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

BY

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I.

Introduction.

During the past few years many of our industries have been passing through a period of depression. Many changes have been made in manufacturing policies during these years. Some of the companies have tried cutting production as a means of improving their financial condition while others have tried to preserve their profit by cutting the wages of their employees. It is the belief of the writer that a more logical solution of the problem would be secured by the application of scientific systems of management. The purpose of this work is to suggest a scheme which might be used in the solution of such problems.

The primary object of the work is an investigation of the operating conditions and power requirements of the marble finishing mills and machine shops in some of the principal cities of the State of Tennessee. No attempt has been made to investigate the complete system of management. This report covers the general operating conditions in the plants together with a more detailed report of the power consumption. For comparative purposes the power consumption was reduced to several units which will be explained later in the report.

The writer is deeply indebted to Mr. W. B. Lincoln for the units used in making comparisons and for many other ideas used in making the investigation.

II.

General Survey of the Field.

Not more than twenty years have elapsed since the manufacturing industries began to develop scientific systems of management. Yet during that period many great advancements have been made. From the beginning the exponents of these systems realized the necessity of having units which might be used for comparative purposes. However, most of the units employed up to this time have been based in some manner on cost. No doubt cost is the important factor in production, but this does not necessarily mean that cost is the only factor which might be used advantageously in making comparative units.

It was with this belief in mind that Mr. W. B. Lincoln made a survey of the hosiery and furniture mills of the State in 1922. Mr. Lincoln's work disclosed the fact that other satisfactory units could be established. So far as the writer has been able to learn, no other investigations of this nature have been made, at least not in Tennessee.

This work is in the nature of a continuation of that begun by Mr. Lincoln. Since this work is a continuation of that made in the hosiery mills and furniture shops, it is hoped that the results of this work will conform to the conclusions given in that report.

III.

Purpose of the Investigation.

The purpose of the investigation was:

First- To study the operating conditions in the marble finishing mills and machine shops of Tennessee.

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

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

Fourth- To determine the most satisfactory unit for making comparisons.

Operating conditions in the marble mills, which are found only in the eastern part of the State, are, on the whole, very good. Since the marble blocks are heavy and difficult to handle, in most cases, care was taken to work out a good routing and transportation system. Since these were important factors, good men were employed to design the plants. The result was that all of the plant was more carefully designed.

In the investigation of the machine shops, operating conditions were found to be, in some cases, very good, and in others very poor. It was found that the operating conditions were always worse in poorly planned plants. The men must have realized, subconsciously perhaps, that they were working under a handicap and as a result did less work. In these cases the floors were usually littered with tools and supplies.

IV.

General Theory.

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

First: The horse power per direct laborer. By direct labor is meant the men actually engaged in the making of the product. This includes the machine operators and the skilled hand laborers.

Second: The horse power per employee. This number includes everybody in the plant.

Third: The horse power per machine operator.

Fourth: The horse power per machine in use.

Fifth: The horse power per machine installed.

No attempt was made to secure the power consumption of the separate machines; to have done so would have been an extremely difficult undertaking and would have been of no practical value for this report. Such information would be of value to the engineer who is designing a plant, but this type of information is usually supplied by the makers of the different machines. In the case of the marble mills a division was made between the power consumption of the saws and the finishing mill. Also when possible, the power consumption of the line-shafts was found. No further division than this was attempted.

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

V.

Description of Method and Apparatus Used.

The power consumption at the steam driven plants was secured as follows: indicator cards were taken by means of a Trill indicator equipped with a special reducing wheel. The speed was secured with an Elgin tachometer. The size and stroke of the piston was secured and the power calculated by means of the indicated horse power formula. In the marble mills cards were taken over a period of ten hours when possible. In every case, except one, the power consumption of the saw mills was secured separately. This was made possible by the fact that the saw mills ran all night,while the finishing mills were operated only during the day. In several cases the power consumption of the line shaft was also found.

In the plants using electric power the consumption was secured by taking readings of the meters of the power company. These readings usually covered a period of ten hours. By taking a reading of the meter in the afternoon after the finishing mills had shut down, and another in the morning before they started, the consumption of the saw mills was found in these plants.

A close examination of operating conditions was made in each plant. A complete list of the machinery was taken in each plant. A note was made as to whether or not the machine was 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 Chapter 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 developed. A more detailed investigation would also have taken more time than was available.

There are no great sources of error in this type of investigation. There was very little danger of error in securing the power consumption. The only other possible source of error was in securing a list of the machines or of the number of workmen. Such errors,while possible, were not apt to occur. In securing the indicated horse power no allowance was made for the size of the piston rod, but this could hardly be called an error, since a correction is made only in case extreme accuracy is desired.

No particular difficulties were encountered in the work. In every case, except one, the managers did all they could to help us. In this particular case we were chased from the plant. Most of the engineers were as anxious to secure information as to the condition of their power plants as we were.

VI.

Observations.

1. The Tennessee Producers Marble Company.

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 modern standard factory design. The trusses are about twenty feet apart. The side walls are made of brick for about five feet up. The rest of the wall is made up of steel sash windows. This applies particularly to the finishing mill. The saw mill has higher walls and less window space.

Artificial light is used in the finishing shop only during the short winter days. The finishing mill has a very good lighting system. Several large lamps are suspended from the central aisle to furnish general illumination. Then other smaller lights are used for central illumination. The saw mill lamps are suspended about ten feet from the ceiling. The artificial lighting could be improved. The natural lighting is excellent.

An examination of Plate I will show that the plant is well equipped for transportation. The routing system is direct throughout the plant. Raw material is brought in on both the Southern and L. & N. Railways. This material is moved by means of two overhead electric cranes to the saw trucks. The same cranes move the material after it is sawed to the finishing mills. A short narrow gauge railway carries the material from under the crane way into the shop. The shop proper is equipped with three hand cranes which run the entire length of the building. The machines are so arranged in the shop that the work moves in direct lines from one end of the shop to the other. The storage spaces are marked on Plate I.

The machinery is well arranged for safety. The motors are high. The belts too are well above the workers' heads. All 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 of fire.

An examination of the sketch will show that the factory was well planned to take care of expansion. There is ample room to add onto either the finishing shop or the saw mills. One 90' extension has already been placed on the original saw mill building.

At the time when the plant was inspected, practically all of the machinery was in operation. There were not any machines in the plant that were not in running condition, nor were there any which were never used.

This plant is completely motorized. A list of the motors and sizes is given in Chapter VII. All the power used is purchased from the Knoxville Power & Light Company. The power requirements were secured by taking meter readings over a period of ten hours. The power data is shown in Chapter VII.

The group drive system is used on the machinery. The rub beds are driven in groups of two. They are connected by a cone clutch so that either may be used separately. The polishing machines are in groups of three machines each. Some of the larger machines have individual drives. The saw mill is divided into four groups. Two groups have four saws each and two have six saws each.

There is about 450' of line shafting in the plant. The maximum length for any section is about 60'. It was impossible to determine the power being used by the line shafting, since part of the plant runs continuously and only one meter is used. The power used for driving shafting must be small, however, because all of the bearings are in excellent condition and well oiled. Then, too, with short shafts there is less likelihood of the shafts being out of alignment.

The workmen found in this plant are about the average found in any industry. They were all secured by direct application at the plant. The men who do the carving work are the only skilled laborers used in marble work. The result is that very little trouble is had with labor.

Water is of vital importance in marble mills. Large quantities are used both in sawing and in finishing. The water for this plant is secured from Second Creek. (See Plate I.) It is pumped to the plant by an electrically driven centrifugal pump. Two pumps are installed. Either may be driven by one motor. The capacity of each pump is 500 gallons per minute. The water is discharged into the same creek.

All of the buildings are heated by steam. This steam is provided by a 125 HP. Dallas boiler operating under five pounds pressure. The boiler is located between the pump house and saw mill on the bank of Second Creek. It is almost underground. The result is that the ashpit is usually full of water almost up to the grate bars and very poor service is secured. Plans are now being formed for improving the heating system.

2. The Knoxville Marble Company.

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 side walls and trusses are of wood. This building is far from fire-proof.

The artificial light here is supplied by a direct current generator, which also runs the motor for a coal conveyor. During the summer months no artificial light is necessary 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 central lights for the separate machines.

The routing system is direct throughout the plant. The raw material is unloaded and placed on the saw carriages by means of derricks. From the saw mill the material is taken into the finishing mill by hand. The moving is done within the shop by means of two sets of overhead cranes. One craneway runs down the central span and one down the span near the railway. (See Plate II.) The loading platform is also shown on this plate.

The weak point in the interdepartmental transportation system is at the door between the mill and the shop. The only way by which the material can be transferred from the derrick to the cranes is by hand. A large saving in labor would be made by putting a short spur of narrow gauge railway through this doorway.

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 very little danger from the drives. The dangerous drives are taken care of here by using screen shields. The aisles are kept free from obstructions. Most of the floor is swept each day.

As stated before the plant is constructed almost entirely of wood. The only exception is that the boiler room is made of brick. The nature of the building, then, makes it a rather poor risk for an insurance company. The workmen add to the danger from fire by allowing greasy clothes and waste to pile up in the corners. The precautions taken against fire are good. Special pipes and hose are provided. The water is stored on a nearby hill giving about a 100# head for the system. Chemical extinguishers are also used.

The main building is not very well arranged for expansion. An examination of Plate II will show that the shop could be enlarged, but that it would be very difficult to increase the size of the saw mill and continue to use the same system of power distribution, that is, by long line shafts. At the time of this inspection about 80% of the installed machinery was in operation. The only machines which are seldom, if ever, used are the hoisting engine and derrick across the railway from the main plant. All the power used in the plant proper is supplied by an 18"x 36" Corliss engine, manufactured at Birmingham, Alabama. This engine is rated at 150 HP. by the owners. At the time of our visit at the plant the maximum load on the plant was 198 HP. A 60 K.W. generator which was commonly used was not in operation. The engine really is not as greatly overloaded as might be supposed. It is really under-rated. An engine of this type running 93 R.P.M. ought to develop 250 HP. The fact that the cards taken from the engine show the engine to be in very good running order is proof enough that it is not greatly overloaded. The engine seems to be in excellent shape in every way. The engineer is above the average and takes pride in his work.

The power plant also contains a Sullivan direct connected air compressor. No arrangements were made for indicating this compressor. The power consumption was approximated by means of information furnished by the makers.

Then, too, there were two hoisting engines. One of these is not used for weeks at a time. The other is used perhaps five hours each day. The average power consumption for the two was estimated.

The exhaust steam from the main engine was used to heat the feed-water and then discharged into the air. The exhaust from the air compressor and hoisting engines is 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 and the addition of a small amount to their radiation surface this company could make a great saving in their fuel bill, by using exhaust steam for heating.

Another place where a distinct saving could be made in fuel is in the main steam lines. The steam lines from the boiler to the main engine and to the compressor are not insulated in any way. The line to the hoisting engines has a cheap grade of insulation on it.

The steam used by all these engines is supplied by two Walsh and Weidner boilers. The boilers are the H. R. T. type. The capacity of each boiler is 125 HP. operating under a pressure of 125#. The boilers have separate steel stacks. Natural draft only is used. The firing is done by hand. Several small cracks were found in the setting. The boilers proper were in very good condition.

Gauges were located in the engine room so the engineer was able to supervise the work of the fireman rather closely.

The main line shaft in the mill was 300' in length. Together with the engine itself it consumed an average of 56 HP. Taking into consideration the fact that half of this was probably used by the engine, it seems that the shaft was in good condition. Observations showed that this condition was true. All the bearings were well oiled and none were running hot.

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

Three sources of water supply are maintained. The boiler feed-water may be secured from a well, the city main, or the Tennessee River. The water used in cutting is taken direct 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 pumps supplying the mill is given with the rest of the power data in Chapter VII.

3. The Meade Marble Company.

The Meade Marble Company is located on the Island Home Pike, about two miles out of Knoxville. The plant is one of the smallest of the Knoxville group. The general arrangement of the plant is shown in Plate III. The two main buildings of the plant are standard factory structures with corrugated side walls and metal sash windows. The boiler room is made of brick. The office building is a frame structure.

The natural light in this plant could be improved by the addition of a few more windows. There is ample room for the placing of these windows. The artificial light is good. Drop cords are suspended from the ceiling to furnish general illumination and most of the machines have special lights with shades.

Either the saw mill building or the finishing mill could be expanded with very little difficulty so as to take care of any amount of expansion. The plant was well planned along this line.

All transportation is done by means of derricks. The raw material is unloaded by means of a derrick operated by a steam hoisting engine. The material is moved in the finishing mill by means of hand operated derricks. This system is much more expensive for handling material than electric cranes. The company is planning to change to cranes in the near future. The routing system is direct throughout the plant.

The necessary safety devices are installed. Most of the machines have individual drives so that the problem of belts is eliminated. The aisles are kept free from obstructions.

Chemical extinguishers are used as a protection against fire.

At the time of the inspection about 80% of the machinery was in operation. One or two rather expensive machines were installed which were seldom used. These machines were not essential for the operation of the plant.

The power plant contains the following machinery: An 18"x 36" Corliss valve engine ordinarily supplies all of the power. A Buckeye balanced valve engine is also installed. This engine is only used in emergencies. Ordinarily it is used as a counter shaft between the Corliss engine and an alternating current generator. This generator is an Allie Chalmbers, three phase, 240 volt machine. It furnishes current for the shop. A 125 volt direct current generator is also installed. A 6"x 8" slide valve engine can be used to drive this generator in case of emergency.

The saws are driven by a line shaft which is belt-driven from the engine. All of the other machinery except the derrick is driven by electricity furnished by the above generators. The power consumption of the saws and also of the line shaft was secured here.

There was no way of indicating the hoisting engine. The power output was estimated.

Two boilers were installed. They were manufactured by the Lombard Iron Works of Augusta, Georgia. The boilers were of the H. R. T. type. They were fired by hand. Natural draft was used. The setting was in good condition. The feed-water was heated by the exhaust steam from the engine. The steam then passed into the air.

A steam driven air compressor was also installed, but it had not been in use for several months.

Water was secured for the boilers and for the mills from a nearby creek. For some unknown reason this water was first pumped into a muddy pond. This water was very muddy when taken from the pond and some trouble resulted due to foaming.

All of the buildings were heated by means of stoves.

4. The Appalachian Marble Company.

The Appalachian Marble Company is one of the Lonsdale group of mills. The company has an old plant and also a new one about one hundred yards from the old plant. The new plant is being arranged to put out finished products but at the time of the inspection some of the operations were performed in the old mill. For this reason the two plants will be treated as one in the report.

The arrangement of both plants is shown in Plate IV. The new plant is a modern factory structure. It was constructed within the last year and contains all of the modern improvements. The old plant consists of a group of cheap frame structures connected in every conceivable way.

Both the natural and artificial light in the new plant are excellent. The artifical light in the old plant is very good but the natural light is very poor.

The new building is so arranged that it could be expanded any amount without affecting either the routing system or destroying the looks of the plant. The building could be extended in three directions with the minimum of cost. The old plant could be enlarged but such an operation would be expensive and not very effective. As a matter of fact,it seems to be the plan of the company to abandon this plant within a few years.

The raw material is unloaded in both plants by means of electric cranes. These cranes are used to load the saw carriages. A rather unique method is used in moving the material from one machine to the next and from one plant to the other.

This moving is done by means of a two-wheeled cart pulled by a horse. This method has proved very satisfactory.

The routing system in the new plant is good. In the old plant some back tracking is done. Taking into consideration the age and position of the plant, it must be admitted that the routing system has been kept in very good shape.

Group and individual drives are used in the new mill, so that few safety devices are necessary. Very large spaces are left between the machines in this plant. In the old plant more belts are used. These belts and drives are enclosed where there is any danger of the workmen getting caught. The aisles are kept free from obstructions.

No protection against fire has been installed in the new building. In the old plant there is more danger of fire and many protective devices are used. An automatic sprinkling system is installed and in some parts of the plant chemical extinguishers are also used.

Despite the fact that this company had one of the most poorly constructed plants of the group visited, they were doing a larger business than any other company. At the time of the investigation over ninety percent. of the machinery was in operation.

Electric power only was used. All of this power was secured from the Knoxville Power and Light Company. A list of the motors installed and the power consumption are given in Chapter VII.

The buildings of these plants were all heated by means of stoves.

Ordinarily, in rub bed polishing the cutting is done by means of sand. At this plant a mixture of sand and lead was used. This method was not any more successful as far as we were able to learn, but was used because the company was prohibited from discharging their waste into the creek which runs behind the mill.

The water used in the sawing and finishing work was pumped from this creek by means of a centrifugal pump driven by motor. Part of the water used in the old plant was secured from the city.

5. The Gray Knox Company.

The Gray Knox Company is located near the junction of the L. & N. and Southern Railways. The plant has been in operation for several years. This can be readily seen by an examination of Plate V. Many additions have been made to the plant. The whole plant is somewhat jumbled, but taking into consideration the fact that the plant is several years old, the conditions are very good. Most of the buildings are made of wood. Some of them are in a good state of repair while others need repairing very badly.

The routing and transportation system has been very well developed along with the additions to the plant. Very little back tracking is done with goods in the process of manufacture. Raw material may be brought in over either the L. & N. or Southern Railway. This material is unloaded from either spur by means of an electric crane. The material is moved to the saws and finishing shop by means of this crane. After the material is within the finishing shop, quite a bit of handling is done by hand. This can hardly be avoided due to the arrangement of the shops. Overhead hand cranes are used for part of this work. This plant is really a combination of two plants. This accounts for some of the peculiar arrangements; for example, the parallel craneways which are side by side.

The natural light in some of the buildings is good and in others very poor. As was stated before, the arrangement of some of the buildings is such as to make good natural light impossible. The artificial light is fair. It is furnished by various sized lamps suspended from the ceiling. Only a few of the machines have central illumination.

The drives have been fitted with protective devices where they are needed. The protection against fire is very good.

It would be difficult to increase the capacity of the plant very much as it is now arranged.

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 at the plant is secured from a 16"x 30" simple Corliss engine made by the Filer and Stowell Company of Milwaukee. This engine is connected by belt to a Westinghouse 100 K.V.A, 240 volt, three phase alternator which operates at 900 R. P. M. The engine also drives a Northern Electric 25 K.W., 125 volt direct current generator which supplies power for the cranes. Several of the saws were driven direct from the engine. The engine was in fair condition. An examination of the cards showed the valves to be slightly out of adjustment. The valves were adjusted while the investigation was being made. At the time of the investigation the maximum load on the engine was 144 HP.

Steam was furnished by two Walsh and Weidner 250 HP. boilers. Only one of these boilers was in use. The boilers were of the H. R. T. type. Natural draft was used. The boilers were hand fired. Each of the boilers had a steel stack. There was a large crack in the stack of the boiler which was in use. The setting of the boilers was in fairly good condition. The feed-water was supplied by an independent pump. This water and the water used in the mills was secured from a nearby creek.

The temperature of the feed-water was about 195° F. An injector was used in case of emergency.

This was the only plant visited in which the exhaust steam was used for any other purpose than heating feed-water. The exhaust steam here was passed from the feed-water heater into the steam heating system. Heat was supplied for all of the plant.

The boiler also supplied steam to a small air compressor. This compressor is seldom used.

6. The Candora Marble Company.

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

The main building of the plant is a standard factory structure having steel trusses and brick side walls. The walls are stuccoed. Steel sash windows are used. The offices are in a separate building. This building is constructed of marble with a tile roof. There are two or three other small buildings. All of these buildings are well constructed and well kept.

The natural light in this plant is particularly good in the section where the finishing is done. The section where the saws are located is not so good. The cover over the loading platform keeps the light out of this part of the plant. The artificial light is fair. The general illumination is furnished by lights suspended from the ceiling. The separate machines are not supplied with lights except in a very few cases.

This plant has an excellent transportation system. The routing throughout is direct. The marble is brought into one end of the building on a standard gauge spur track. It is unloaded by means of an overhead crane. The marble is stored on the sides of the track and also on the ground at the opposite end of the building from the spur track. The unloading crane moves the material to the different machines within the shop. The finished material is taken to the crating room and loading platform on a narrow gauge track.

All necessary precautions are taken for danger. The motors are above the workers' heads. The switches and dangerous drives are enclosed. The aisles are kept clear of material. Fire protection is not necessary.

The plant is well arranged to care for expansion. The main building could be extended on either end with very little trouble.

Most of the machines were in use at the time of the inspection. Several new machines were being installed. All of the machines were in operating condition. There were no expensive idle machines in the plant.

All of the machines are run by means of electric motors. The power is secured from the Knoxville Power and Light Company. The power data is given in Chapter VII.

Both the group and individual drives are used. The saws were in groups of four each. The rub beds were in groups of two.

The line shafting was in excellent condition. The boxes were well lubricated. The shafting was in short lengths due to the group drive system. The power used by the line shafting could not be secured.

The workmen at this plant are secured by direct application. The turnover is not very large. The workmen seemed to be above the average. There was very little loafing on the job.

The water is secured from a nearby pond which is fed by springs. The water is drawn from the pond by means of a motor driven centrifugal pump. Of the two pumps installed, only one is used, except in case of emergency. The capacity of the pumps was not secured.

The buildings are steam heated. The steam is furnished by a 50 HP. H.R.T. boiler operating under 30# pressure. 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 raw material is operated by an American hoisting engine. The steam is supplied by a vertical boiler mounted on the same frame as the engine. The boiler uses an average of one ton of coal per month.

7. The Andres Stone and Marble Company.

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

This company is engaged in the finishing of marble. It is different from the other companies, however, in that only the worst of the marble from the quarry is finished. The better marble is sent to one of the Company's plants in Milwaukee.

The buildings of this plant are standard factory structures with corrugated metal side walls.

The natural light in the plant is very good. The buildings are equipped with modern steel sash windows. The artificial light is not so good. The lights are suspended from the ceiling and do not give illumination where illumination is needed. This plant runs only during the daytime, so that the question of artificial light does not need the consideration that it should have in most plants.

The routing system is well arranged. The marble is unloaded from the cars by means of an overhead crane and stored as shown in the sketch. This same crane is used to load and unload the saw carriages and also to carry the material which has been sawed to the other machines. The arrangement of the finishing machines within the shop is rather poor and necessitates the use of short spans of narrow gauge track and also more handling.

All of the machines are motor driven. Some of the machines have individual motors and others are driven in groups. Both alternating and direct current are used.

The precautions taken for safety are poor. The only protections installed are those required by law. The floor is littered with supplies and junk. Very little is done to keep things safe or neat. Fire precautions were hardly necessary and none were used.

Ample room is provided for expansion. There is enough room in the present plant for placing machinery that will increase the output 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 drive. The boxes were all well lubricated and in good working condition.

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

As was stated before, both direct and alternating current are used. The alternating current is secured from the Knoxville Power and Light Company. Alternating current is used because sufficient direct current could not be generated. The direct current is furnished by means of a Corliss engine belt connected to a 150 K.W., 240 volt, Sprague generator. The generating unit is not in the best of condition. The greater part of the load on this unit is that of the cranes. This load varies greatly every instant. This is very hard on the engine and makes it almost impossible to keep it in good condition. The engineer in charge of this power plant was above the average. He tried to keep the plant in good condition.

Steam was supplied by one 135 HP. Haynes boiler. The boiler was of the H. R. T. type. It was fired by hand. Natural draft only was used. A small vertical boiler was also installed. This boiler was only used in cleaning the main boiler. The feed water heater was made by the Milwaukee Reliance Boiler Works. The feed-water temperature was 195° F. The exhaust steam was used to heat the feed-water and then exhausted into the air.

This was the only plant visited in which complete records were 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 amount of power generated and of all the supplies used in generating it.

8. The Layne and Bowler Company.

The manufacturing plant of this company is located on Chelsea Avenue, in the northern part of Memphis, Tennessee. The company has three manufacturing plants: one at Memphis, Tennessee, one at Houston, Texas, and one at Los Angeles, California. The company is engaged in the manufacture of turbine pumps and well screens for railway, mining, and irrigation work. At the time of this inspection the Memphis plant was turning out well screens and turbine pump cases. The remaining parts of the pumps were being made in the other plants.

The buildings at this plant are standard, one story, factory structures. The side walls are made of corrugated sheet metal. They are all in first class condition.

In the case of the machine shop and other buildings, where lighting was essential, most of the side walls were made up of windows. In addition to these windows there was a raw in the north side of the roof. The natural light was excellent. The artificial light, too, was good. Both flood lights and central lights were installed.

The buildings were well equipped from a sanitary viewpoint. Rest rooms, wash rooms, and toilets were provided. All of the buildings were cleaned out regularly. All of the buildings were heated by stoves.

An automatic sprinkling system was used as a protection against fire.

The safety devices were good. All belts were enclosed.

The motors also were arranged so that there was very little danger of injury from them. The aisles were kept open.

Transportation facilities were good. Material is brought to the plant on a belt line railway. This material is unloaded by means of an electric crane. The material is moved within the plant by means of narrow gauge railways. This railway system is shown on Plate VIII.

The routing is direct throughout the plant. Practically no backtracking is done.

The machines are all motor-driven. The power is obtained from the local public service company. The motors were all of the three phase induction type. Westinghouse and General Electric motors were used. These motors, like those at practically all of the plants, were underloaded. A list of the motors is given in the chapter on power requirements.

At the time of this visit a very low percentage of the machinery was in operation. This was due to a lull in business. The machines were all in good condition and could be started on short notice. The machine shop was the only part of the plant that was in full operation. This shop, especially, was laid out along scientific lines. It contained the usual machines found in machine shops and several additional machines designed for production work.

The workmen employed in this plant were above the average in intelligence. They all seemed contented and were turning out a high grade of work.

This company uses the system which the turbine manufacturers use to a great extent; that is, when a contract is taken for an installation, one of the company engineers is sent to make an investigation of the existing conditions. The pump is then made to fit these conditions. Every pump has to pass a rigid test before it is sent out for installation. The testing department is separate from the other parts of the plant. It is one of the best equipped departments in the plant.

The company installs practically all of the machinery which it manufactures. A separate corps of workmen is employed for this work. The installation is considered a very important part of the company's work.

9. The Chickasaw Iron Works.

The plant of the Chickasaw Iron works is located in Memphis, Tennessee, at the intersection of Second Street and Winchester Avenue. This is near the business center of the city. The company is engaged in general machine and foundry work.

The building which houses the plant is made of brick. It is very old. The plant seems to have been expanded several times with very little care as to how the expansion was made.

The light in this plant is very poor; at the time of the inspection all of the lights had to be used during the day. There was practically no natural light. Numerous belt drives were used and these helped to cut off the light. The power for lighting was secured from the public service company.

Very few safety devices were found in this plant. All of the belts were uncovered. The aisles were kept clear of material but this was probably more on account of necessity than for safety.

No devices were installed as a protection from fire.

Transportation facilities were only fair. Derricks were used in the foundry to handle the heavy work. In the shops most of the work was done by hand. The routing system was fair, if consideration is given the jumbled condition of the plant.

All of the power is furnished by a 12"x18" Atlas slide valve engine. This engine takes steam for practically all of the stroke. Sample indicator cards are shown in Plate XVI. The engine is throttle governed. The engine was in as good condition as it is possible to get this type of engine. There was an indicator on the engine. Cards had been taken only a few days before this inspection. Due to the fact that an air compressor, which operated only part of the time, was a large part of the load, some difficult was encountered in securing a balanced card.

The machinery was driven by this engine through a somewhat complicated system of line shafting. No attempt was made to secure the power consumption of this shafting but it must have been rather high.

In spite of its jumbled condition, this plant seemed to be getting all of the work that could be handled. At the time of this inspection nearly ninety percent. of the machinery was in operation. Everything was crowded. The tools had to be kept in the engine room. The management of this plant must have been especially good or they could not have gotten along so well under the existing conditions.

The workmen were about the average in intelligence and industry. Negroes were used for manual labor.

Steam was supplied for the engine by one 75 H.P. boiler of the H.R.T. type. The boiler was fired by hand. The setting was in good condition. The boiler was placed in an extremely awkward position, making the work of firing very difficult. The coal was at a higher level than the fire doors. No insulation was used on the steam pipes.

The foundry was a very dark and disagreeable place. The storage room for patterns and also the pattern shop were on the second floor. Two derricks were used in the foundry proper for handling the ladles. The cupola was situated so that it was charged in a separate room from the foundry. The metal outlet was into the foundry. This company had the reputation of turning out very good work. At the time of the inspection they were making all of the castings used at the works of the Layne and Bowler Company.

The managers of this company seemed gifted with an ability to operate successfully under extremely poor conditions.

10. The Nashville Machine and Supply Company.

The Nashville Machine and Supply Company is located near the center of Nashville, Tennessee, close to the Cumberland River. The company has a well equipped machine shop. This shop can handle almost any type of general repair work. In addition to the machine shop a rather large stock of supplies is kept on hand. Most of the supplies are used in small manufacturing plants in and near the city.

The plant occupies a two story brick building. The lower floor contains the machine shop, forge shop, a supply room, and the offices. The second floor is used for storage, woodworking and electrical repair work. There is also a brass foundry on this floor.

The building occupied by the plant is rather old and is in a poor state of repair. It is shut in on three sides by other buildings. As a result of this, the natural light is very poor. There are windows on two sides only and these windows are small. Artificial light is necessary at all times. The artificial light is fair. Some of the machines which operate most of the time are furnished with special lights.

This plant is not on a railroad. The transportation of material to and from the plant is accomplished by means of trucks. All moving of material within the plant is done 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 were enclosed in screen cases while others were not protected in any way.

Protection against fire was secured by means of an automatic sprinkling system.

As the plant is now arranged the only possible way to expand would be to buy one of the adjoining buildings. The building was very crowded at the time of the inspection. Seventy-five percent. of the installed machinery was in operation at that time.

Ordinarily, the machinery is driven by a steam engine. The power is furnished by a slide valve steam engine. The engine is 10"x12". It was manufactured by the Chandler and Taylor Company of Indianapolis, Indiana. The steam was furnished by one 75 H.P. boiler. The boiler is of the H.R.T. type and is fired by hand. The entire power plant is in poor condition and at the time of the inspection was not being used.

When the steam plant is not in operation the power is furnished to the line shaft by means of a 40 H.P. three phase induction motor. The power is secured from the Nashville Railway and Light Company. No opportunity was obtained for getting a comparison of the cost of power by the two methods.

Two main line shafts were used together with the necessary counter shafting. The shafting was in fair condition. The power used by the shafting could not be secured.

The workmen employed at this plant were very good. They seemed to be well pleased with existing conditions. Very little soldiering was noticed.

11. The Englert Machine Works.

The Englert Company is located in Nashville, Tennessee. It is in the center of the city near the Cumberland River. The company does general repair work and manufactures ornamental designs in metal.

The plant is housed in one large building one story in height. The side walls of this building are made of brick. The roof is supported by means of wood columns.

The natural light in this plant is rather poor. There are windows on only one side of the building. In addition to these windows there is a skylight in the roof. Some artificial light is used at all times. The artificial light is fair. The central lights are especially good.

This plant is not on a railroad. All of the transportation is done with trucks. No cranes or other mechanical devices are installed for handling the material within the shop.

There was a tendency on the part of the workmen at this plant to leave things where they used them. As a result of this practice, the plant was in a more or less jumbled condition. A few safety devices were installed, such as screens for belt drives.

There was no protection against fire.

It would be practically impossible to expand this plant. It is enclosed on all sides by other buildings. The only thing which could be done to increase the space for machinery would be to add another story and store the raw material and supplies in the added story. The plant was not running at capacity at the time of this inspection.

All of the machinery is driven by motors. The group drive is used. The power is secured from the Nashville Railway and Light Company.

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

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

The workmen here were very good, being about the average found in the machine shops.

12. Jones Machine and Foundry Company.

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

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

The natural light in the shops is good. Windows are cut in all of the walls. No artificial light is necessary during the day except in cloudy weather. The artificial light is fair. All of the light is furnished by lamps suspended with drop cords from the ceiling.

This plant is 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 with motor trucks. A hand operated derrick is used for loading and unloading heavy work.

The machinery is arranged within the plant so as to avoid unnecessary handling of heavy material.

The shops are kept in very good condition. All of the tools and supplies were kept in their proper places. All necessary safety devices were installed. Practically all of the belt drives were enclosed.

The only devices used as a protection against fire were chemical extinguishers.

The plant could be expanded to any extent with very little trouble. The buildings now in use are very crowded.

All of the machinery was driven by means of electric motors. The group drive system was used. All of the motors were of the induction type. The power was secured from the local public service company. A list of the motors and power requirements is given in Chapter VII.

Two line shafts were used. These shafts were in good condition.

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

The foundry was in good condition. All of the moulding work was done by hand. This department was well arranged.

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

Employees were secured through direct application. Only a few men were employed. There was practically no turnover. The men employed at this plant were better workers than the average found in the machine shops.

The buildings were heated by means of stoves.

13. The Fulton Company.

The Fulton Company is located in Knoxville, Tennessee, near the intersection of the Louisville and Nashville Railway and Kingston Pike. The company is engaged in the production of many articles, most of which are used in steam fitting work. The principal product of the company is automatic pressure control valves. Practically all of the articles which are being manufactured were invented by Mr. Fulton who is now the head of the company.

The manufacturing plant of this company occupies several large buildings. The layout is shown in Plate XIII. The buildings are all fram structures. The outside walls are stuccoed, giving the entire plant a very pleasing appearance. These buildings are of various heights, depending on their use. The tallest building has three stories.

The entire plant has been very carefully planned. The lighting, both natural and artificial, is excellent. The side walls of practically all of the buildings are made up largely of windows. Steel sashes are used. Very little artificial light is used during the day. The artificial lighting system is well planned. In some of the shops indirect light only is used. In others mercury arcs are used for general illumination and each machine has a central light.

As was stated before, this plant is located on the Louisville and Nashville Railway. All raw material and supplies are brought in over this road. Most of the finished material is shipped on this road.

The loading and unloading of material is done mechanically. Cranes are provided for this work. An underground tunnel is used in moving the coal from the railroad to the storage bin near the boiler room.

The routing system is good throughout the plant. There was very little unncessary moving of material within the plant. There was only one department in which a change in the routing system would have saved any appreciable amount of money. This was in the corrugating department. Between each finishing process in this work the material had to be annealed. The machines were arranged just backward for this work. The foreman realized that the machines should have been reversed. The machines were changed during the time when this inspection was made.

Interdepartmental transportation was accomplished by means of small carts which were moved by hand. While this system is very satisfactory, it is the belief of the writer that a saving could be made by the use of mechanical conveyors. Most of the parts were small and could be easily handled in this manner.

The shops are all kept in good condition. Tool rooms are provided for each department. The tools are checked out. The inspecting department is entirely separate from the production departments, so as to prevent faulty material from being slipped by. The floor space is large, allowing the use of wide aisles. All of these aisles are kept clear. The drives are so arranged that there is very little danger of injury from them. The dangerous drives are screened in.

An automatic sprinkling system is used as a protection against fire. This system has a separate tank which is kept full of water at all times, thus insuring the necessary supply of water in case fire should break out. The production could be increased a large percent. without the addition of new buildings. Then, too, as the plant is now arranged, additions could be made to all of the buildings without destroying the arrangement or the looks of the plant.

All of the machinery was driven by means of electric motors. Both the group and individual drives were used. Only the large machines had individual drives. The power was secured from the Knoxville Power and Light Company. A list of the motors and power requirements is given in Chapter VII.

The shafting was all in good condition due to the use of the group drive. The shafting was kept in good condition. A man was employed to inspect the shafting and belting each day.

The workmen employed at this plant are secured largely through application. This applies particularly to the common laborers. Some of the more skilled men are secured through employment bureaus and other agencies. The workmen were above the average found in most of the plants. One reason for this fact was that the men were on piece work and had to stay on the job in order to make good wages. The tool makers were practically the only workers who were not on piece work.

This plant was the only one inspected which was operating under real scientific management. Detailed organization charts have been worked out and these must be followed, both by the executives and by the men under them. The system has proved to be a complete success.

14. The Ty-Sa-Man Machine Works.

The Ty-Sa-Man Company is 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 two other buildings are frame structures.

The first floor of the main building contains the machine shop, wood shop and offices. The second floor is used for storage. It also contains the drafting rooms. One of the smaller buildings contains the forge shop and boiler, the other contains the structural steel department.

The natural light in the shops is good. Most of the machines are placed in a row near the windows. The artificial light is fair. The general illumination is good but some of the machines which are in constant use should be supplied with more light. These machines are used at night part of the time.

The plant is located on the Southern Railway. Material may be placed on or taken from the cars by means of a derrick. This derrick is operated by hand. Most of the local work is handled by means of trucks. No mechanical devices are used in this plant for handling material. All of this work is done by hand. A bucket conveyor is used to take the coal from the cars to the storage bin.

The machines are arranged within the plant so as to cause the material to move from one machine to the next in so far as it is possible. Routing is not one of the essential features in a plant of this type.

The shops are kept in good condition. All of the aisles are kept clear of obstructions. The buildings, too, are in good condition. All necessary safety devices are installed.

No system of protection against fire is used.

Ample room is provided for expansion. At the time of the inspection the plant was running at full capacity. The company had orders on hand for three months of work.

This entire plant was operated by means of electric motors. The power was secured from the Knoxville Power and Light Company. A list of the motors and power requirements is given in Chapter VII of this report.

The tendency in this plant was to use as few motors as possible. One long line shaft drove most of the machinery. This shaft was in very good condition.

A gas engine was also installed for power purposes. This engine is used only in emergencies. It has not been in use for several months.

Employees are secured through application. The employees here were always on the job.

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

VII.

Calculations and Power Data

1. Marble Mills.

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

The machines which were installed in the marble finishing mills are classified in Table I. The arrangement of the columns is explained in the space below the table. For each plant the columns A and B were added. These results were then added together giving the total number of machines in the plant. These results are used in 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 were explained in the first part of this report, 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 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 determined by means of the formula: $I.H.P. = PLAN/33000$.

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 column "horse power of saw mills" is put in because this part of the plant was used at night as well as day. This enabled the writer to secure the power used by this part of the plant. The columns in which the horse power consumption is reduced to the different units nee no explanation. In Tables 3A, 3B, and 3C the power consumption reduced to the units shown is indicated in graphical form. The tables should be of value to the reader as they place directly before him the results of the work.

2. Machine Shops.

The same procedure was followed in recording the results of the machine shop work as in the marble finishing mill work. Table IV shows a classified list of the machinery used in the machine shops. Table V gives the results in tabular form as in Table II. In Tables 6A, 6B, and 6C, the results of the machine shop work are shown graphically.

1. Tennessee Producers Marble Company.

Power Data

Size of Motors	Number	Total H.P.
3 H.P.	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 hours)

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 Company.

Power Data

Total mill.

M.E.P.	I.H.P.
40.0	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
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 Company

Power Data (con.)

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 hoisting engines (estimated)	10 H.P.
Total load for mill	168.0 H.P.
Total load on boilers	228.0 H.P.

Engine:

Bore	18"
Stroke	36"
R.P.M.	93
I.H.P.	M.E.P. x 43

3. Meade Marble Company.

Power Data

Total mill.

M.E.P.	I.H.P.
33.0	111.0
40.0	134.0
43.0	144.0
34.5	116.0
31.2	105.0
35.5	118.0
34.0	114.0
32.5	109.0
41.0	137.5
35.0	117.0
38.5	129.0
35.0	117.0
35.5	118.0
36.5	123.0
38.0	127.0
Average load	121.3

Engine:

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

Meade Marble Company

Power Data (con.)

Sawmill only.

M.E.P.	I.H.P.
23.0	77.0
25.5	85.0
25.5	85.0
25.5	85.0
Average load	83.0

The following motors were driven by power generated at the plant.

Size of motor.	Number.	Total H.P.
25.0	3	75
7.5	2	15
5.0	5	25
2.0	1	2
Total	11	117

4. The Appalachian Marble Company.

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 on motors to rated capacity: $\frac{272}{1391.5} = 19.5\%$

5. The Gray-Knox Marble Company.

Power Data

Total mill.

M.E.P.	I.H.P.
35.0	117.0
38.0	127.0
35.5	119.0
35.0	117.0
33.0	111.0
40.0	134.0
38.5	129.0
36.5	123.0
43.0	144.0
34.5	116.0
31.2	105.0
35.5	118.0
34.0	114.0
32.5	109.0
41.0	137.5
Average load	121.0

Sawmill only.

24.5	82.0
25.5	85.0
25.5	85.0
23.0	77.0
Average load	82.2

The Gray-Knox Marble Company.

Power Data (con.)

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 The Knoxville
Power and Light Company 660 K.W.H. (7.5 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 Company.

Power Data

Size of Motor.	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: 1620 K.W.H. (8.83 hours)

Average load: (total plant) 246 H.P.

Ratio of average load on motors to rated capacity: $\frac{246}{622.5}$ = 39,5%

Power used by sawmill: 1470 K.W.H. (13 hours)

Average load on sawmill: 151 H.P.

Ratio of average load on motors to rated capacity: $\frac{151}{250}$ = 60.5%

7. Andres Stone and Marble Company.

Power Data.

Total mill.

M.E.P.	I.H.P.
31.5	138
26.5	116
28.5	125
34.5	151
35.0	153
30.5	133
29.5	129
32.5	142
28.0	122
28.0	122
31.0	136
28.5	125
27.5	120
Average load	131.7

Andres Stone and Marble Company.

Power Data (con.)

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

Electrical power secured from the Knoxville Power and Light Company: 170 K.W.H. (7 hours)

Average load: 32.6 H.P.

Ratio of average load to rated capacity: $\frac{32.6}{140}$ - 23.3%

Total power consumption of the plant: 164.3 H.P.

8. The Layne and Bowler Company.

Power Data

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 on motors to rated capacity: $\frac{56.5}{279.5} = 20.2\%$

9. The Chickasaw Iron Works.

Power Data

M.E.P.	I.H.P.
36.0	44.0
33.5	41.5
34.0	42.0
33.0	41.0
23.0	29.0
35.0	43.0
29.0	36.0
34.0	42.0
Average load	39.8

Engine:

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

10. The Nashville Machine and Supply Company.

Power Data

Size of Motor	Number	Total H.P.
40	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: $\frac{32.8}{40} = 82.0\%$

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 hours)

Average load: 13.8 H.P.

Ratio of average load on motors to rated capacity: $\frac{13.8}{19} = 72.5\%$

12. Jones Machine Company.

Power Data

Size of Motor	Number	Total H.P.
5	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 hours)

Average load: 37.5 H.P.

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

13. The Fulton Company.

The Fulton Company has 1000 horse power of electric motors installed. These motors vary in size from ½ horse power to 50 horse power. The average is approximately 7.5 horse power.

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

Total electrical power used:	2030 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 Data

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

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

Average load: 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.

After a careful examination of the data included in this report, the following conclusions were arrived at:

First: The power requirements of marble mills can be reduced to certain definite units which may be used for comparisons. 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 units are shown graphically in Tables 3A, 3B, and 3C. An examination of these plates will give the reader a good estimate of their usefulness.

Second: The relations mentioned above are affected to a large extent by operating conditions. Take, for instance, the unit used in Table 3A, the horse power per machine installed, with this unit the Meade Marble Company shows the greatest percentage of variation from the average. This condition is explained by the fact that the Meade Marble Company uses smaller machines, and consequently more time for the work, than does the Gray-Knox Company or any of the other companies. In Table 3B the Knoxville Marble Company, the Gray-Knox Company, and the Andres Stone and Marble Company show the largest amount of power per machine in use. This condition exists because nearly all of the work at these plants is on the saws and rub beds, machines using a large amount of power. Table 3C gives the power per employee. No distinct relation was obtained with this unit but it should be valuable to use in connection with the other units.

Third: The unit which could best be used for 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.

An examination of the data obtained at the machine shops has lead to the following conclusions:

First: That the horse power requirements of the plants visited cannot be reduced to any satisfactory unit for comparisons. In connection with the above conclusion the writer wishes to state that it is very probable that some relation would exist if the companies were engaged in the same work. However, no two of the plants covered by this report are engaged in the same type of production.

The power requirements for the machine shops were reduced to the various units. The results are shown graphically in Tables 6A, 6B, and 6C.

IX.

Bibliography.

Mechanical Engineer's Handbook	- Marks.
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.

--*-*-*-*

TABLE 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			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			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	86	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	[illegible]	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.[illegible]
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.

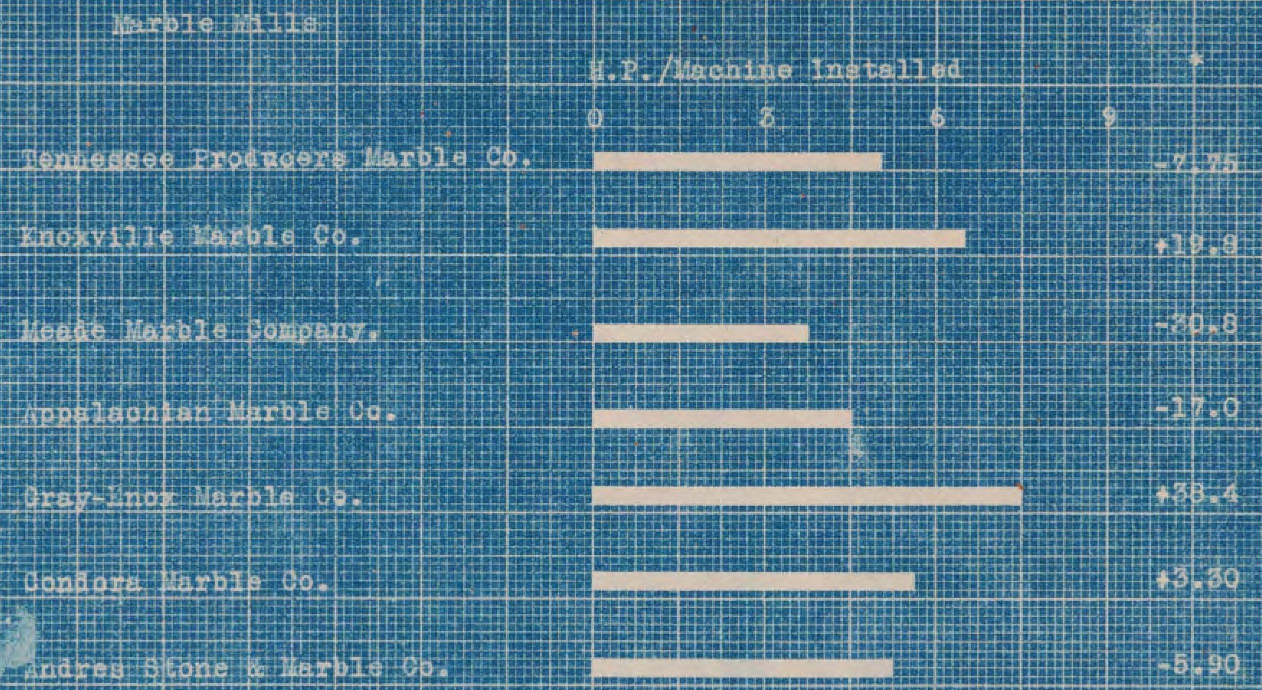
4-Appalachian Mar. Co.

5-Gray Knox Marble Co.

6-Condora Marble Co.

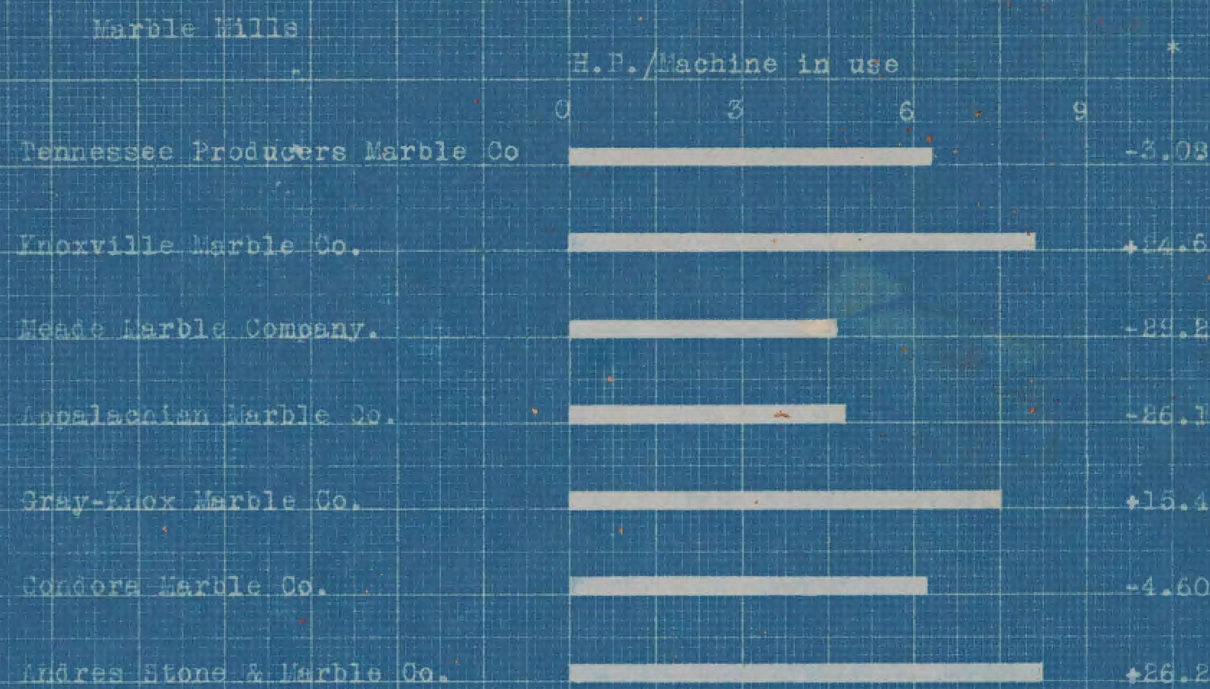
7-Andres Stone & Mar. Co.

TABLE 3A



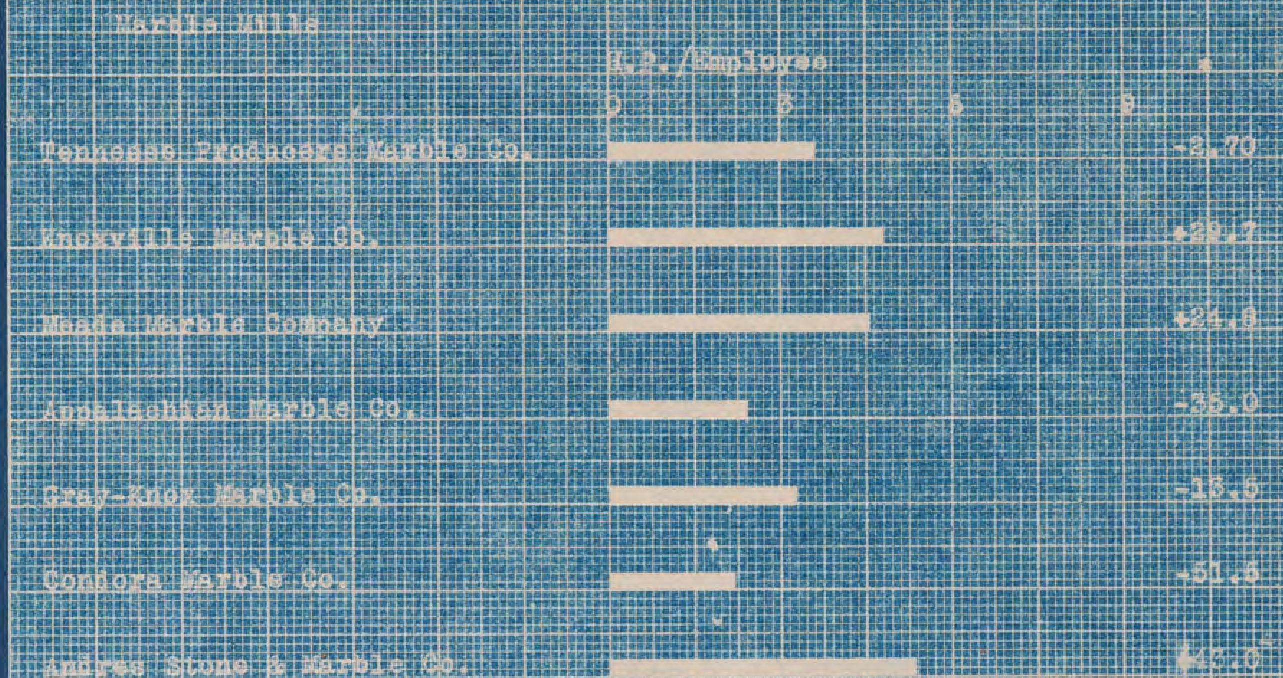
* This column gives the percent of variation from the average.

TABLE 33



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

TABLE 30



*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	-	-	1	-	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	[illegible]	-	-
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-Layne & 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.

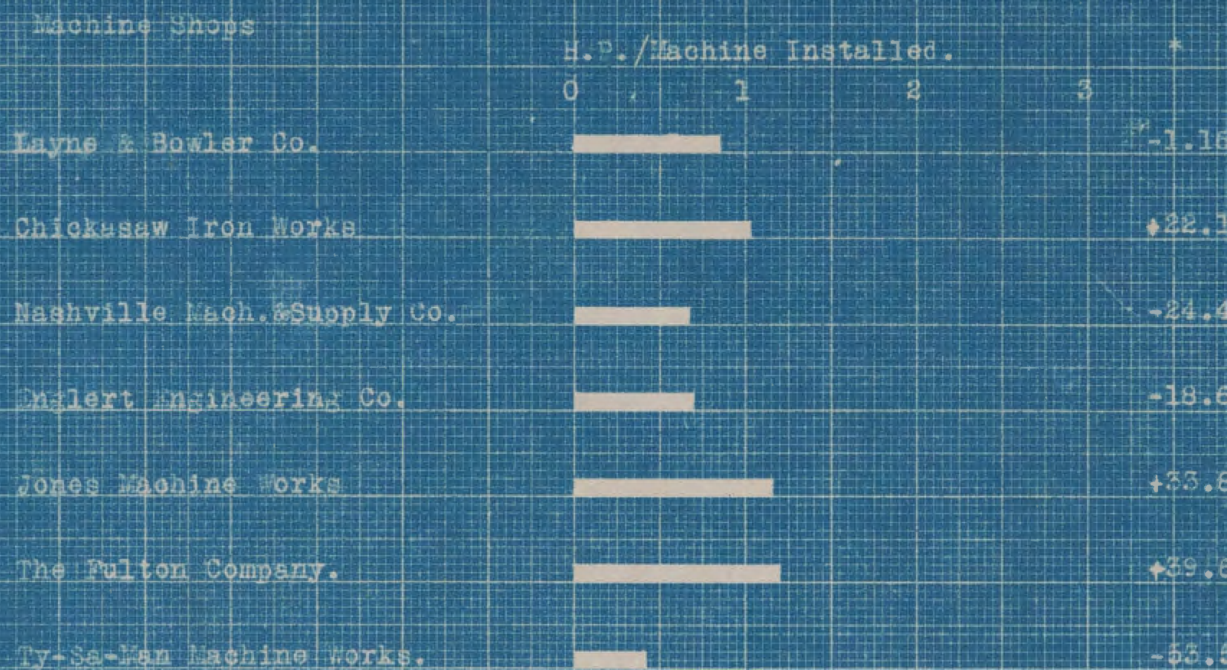
4-Englert Engineering Co.

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.

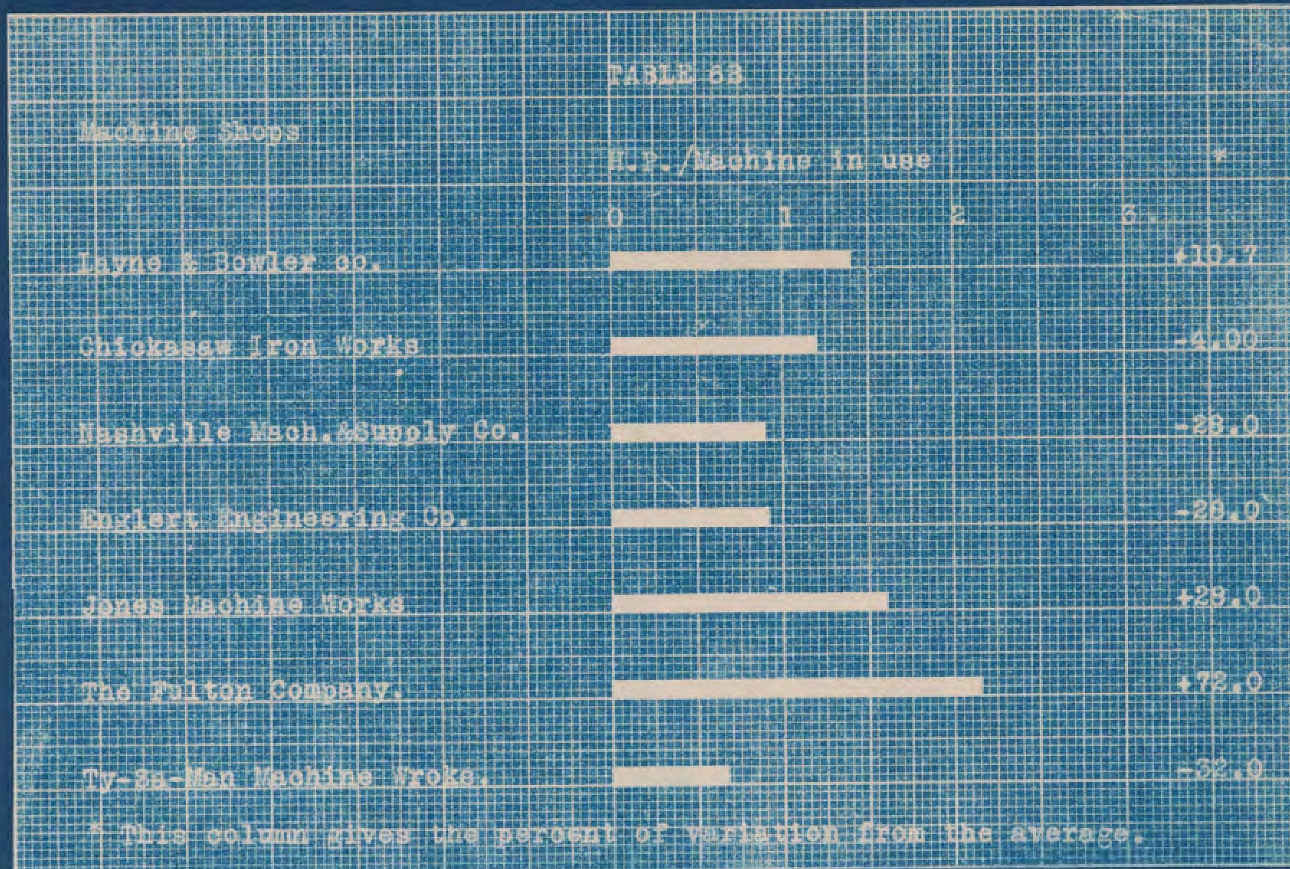
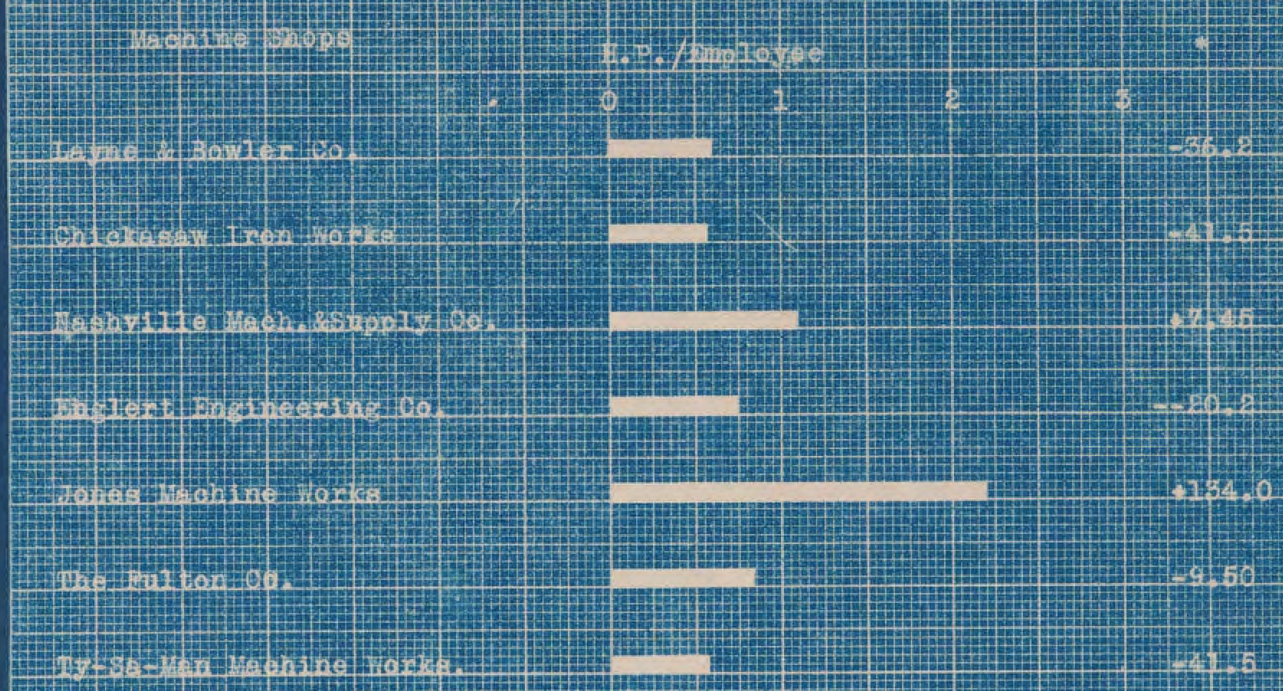


TABLE 63
Machine Shops
H.P./Machine in use
*
0
1
2
3
Layne & Bowler co.
+10.7
Chickasaw Iron Works
-4.00
Nashville Mach.&Supply Co.
-28.0
Englert Engineering Co.
-28.0
Jones Machine Works
+28.0
The Fulton Company.
+72.0
Ty-Sa-Man Machine Wroke.
-32.0
* This column gives the percent of variation from the average.

TABLE 60



* 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.

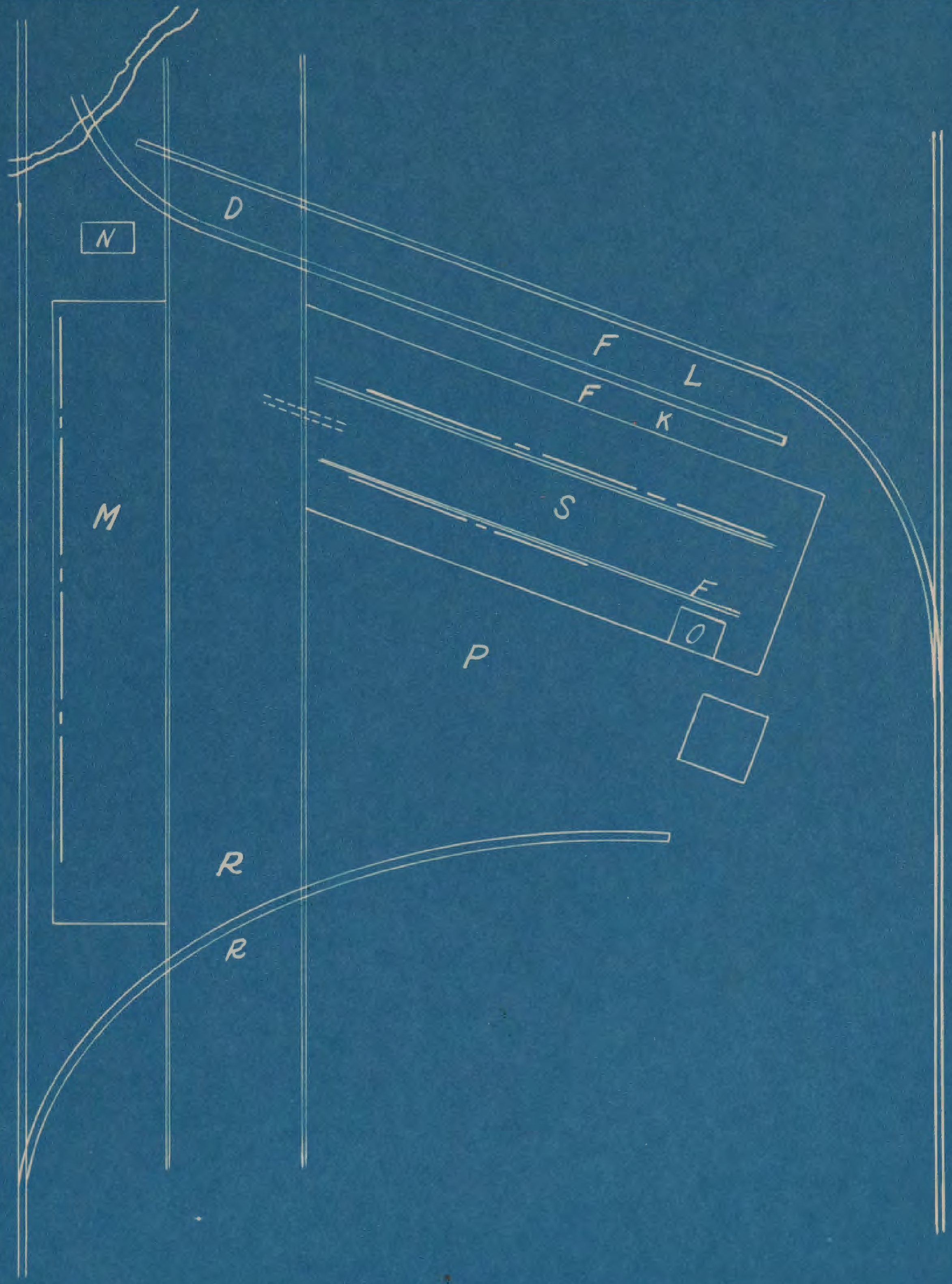


PLATE I

PLAN OF THE TENN. PRODUCERS MARBLE CO.

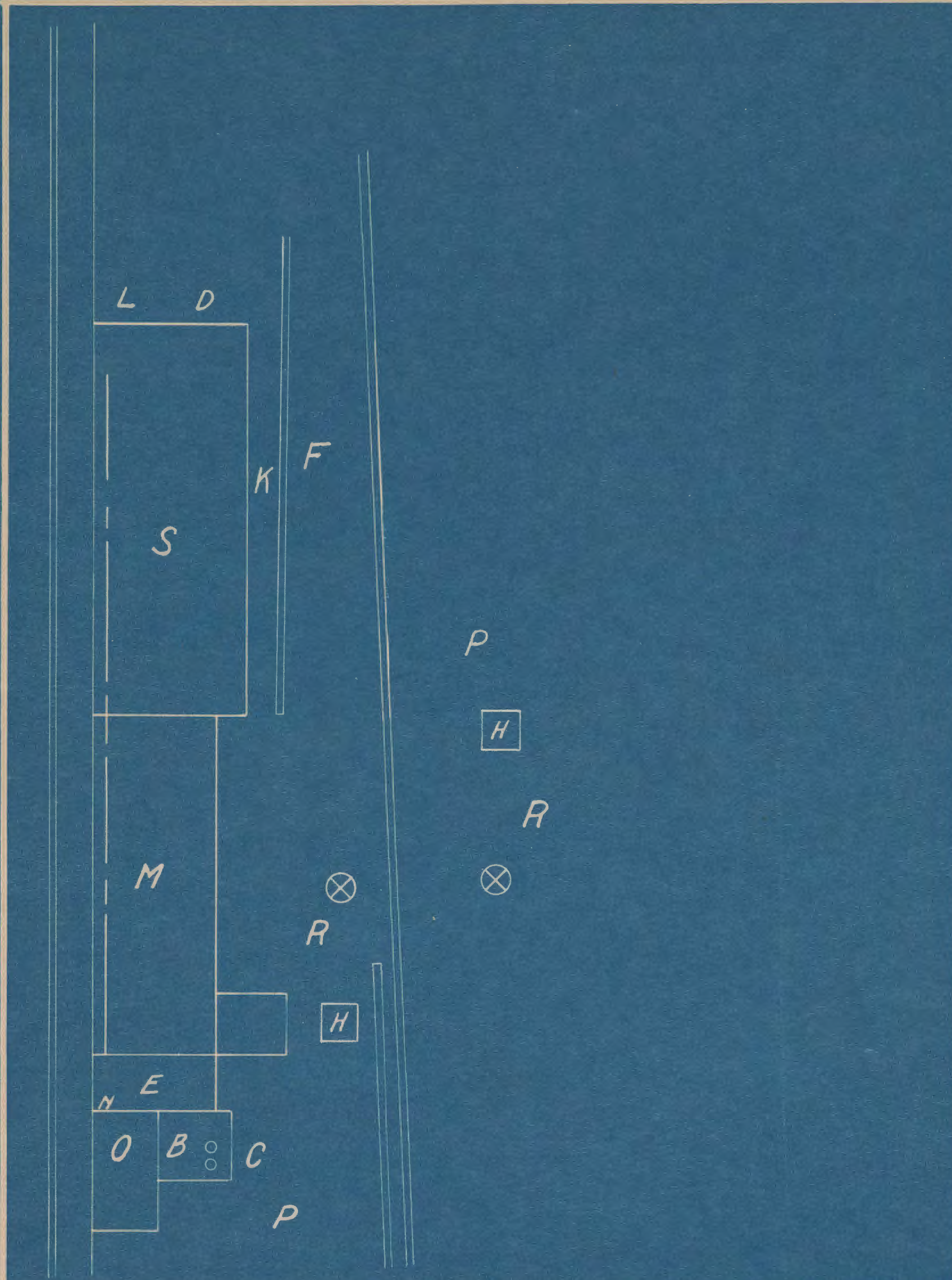


PLATE II

PLAN OF THE KNOXVILLE MARBLE CO.

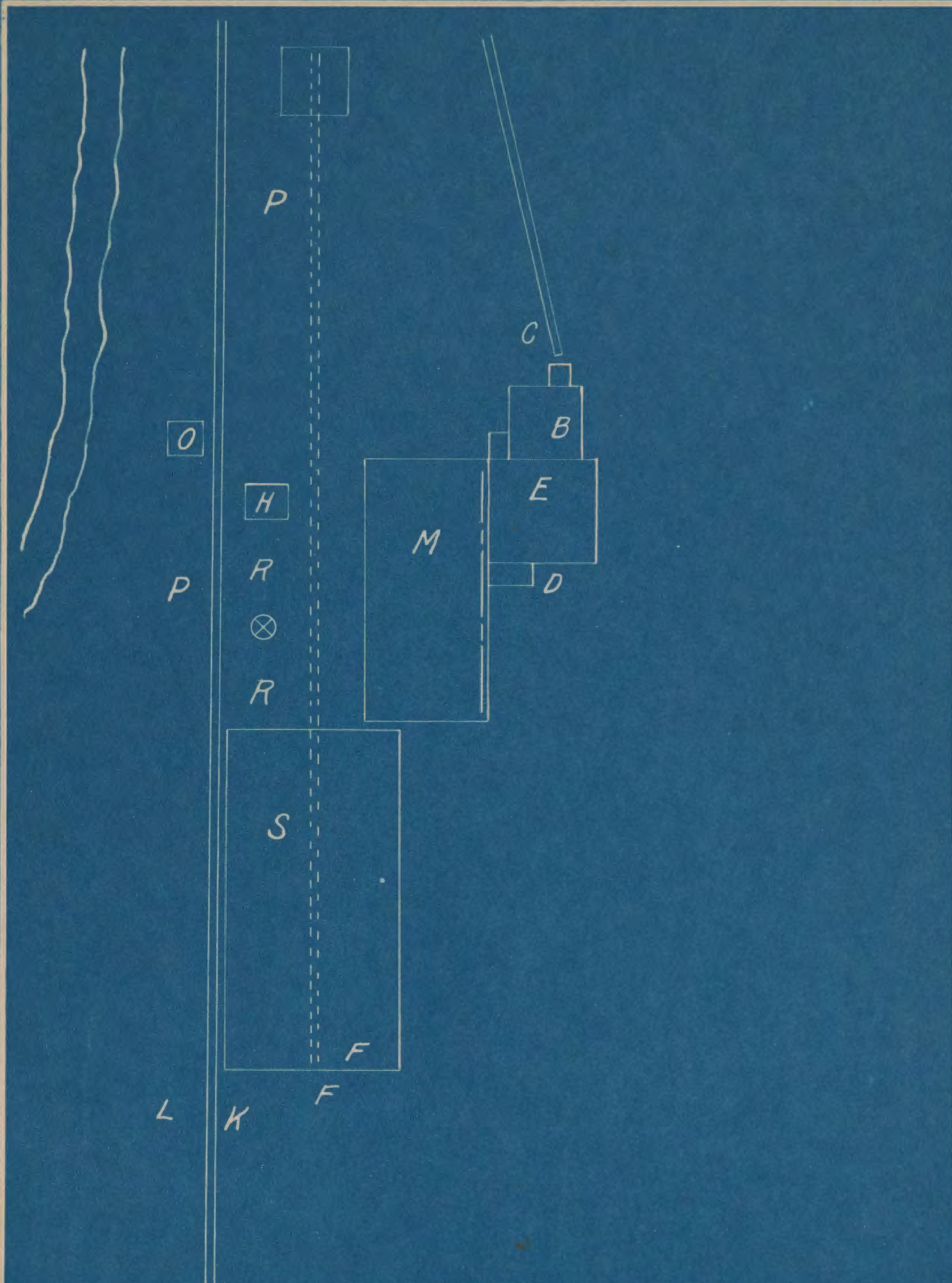


PLATE III
PLAN OF THE MEADE MARBLE CO.

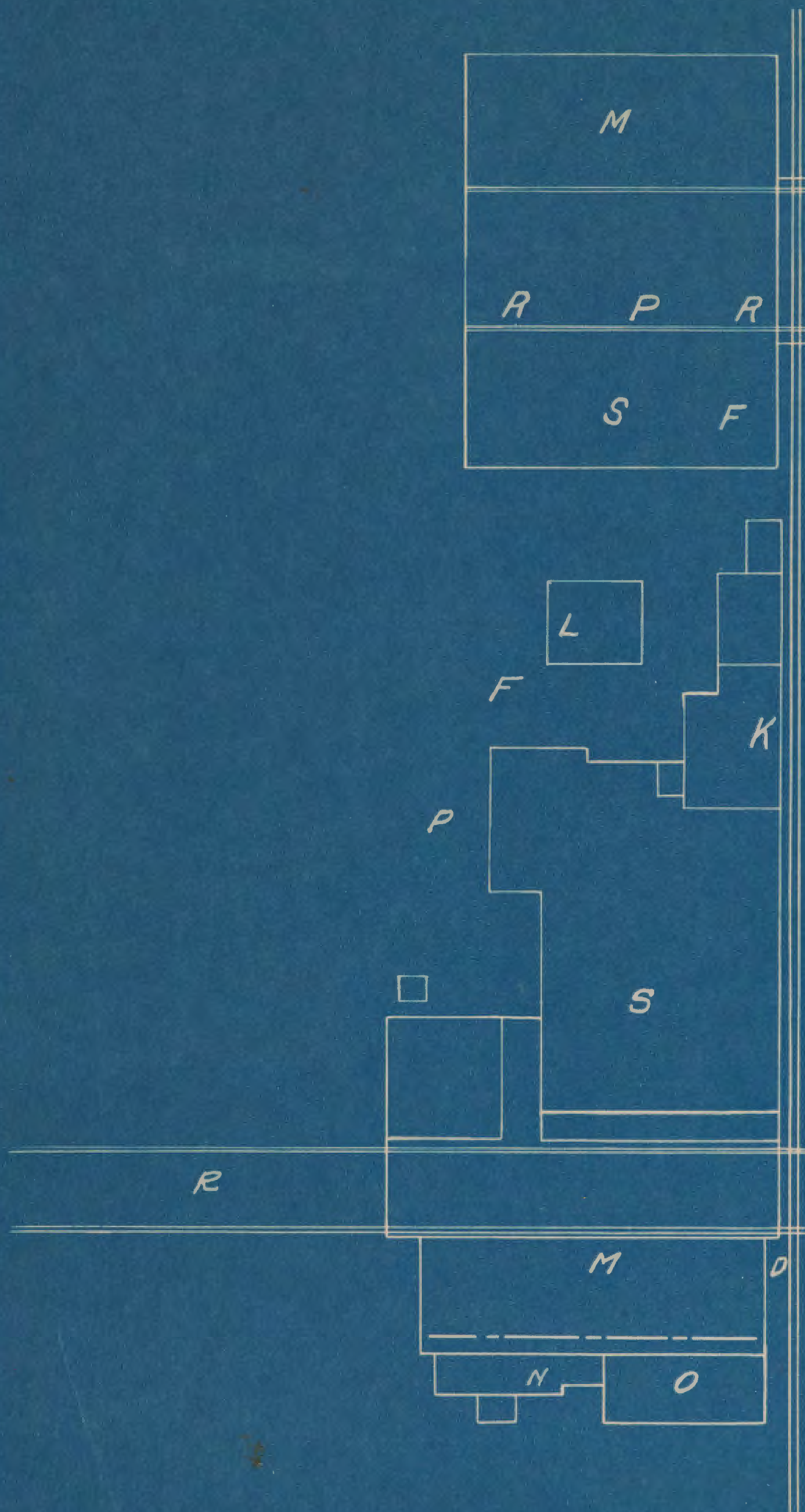


PLATE IV

PLAN OF THE APPALACHIAN MARBLE CO.

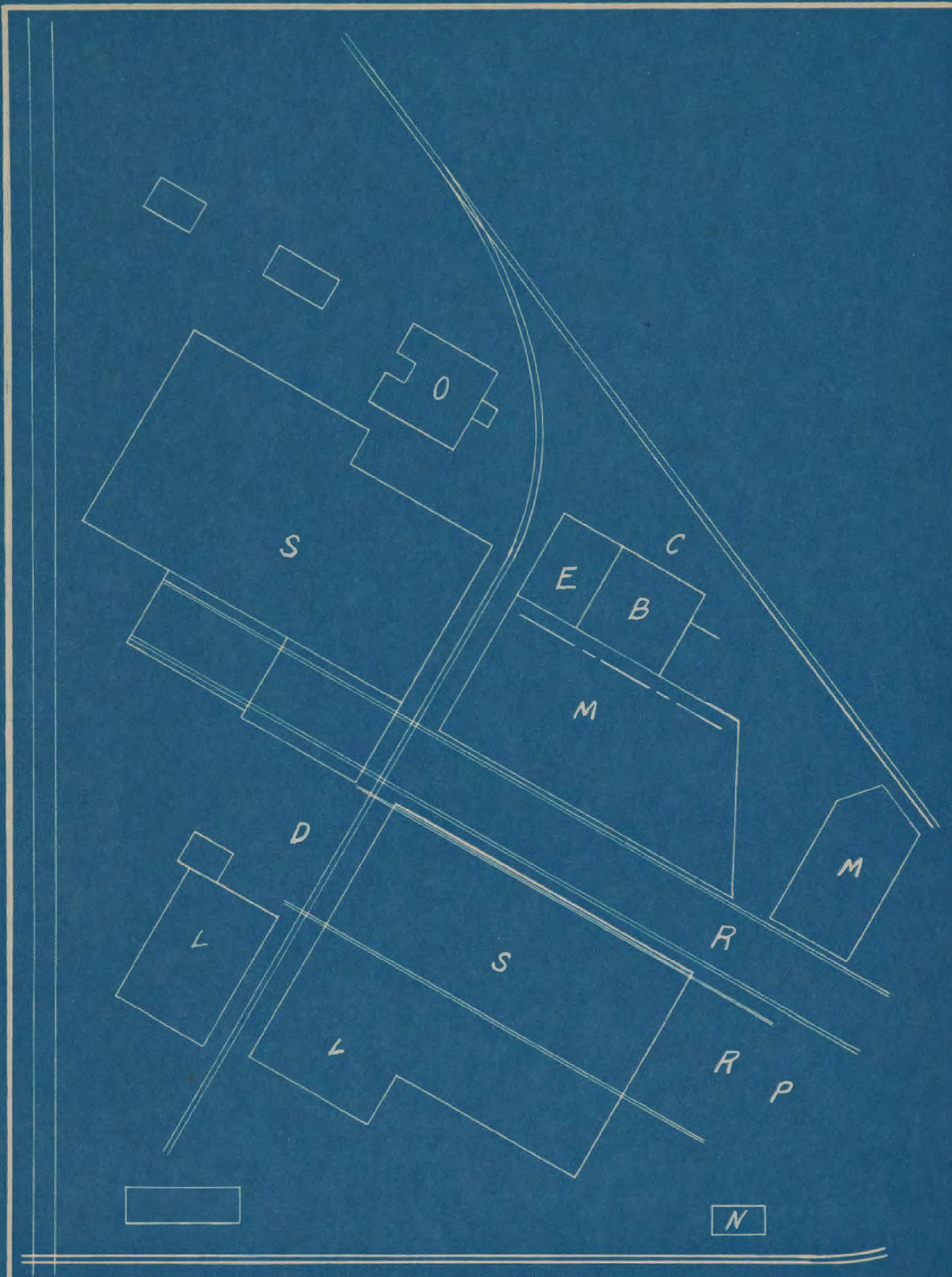


PLATE V

PLAN OF THE GRAY-KNOX MARBLE COMPANY

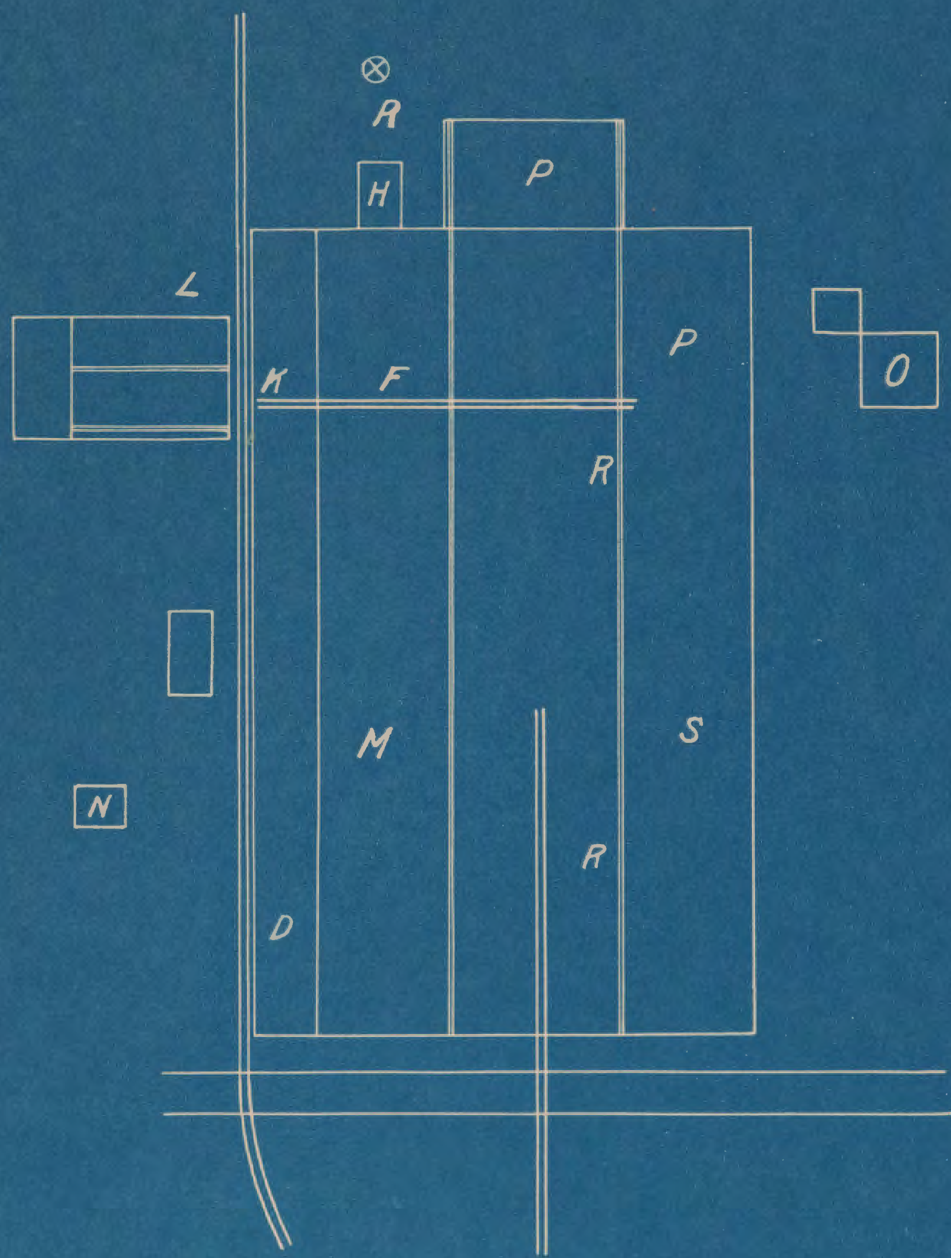


PLATE VI

PLAN OF THE CONDORA MARBLE COMPANY

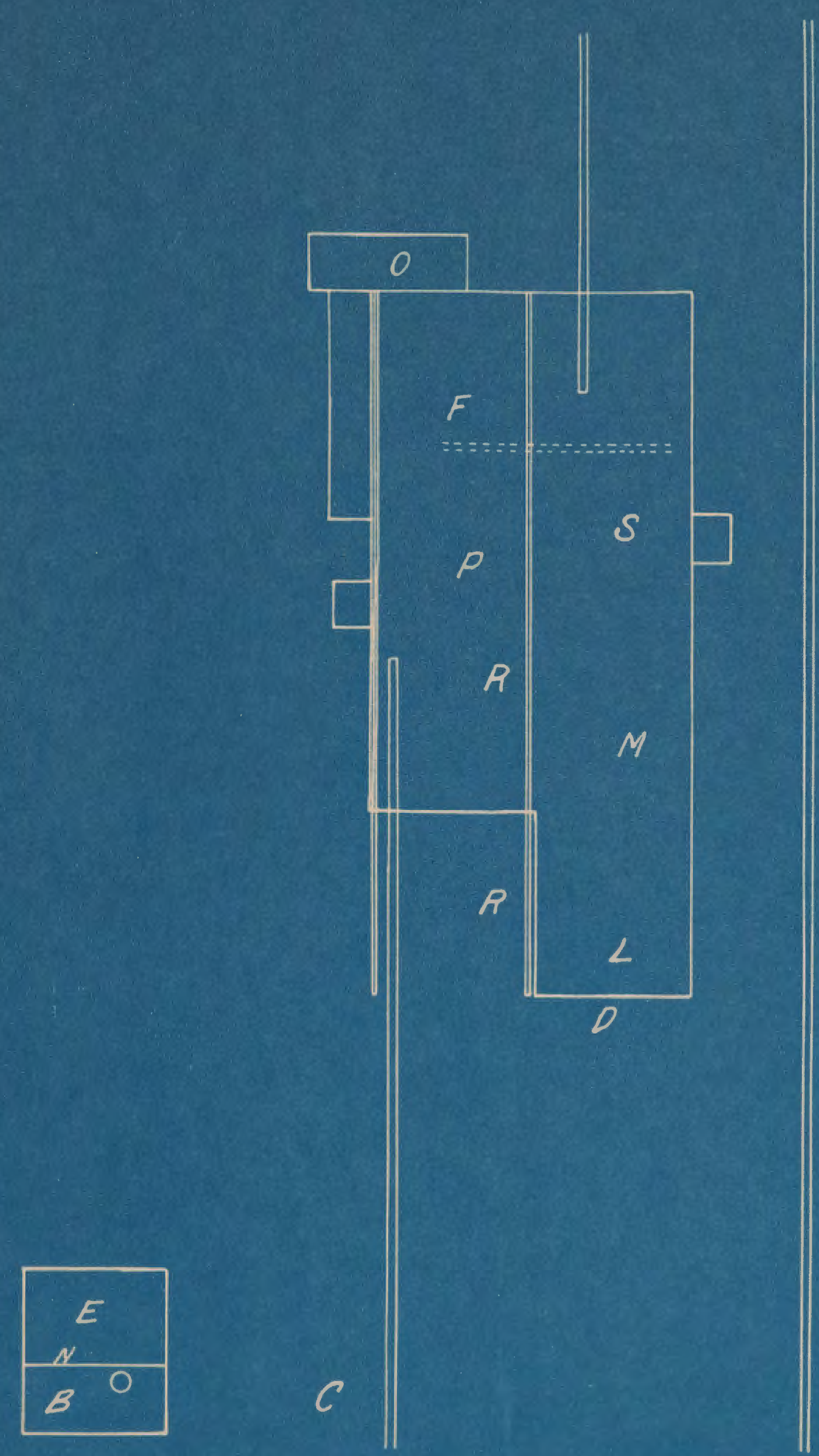


PLATE VII

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.

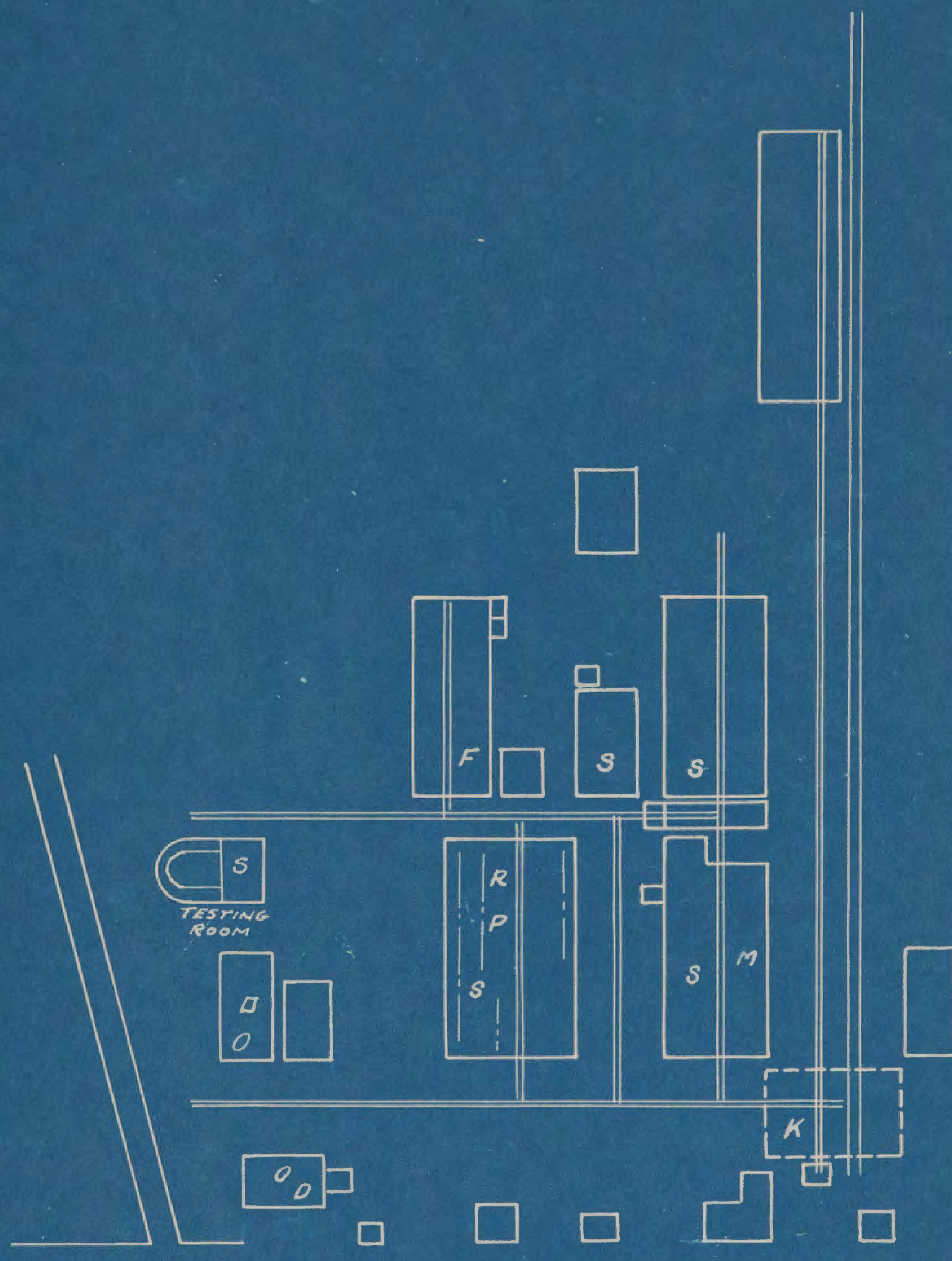


PLATE VIII

PLAN OF THE LAYNE-BOWLER CO.

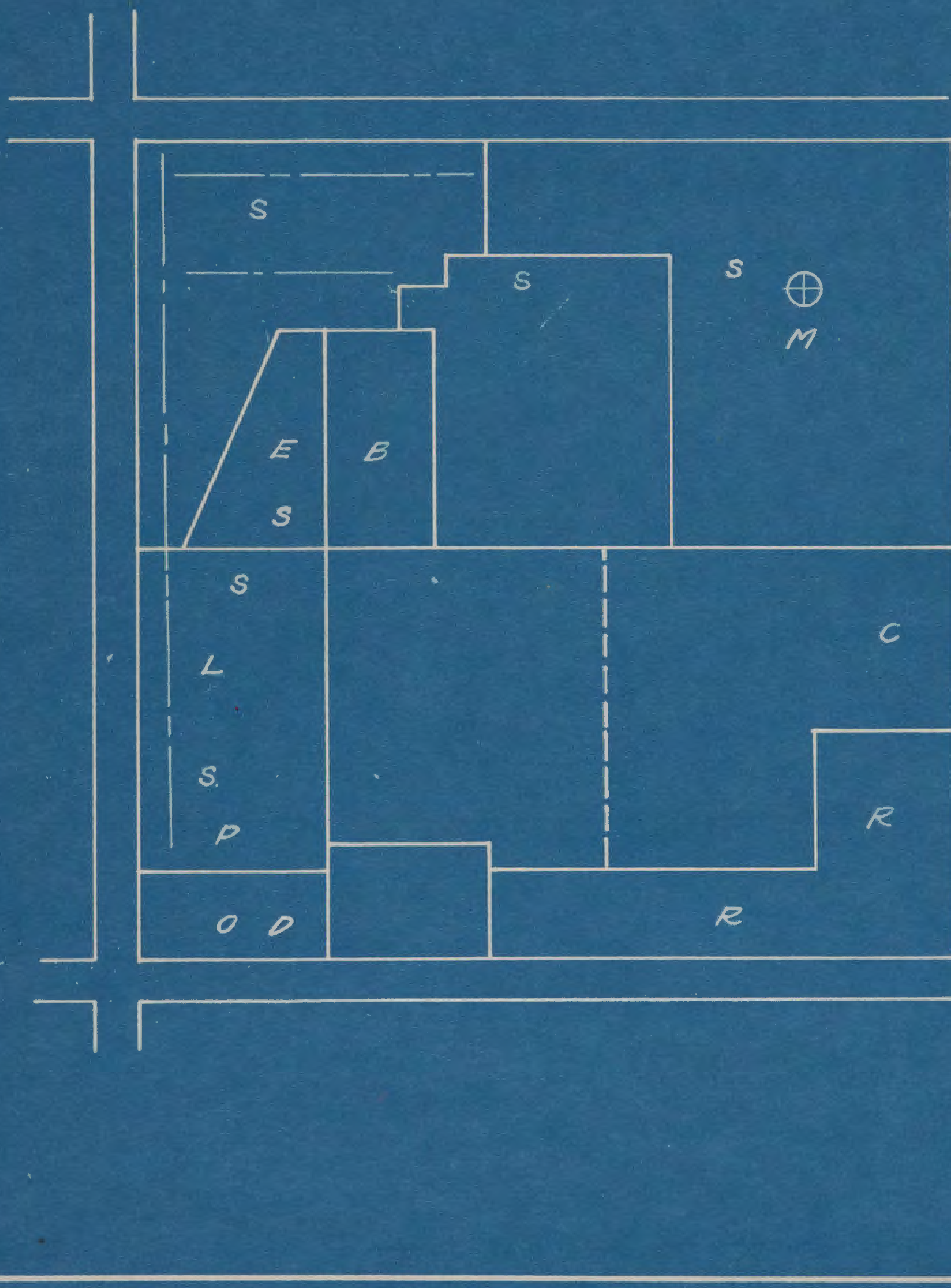


PLATE IX

PLAN OF THE CHICKASAW IRON WORKS

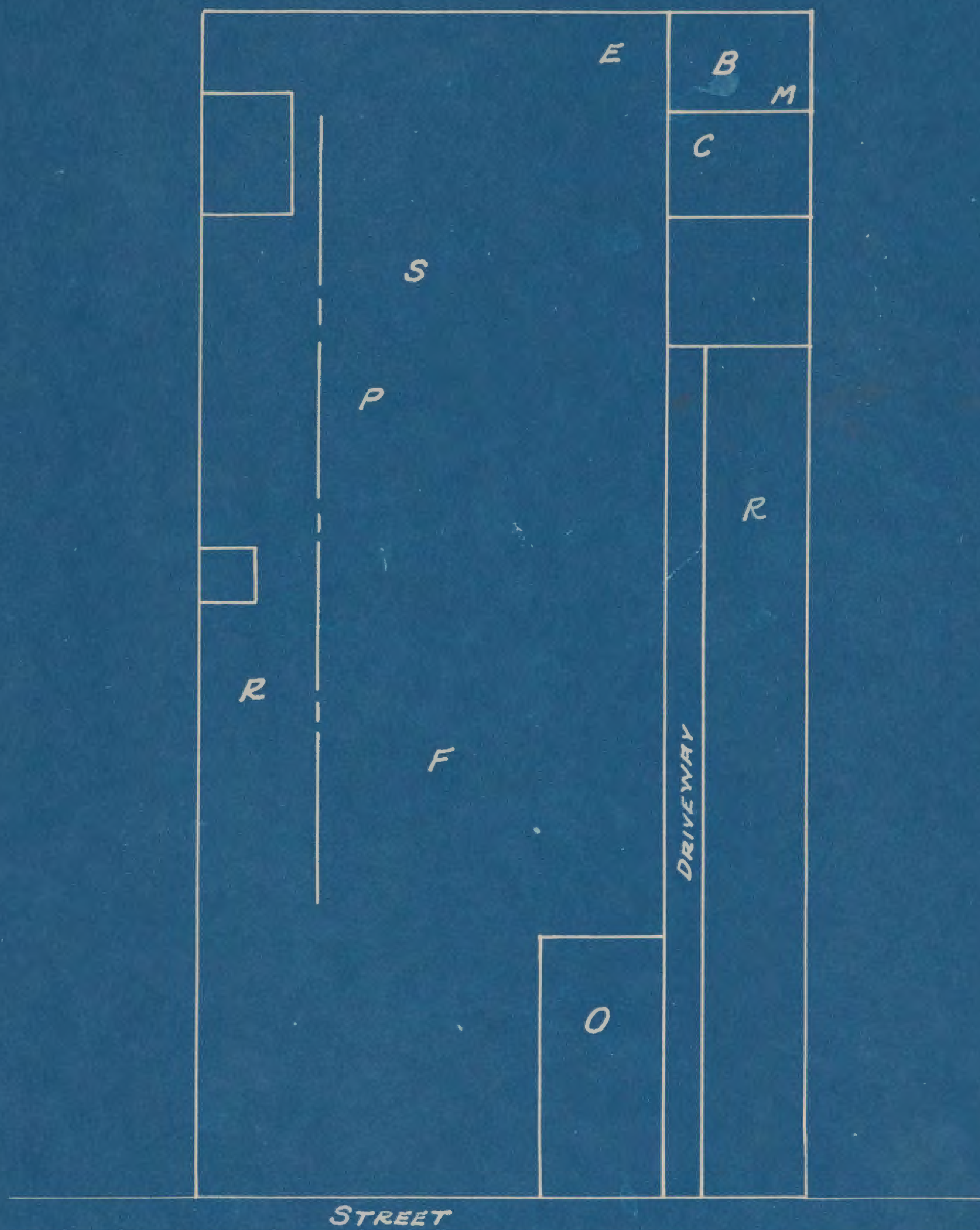


PLATE X

PLAN OF THE NASHVILLE MACH. AND SUPPLY CO.

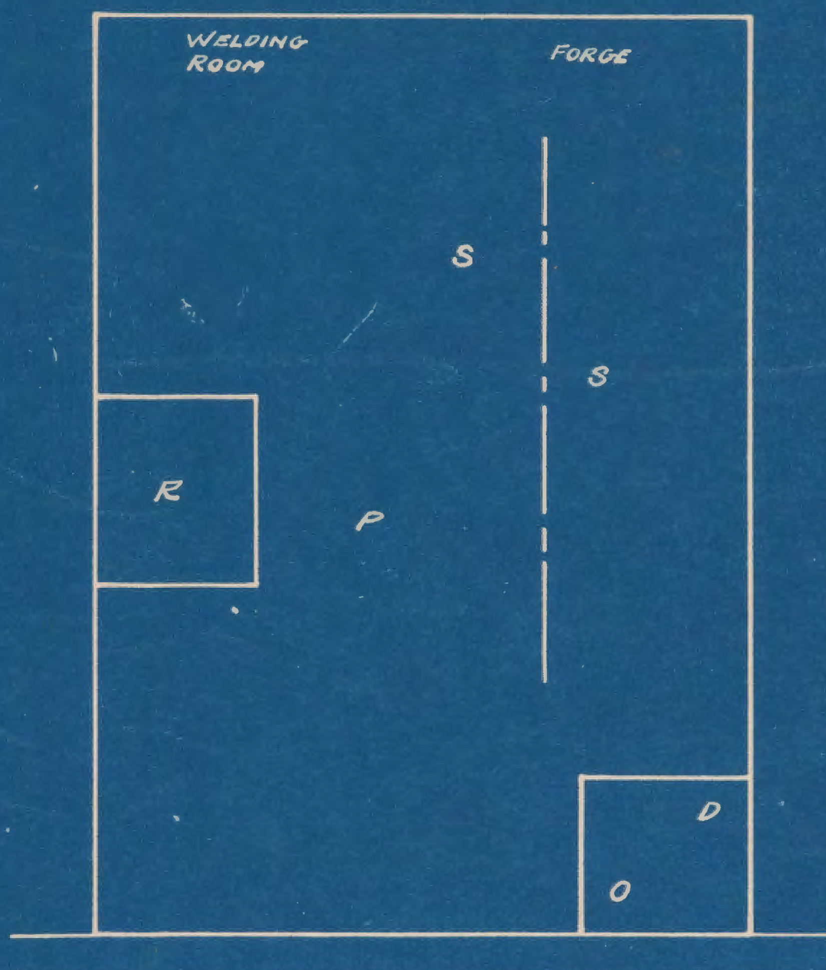


PLATE XI

PLAN OF THE ENGLERT ENGINEERING CO.

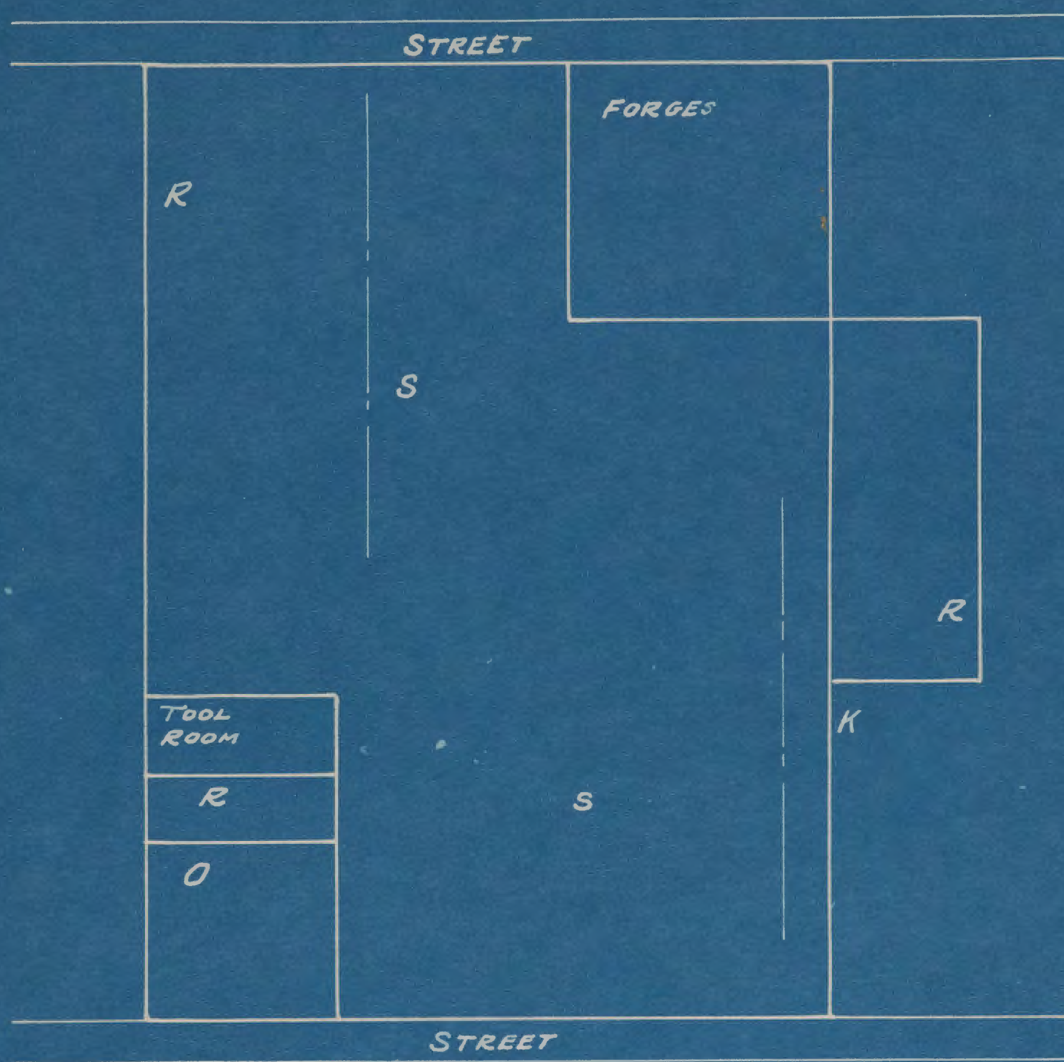


PLATE XII

PLAN OF THE JONES MACHINE CO.

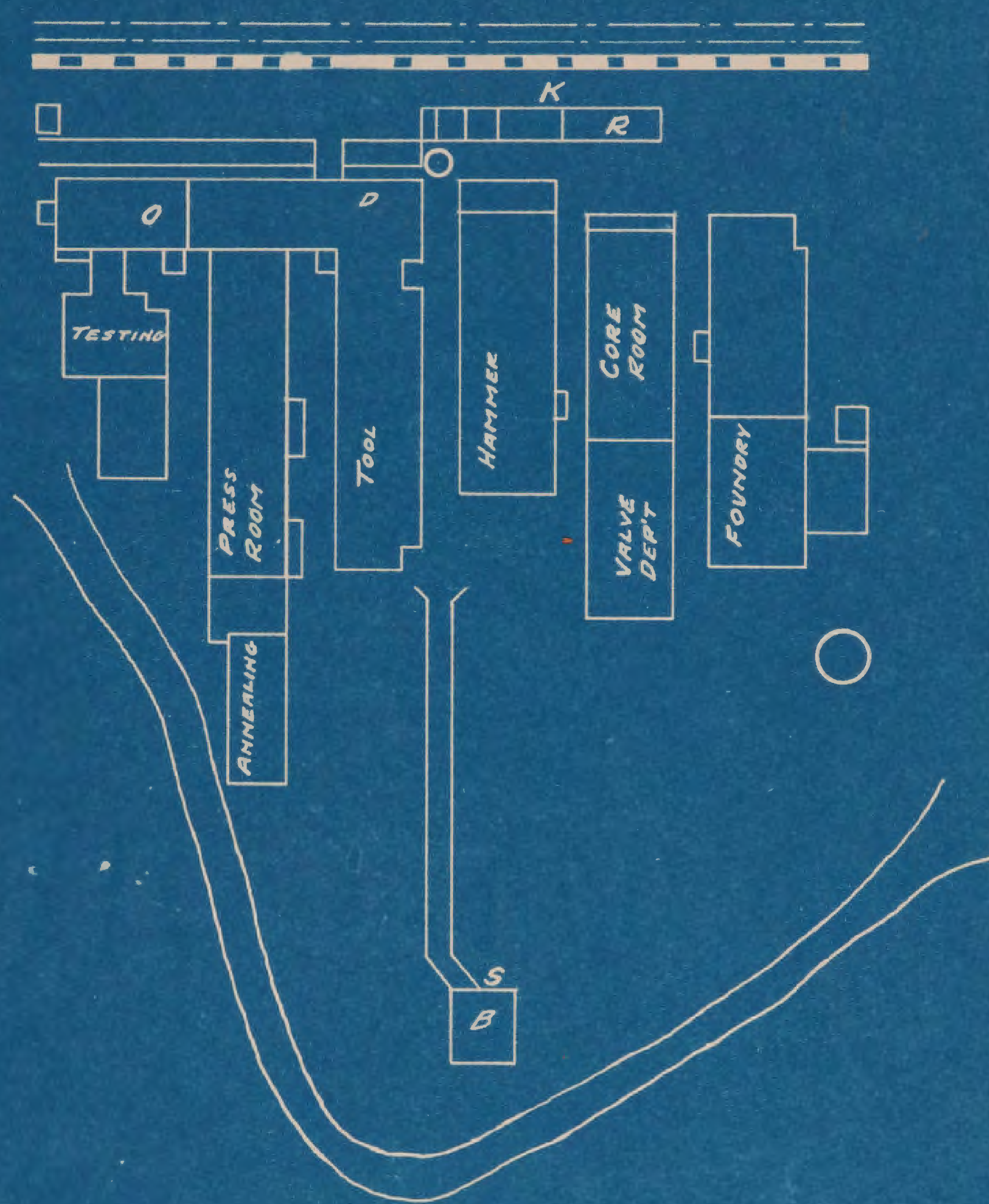


PLATE XIII

PLAN OF THE FULTON CO.

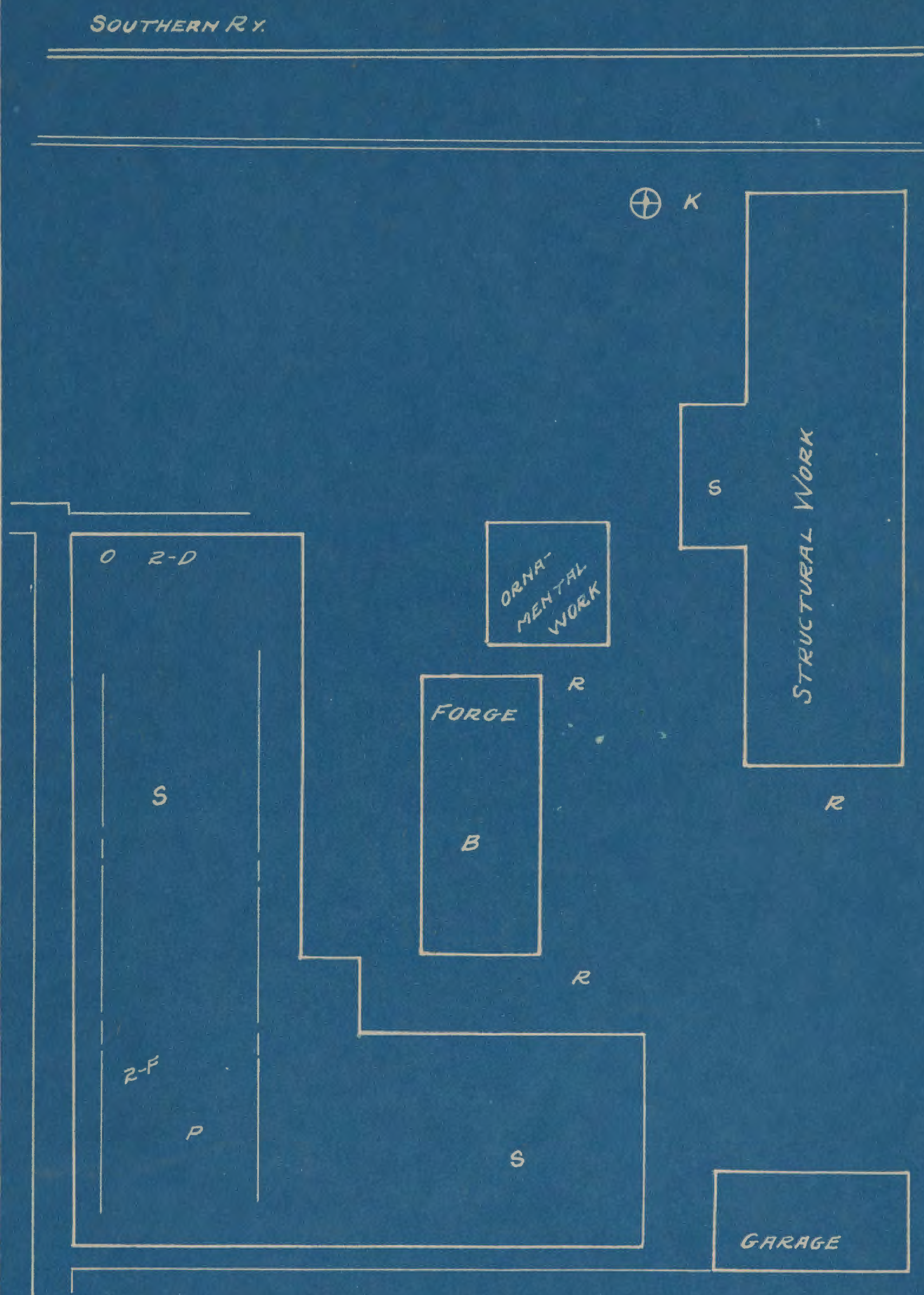
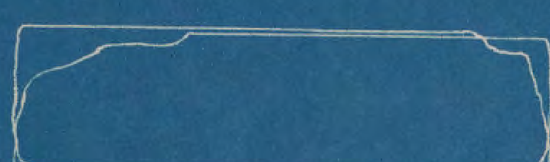


PLATE XIV

PLAN OF THE TY-SA-MAN MACHINE CO.

CORLISS VALVE
AT
ANDRES STONE & MARBLE CO.

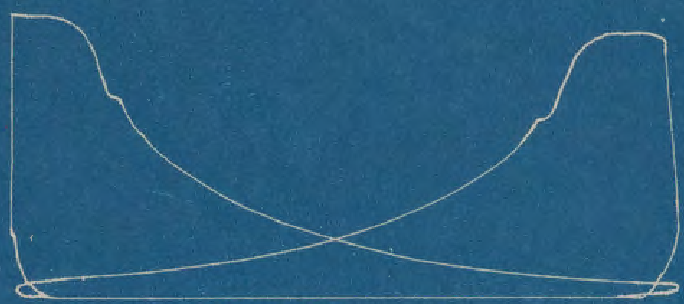
HARDIE-TYNES CORLISS
AT
KNOXVILLE MARBLE CO.



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 conclusions drawn therein, but approves the thesis only for the purpose for which it is submitted.

Signed W. R. Woolrich

Associate Professor of

Mechanical Engineering.