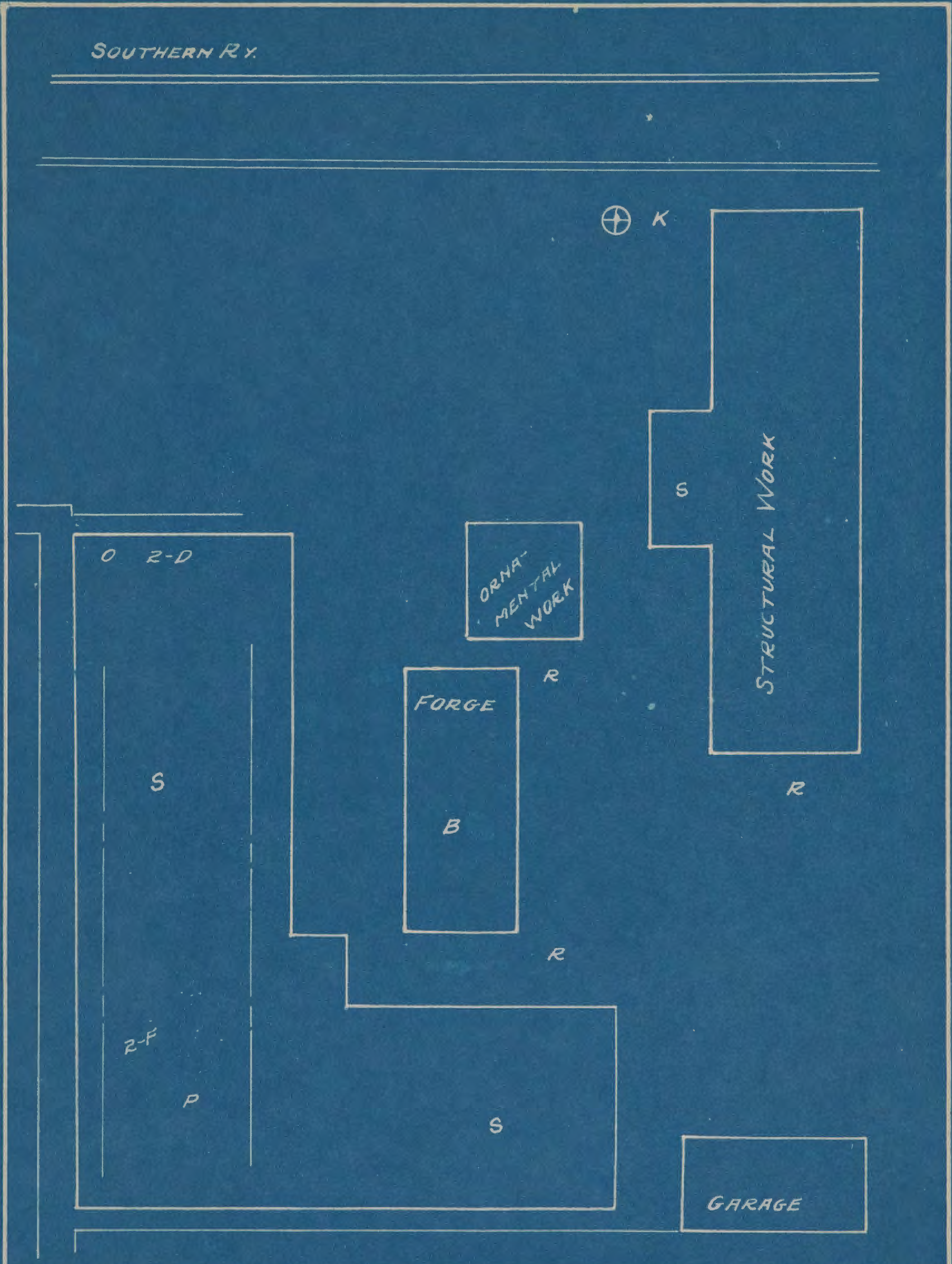
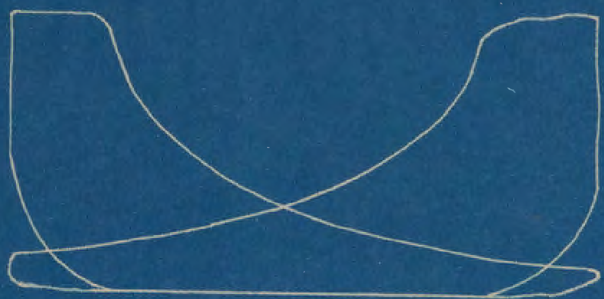


PLATE XIV

PLAN OF THE TY-SA-MAN MACHINE CO.

CORLISS VALVE
AT
ANDRES STONE & MARBLE CO.

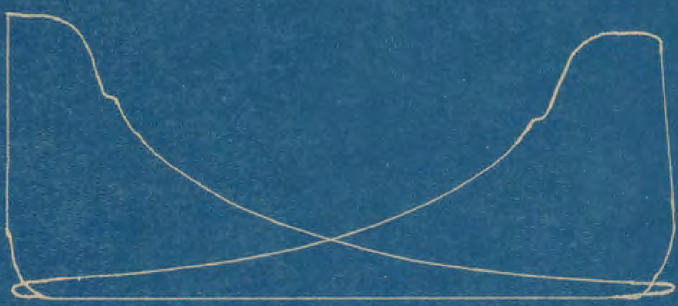


HARDIE-TYNES CORLISS
AT
KNOXVILLE MARBLE CO.

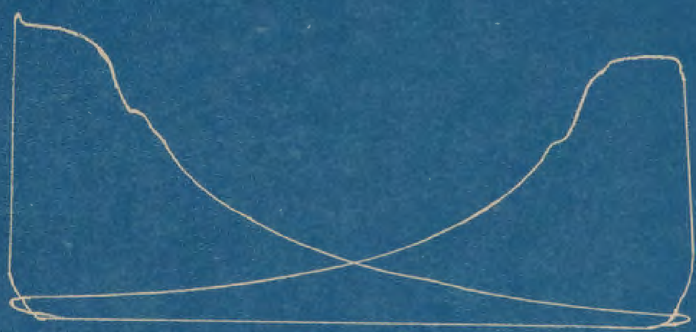
SLIDE VALVE
AT
CHICKASAW IRON WORKS

PLATE XV

SAMPLE INDICATOR CARDS



CORLISS VALVE
AT
THE GRAY-KNOX MARBLE CO.



CORLISS VALVE
AT
THE MEADE MARBLE CO.

PLATE XVI
SAMPLE INDICATOR CARDS

APPROVAL

The foregoing thesis is hereby approved as a creditable study of an engineering subject, carried out and presented in a manner sufficiently satisfactory to warrant its acceptance as a prerequisite to the degree for which it has been submitted. It is to be understood that by this approval the undersigned does not necessarily endorse or approve any statement made, opinion expressed, or conclusion drawn therein, but approves the thesis only for the purpose for which it is submitted.

Signed W. R. Woolrich

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