POWER REQUIREMENTS IN THE CEMENT INDUSTRY

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PREFACE

The work of investigation to determine power requirements in the cement industry, the results of which are embodied in this thesis, was undertaken by Professor Garver during the school year of 1916-17. Much of the labor was not completed until the following year, at a time when war work was beginning to press heavily on the time of all university men. Because of this fact Professor Garver did not take the time to prepare in finished form the material which had been gathered. Later he entered the naval service and died early in February, 1919.

At this time when assembling the records of the work and putting them in form for preservation, practically nothing has been done to change the hasty character of the written notes or to elaborate on methods or results. Incomplete as they may be, they represent valuable work and the final result is clearly shown. The problem was a difficult one, incapable of solution excepting by some one thoroughly familiar with the technique of the process and with methods of research. Professor Garver possessed both of these qualities and was able to bring definite conclusions from a complicated set of primary conditions.

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POWER REQUIREMENTS IN THE CEMENT INDUSTRY

In undertaking a study of the power requirements in cement mills we are immediately confronted by the variety of processes, methods, machines and types of prime movers that are found in present day practice; all or most of which are to a greater or less extent adapted to the work to be done and the particular problem to be met in the local community in which the mill is located.

For example, that steam power is preeminently the thing in certain localities goes without saying. Whether condensing or non-condensing is an economic problem presenting different features in the various parts of the country. Such variable conditions apply to gas or oil engines in an equally general manner. It is therefore far beyond the scope of this paper to undertake to point out or arrive at any conclusions as to the advantages or disadvantages of the possibilities in the choice of power. The matter of equipment, although more nearly standard, is a subject that could probably be fruitfully discussed by cement manufacturers. Fortunately the main data for the following discussion was taken during the transition period from a dry grinding - slurry process to a wet grinding - slurry process in one of the larger plants of the central west. A rough comparison of the two processes can therefore be made and as will be noted later to the marked advantage of the latter process and perhaps some feature of importance as regards equipment can be gathered by those who wish.

The writer well understands that many cement men do not approve of the slurry process in cement manufacture, considering the addition of water in as large proportions as 20% to 40% all of which must subsequently be evaporated in the kilns with the attendant heat absorption as unnecessary. Again we plead the subject beyond and foreign to this paper. We should note, however, that this process leads to an excellent uniform product in the plant at which the following power study was made, and offers possibilities of blending the daily and hourly changes in the analysis of the mixture, characteristic of the western plants, unsurpassed by any other method. And further, that the absence of dust makes the process appeal most strongly to all who truly realize the difference in this regard in the two methods. For an interesting discussion of the relative virtues of the two processes see Vol. 33 Transactions of the American Society of Mechanical Engineers (1911).

As noted above the data for this paper was taken from a well known western plant of 4000 barrels nominal capacity. And that the figures and calculations to follow may be more easily understood we will introduce at this place a brief description of the mechanical operation, methods and equipment of the plant. As the change in process involved the changing of the preparation of the raw material from dry grinding by Griffen mills, driven by gas engines using natural gas as fuel, to wet grinding by ball and tube mills, motor driven, with power generated in a central station by a

750 k.w. generators direct connected to 1000 H.P. Macintosh and Seymour Diesel engines, the data really covers two distinct plants in the raw end of the mill. Therefore we will speak of the old and new plant with the understanding that the terms apply to the raw end of the mill with the term of old plant meaning the gas engine Griffen mill layout and the term, new plant meaning the motor driven ball and tube mill installation. The test data was taken over a period of sixteen days, but whenever possible data for the year 1916 is used to figure production, power per barrels of cement, etc. Many estimates are included for minor factors, these being given by Mr. John Norvig, then Superintendent of the plant and to whom the writer wishes to express his great appreciation for the assistance rendered.

GENERAL PLAN OF PLANT UNITS

The Quarry.

Rock - The lime stone rock lies in a stratified ledge varying in depth from 26 ft. to 30 ft. It carries an overburden of soil, varying from a slight deposit to 10 ft. This overburden if very heavy is stripped by a No. 60 Marion, 70 ton steam shovel, with a capacity of up to 125 - 6 yard cars per 10 hour day, the dirt being left in a deserted part of the quarry. If the burden is light it is usually handled with the rock with a compensating decrease in the amount of shale handled. The rock is shot down with dynamite charged in 4 1/2" holes spaced 12 ft. and 12 ft. back from the face of the deposit.

Two rows of holes are used, drilled staggered and charged with 165 to 175 pounds of dynamite in the first row and 175 to 185 pounds in the second row. The holes for the charge are drilled with two portable Cyclone drills driven by 12 h.p. gasoline engines. They operated a total of 4557 hours, in 1916, and on a basis of an average of 100 ft. of 5 3/4" hole per 10 hour day gives .0370 h.p. hours per barrel of cement. The material is loaded into 5.5 ton cars by a 110 ton Bucyrus shovel. This shovel carries a 75 h.p. boiler, and averages 240 cars per 10 hour day or approximately 1375 tons. The best performance has been about 2600 tons. This shovel operated 89.5 hours during an observed period of 16 days during which time 49,200 bbl. of cement were produced, this gives .1365 boiler h.p. hrs. per barrel. This item is then .1273 boiler h.p. hrs. per barrel of cement. Forty cars are used in this section of the quarry. The cars are hauled by two 10" x 16" Davenport, narrow gage locomotives of 15 - 18 ton size and 35 boiler h.p. each.

Shale . - The shale pit gives a good quality of shale that is soft enough to be scraped from the sides of the pit by a steam shovel, no blasting is generally resorted to. This excavating is done by a No. 91 Marion, 100 ton shovel. It handles about 70 cars of 10 tons each in a 10 hour day. This section of the quarry is operated only about three days per week, during which period sufficient material is produced to operate the mill for the whole week, the crew then goes to the stripper shovel. The power used for the 16 day period was .0594 boiler h.p. per barrel of cement. The shale pit is some distance from the mill, the cars being handled by a 12" x 16" Davenport and a 12" x 18" Porter locomotive. These are of standard gage and about 22 ton weight. The Davenport has a 35 h.p. boiler and the Porter a 50 h.p. boiler, giving .0776 boiler h.p. per barrel of cement.

The Quarry Incline.

As the floor of the rock quarry is lower than the main level of the mill the material is raised to the crushers over an inclined double track. The cars are hoisted by Lidgerwood hoists, steam being supplied by a 115 h.p. boiler. with the rebuilding of the plant this work will be done by two 35 h.p. motors. As no direct values for the power absorbed here could be secured the calculated value of 35 h.p. will be used. The hoists operated 101 hours furing the 16 day period giving .0718 h.p. hrs. per barrel of cement produced. This incline is equipped with a spring switch so that all empty cars are shunted to the same track regardless of which of the two incline tracks they were taken up.

The Rock Crushers.

The rock on being dumped from the cars goes to a Fairmount crusher, with a three foot roll, five feet long, revolving 40 r.p.m. It is operated from the line shaft of No. 1 steam engine The power could not be measured direct, due to the fluctuating nature of the work as to power and time actually crushing rock. Estimated at 150 h.p. for the peaks and 125 h.p. as an average figure, it operated 101.5 hours during the 16 day period resulting in .2573 h.p. hours per barrel of cement. It crushes to 8" or smaller. From the crusher the material goes to the bucket elevator.

Bucket Elevator.

Operated from line shaft of No. 1 steam engine. Estimated power 35 h.p. on peak conditions with an average of 20 h.p. This figures .0412 h.p. hours per barrel of cement. This elevator leaves the material in bins, from which it goes to the Williams No. 6 crushers.

Williams No. 6 Crushers.

Two are installed, one only being used at a time. They operate at 900 r.p.m. with a capacity of about 350 tons per day. Here the rock is reduced to 1 inch in diameter or smaller. Peak load 150 h.p. and the average 125 h.p. This crusher operated 101 hours for a total of .2565 h.p. hours per barrel of cement. From the crusher the material goes to the elevator and screw conveyor.

Elevator and Screw Conveyor

The elevator requires 25 h.p. at peak load with an average of 15 h.p. The conveyor operated only about 5% of the time with a peak load of less than 15 h.p., it is therefore omitted from the total. The elevator operated 101 hours or .0308 h.p. hours per barrel of cement.

Shale Crushers.

Two No. 3 Williams crushers break down the shale to 1.5" or smaller. They require an average of 35 h.p. each at 500 r.p.m. They operate about 50% of the time or give a power consumption of .1260 h.p. hours per barrel of cement.

Shale Elevator.

This equipment requires about 25 h.p. peak and 15 h.p. as an average. It operates 50% of the time. The power consumption equals .0308 h.p. hours per barrel of cement.

The raw material is now through the preliminaryngrinding and is stored in bins. It is then fed by gravity inte electrically driven cars and fed to the dryers.

Electric C ars.

These cars are fed by gravity from the storage binsabove, which hold about 3160 lbs. of rock and shale. A division plate in each car separates the two materials. This plate is set by the laboratory analysis of the stock in the storage bins, each division representing approximately 1% $CaCO_3$. This is the first step in securing the proper mixture. Three cars were operated in connection with the old plant, but only two are needed with the new method due to better arrangement and shorter hours. The cars require about 10 h.p. each. Assuming that they are drawing current 50% of thettime the power requirements are, for the old plant .0937 h.p. hours per barrel of cement and for the new plant .0585 h.p. hours per barrel of cement. In the old plant the cars fed the dryers.

Dryers.

Three dryers were used in the old plant each 5' in diameter by 50' long. Opperating at 2 r.p.m. they consume about 125 to 150 cu. ft. of gas per barrel of cement. They are rotated by 35 h.p. motors and consume an average of 30 h.p.

Dryer No. 1 ran 7,478.5 hours in 1916
Dryer No. 2 ran 7,594.5 hours in 1916
Dryer No. 3 ran 7,116.75 Hrs. in 1916

Giving a total of .0540 h.p. hrs. per bbl. of cement.
In the new plant the cars fed an endless belt that feeds the ball mills. This belt is operated from the same circuit that the grinding mills are on and the data from them therefore

includes this item. However it is operated by a 35 h.p. motor which usually draws cement equivalent to about 30 h.p. From the dryers the material goes by means of conveyors to the Griffin Mills.

Griffin Mills

The griffin mills are arranged in four sections designated as Nos. 1-A, 1, 2, and 3. Each of these sections contains eight mills with a usual operating condition of seven, i.e., each section allows one mill to be down for repairs at all times. Each section is independently operated by a gas engine as follows:

Section No.	Engine No.
1-A	6
1	1
2	4
3	7

The sizes and speeds of these engines may be seen on the power equipment sheet in another part of this paper. The fineness from the mills is controlled by a 50 mesh screen in each of the griffin mills, the upkeep cost of these sereens is very heavy averaging as high as 1.5 cents per barrel of cement. This loss is mostly due to pebbles being dthrown from the grinding surfaces with sufficient force to pierce the screens. The fineness is maintained at 91% to 92% through a 100 mesh screen. Cross conveyors run under each mill discharging the pulverized raw material to long conveyors extending the length of the battery. From the conveyors the material is elevated and carried by other cross conveyors to the pug mills. These conveyors and elevators are driven from the engine shaft and the power included in that comsumed by the griffin mills. An estimate of the requirements of the different sections of this equipment has been made on the engineers calculations for the substitution of electrical power. It has not, however, been separated here as the total amount is small and should, in our opinion, be charged to the raw grinding in any case.

Pug Mills.

The pug mills are of the ordinary vertical type, six feet in diameter and eight feet high. Inside the mill a vertical shaft, carrying heavy cast iron blades, on a slant, is rotated by bevel gears. This shaft is rotated by a line shaft operated by a 35 h.p. motor. The power is variable according to the output of the Griffin mill.

The dry raw material is mixed with about 20% water in these pug mills, the action of the paddles or blades giving a good primary mix, the material is then passed to slurry storage tanks by means of centrifugal pumps. These pumps aiding materially in the mixing of the water and raw material.

The storage tanks used for the slurry or mix of water and raw material are built up of plate steel. They are 14 feet in diameter and 15 feet high. This size gives 1.47 bbls. of clinker per inch of slurry in the tanks. When the 3% of gypsum is added before the grinding of the clinker, the equivalent figure becomes 1.5 barrel of cement per inch of level in the tanks. The agitators for these storage tanks are operated from the engine line shafts. All of these tanks are so located with the exception of one section that the slurry flows to the kiln room by gravity. This one exception requiring about 20 h.p. on a centrifugal pump to handle the material, Thus giving .1250 h.p. hours per barrel of cement produced.

In the new plant the wet or slurry process is being continued but a great many of the above mentioned accessories necessary to the dry grinding of the raw materials with griffin mills is eliminated as the pulverization in the ball and tube mills is done wet automatically producing the slurry and doing away with dryers and pugmills, and in addition the process of grinding insures a good mix of the materials. Further the new equipment is so arranged that the sluffy discharges to the storage tanks by gravity. The storage tanks for the new plat are of concrete . Under the severe conditions of the process, steel deteriorates very rapidly making the more perminent construction veryn desirable.

From the storage tanks the material is fed to six circular tanks 14 feet in diameter and 15 feet high immediately back of the kilns. These are fed from any or all of the storage according to the analysis in the stored slurry. By this means any slight variation in the output of one batter can be compensated for by admixtures from thenmaterial produced in some other section. These six tanks in turn feed into a common feeder leading to the kilns. Thus another and final opportunity to blend the product is afforded. This common feed tank is 10 feet in diameter and 12 feet high. The aggitators for these last mentioned tanks and the feeder tank are driven by a 35 h.p. motor. This machine is not always loaded usually drawing 20 to 30 h.p. The feeder mechanism itself is driven from the kiln motor.

motor.

The kiln room contains six rotary kilns as follows:-

4 - 125 ft. long by 7.5 ft. diam. Normal capacity 600 bbls per 24 hours
2 - 165 ft. long by 8.0 ft. diam. Normal capacity 800 bbls. per 24 hours.

The actual capacity depends on the rate of driving the kilns, the rate of feed, and on the condition of the slurry. This last item will be spoken of again under the discussion of the effect of the fineness of the pulverization of the raw material. When operating at about the above rating the small kilns require in the neighborhood of 150 lbs. of coal per barrel of cement. This figure rises rapidly with the crowding of the kiln and for this reason these smaller kilns are seldom run over the normal capacity. The large kilns require 110 to 115 pounds of coal per barrel of cement at 800 barrels per 24 hours, With an increase to 150 pounds of coal, if they are made to produce 1000 barrels per 24 hours. These figures are on the basis of a fineness factor of about 92% and a corresponding greater output is now produced as the average fineness is 97%. All kilns are driven by motors of 35 h.p. capacity, with speed regulations of 1 to 3, i.e., one revolution in one to three minutes on the kilns. The speed depends on the ease of fusion of the raw material. The stack temperatures are about as follows - for the small kilns 1100°F and for the long kilns 500 to 700°F. These differences illustrate the ability of the long kiln to absorb heat both for the production of clinker and also for the evaporation of the water present in the slurry. If all the kilns were of the larger type the output would not only be increased but any objection to the wet process of burning the raw material would be reduced to a minimum. The short kilns normally operate slower than the longer ones, about one revolution in 110 seconds, due to the difference in pitch. The longer kilns being pitched 3/8" per foot while the short kilns have a pitch of 11/16" per foot. Other things being equal the output and the efficiency are both increased by an increase in speed of revolution. This is probably due to the increased agitation and consequently more efficient burning. The power required to operate a kiln depends on the load and speed, and varies in this plant from 18 to 40 h.p. with an average of 30 h.p. On this basis the power consumption is as follows - 6 x 30 x 43931 = 7,920,000 h.p. hours or 1.07 h.p. hours per barrel of cement. This item includes the drive of the feed mechanism spoken of above. The kilns are fired by pulverized coal. The boal being pulverized in another portion of the plant and carried to storage bins in front of the kilns by conveyors. These bins hold a supply sufficient for about an average 8 hour run. They are hopper bottom and are fed by a 5" screw conveyor. The coal is blown into the kiln by a jet of air and burns very similarly to a gas flame with an intense heat a short distance from the feed pipe. The air is provided by an American Blower Company plate type fan at a pressure of 15" of water. This is reduced at the jet by the injector effect and carried withnit the proper amount of pulverized coal to give the intensity of heat desired. The coal fed is operated by a 2.5 h.p. variable speed motor, the control being both of armature and field, approximately 50% on the armature and 33% by means of the field.

The American Blower Company fan is driven with a 125 h.p. motor and normally draws 100 h.p. On the basis of the year 1916 thenpower consumption would therefore be 100 x 43931/1231761 = .5940 h.p. hours per barrel of cement.

The slurry being burned to clinker it is dropped from the end of the kiln into the hot pit by gravity. From this pit it is removed by a McCaslin conveyor 24 x 24" buckets, operated by a 10 h.p. motor which gives a consumption of .0595 h.p.hours per barrel of cement. As the clinker is now near a red heat the conveyor discharges it by means of a series of trippers into any one of three coolers. These coolers are 6 feet in diameter and 60 feet long. Eight inch channels along the inside aid in the aggitation of the hot clinker as it passes through the cooler. Each cooler has a separate stack and thus a natural draft is produced which draws the cool outside air over the hot mass reducing it to a temperature such that it can be worked in the subsequent process. Water is sprinkled over the entering clinker to aid the cooling process. This addition not only aids the cooling but helps the quality of the resultant cement and preserves the back of thecooler. Three coolers are in the battery but two only are operated at one time. They are revolved by a 75 h.p. motor and the normal output keeps it pretty well loaded. As the power was not separated from that consumed by other motors in the same section of the plant this estimate of full load on the motor as an average load must be taken as the actual consumption. On this basis the power required is 43931 x 75= 6 = .447 h.p. hours per barrel of cement. This discharge end of the cooler is perforated with two inch holes and at the extreme end is a small crusher to take such material as will not pass these holes. The clinker is usually about 100°F on leaving the cooler. From the cooler the clinker passes to automatic rotary scales where the gypsum is added. Then it is elevated some twenty feet to bins by means of a 15" x 24" conveyor moving about 90 feet per minute. This elevation requires about 10 h.p. as the motor is of that size and well loaded. This operation therefore requires .0595 h.p. hours per barrel of cement. From bins the clinker is fed to the grinding room by two 16" conveyors over the bins. They are operated one at a time by a 35 h.p. motor. This distribution thus consumes .2083 h.p. hours per barrel of cement. This particular figure is perhaps a little large as one of the cement elevators from the finish grinding is also operated by this motor. The division of power is not practical and the resulting total would be the same in any case so that no material error enters due to this condition.

The finish grinding or pulverization of the clinker is accomplished in two sections of the plant, Known as Sections three and four. Section three has 12 griffin mills operated under the old conditions, by a 500 h.p. Westinghouse gas engine. This section was tested for power consumption by means of indicator tests of this engine under varying loads. The change in load being accomplished by the removal or addition of mills on the line shaft. The whole of the line shaft ran all the time so that no load conditions represent the power consumed by the shafting and such small elevators as could not be conveniently removed from the main line shaft. The results of this test follow. Special attention is called to the variation in the speed on this engine under the varying loads. This, of course, makes the comparative results very indefinite as the speed factor is so important in such power problems. As the governing apparatus of this engine was so imperfect the results have been reduced to a common speed basis, as was done in the case of the griffin mill engines on the raw side, this makes the results open to criticism but seem to be the bestpossible correction for this case. Fortunately the same set of mills under the same conditions are now operated by a 400 h.p. motor. This motor is on a circuit by itself and the power readings can therefore be taken with great accuracy. Such a test was run with the results shown on the accompanying data sheets. Special attention is called to the fact that the mill shaft speed when driven with the old gas engine varied from 120 to 168 r.p.m. but that a constant speed of 148, the best speed, was used in the calculations. When the test on the same section when driven electrically was undertaken the data shows that it was impossible to maintain a speed of 148 with more than eight mills on the shaft as the current drawn reached 1450 amperes which is the safe limit for the machine in question. The lower speed of 126 was found by the testing crew to be that in use since the installation of the electric drive and therefore a set of runs on that basis was taken with the results shown. Note should be taken of the fact that the average for the run at 148 r.p.m. on the mill shaft gives an average power of something over 50 h.p. per mill but that this figure would decrease as the number of mills on the shaft increased. Bringing the average nearer the chosen figure of 50 h.p. per mill as determined by gas engine test. When the run at 126 r.p.m. is recalculated at 148 r.p.m., an entirely arbitrary basis, the average for the whole range is almost exactly 50 h.p. per mill. If the lower speed of 126 r.p.m.

is to be montinued a lower figure than 50 h.p. per mill would be justified but as the other section operates at that speed for the purposes of this paper the higher figure of 50 h.p. mill will be adopted. Section number four cantains 18 mills, operated by two 500 h.p. Westinghouse gas engines. each driving a battery of 9 mills. It is the custom to operate but 8 mills at a time allowing one as a leaway for repairs, etc. Tests were made of these gas engines with the same general results as found in the other sections; that is, that the governing of the engines was so faulty that consistant results were not possible. Recourse was again made to the plan of figuring power on the average speed, very nearly the proper speed, and assuming the results proportional to the number of mills in the shaft. The results of the tests follow in detail. Bearing in mind the fact that the actual speed was not used in the power calculations the data is self explanatory.

Power consumption.

Under each Griffin mill is a short screw conveyor leading into a long screw conveyor runing parallel to the battery, these main or battery conveyors discharge into elevators which elevate the finished product to a height equal to the tops of the storage bins. Along the top of these storage bins extend in various directions cross conveyors to distribute the cement to any part of the house desired. These various conveyors are operated by small motors agitating in all some 70 h.p. However, only a few of these are operated at one time with an average load of nearly 50% of the installed capacity. The power for the conveyors etc. averages about .199 h.p. hours per barrel of cement.

Section three is not adjacent to the clinker storage and material is conveyed over by a belt, which discharged to an elevator which feeds two auxiliary circular storage tanks. From these tanks the clinker is taped into push cars operated manually and are discharged into the individual hoppers of the Griffin mills in that section. These hoppers hold enough for three or four bbls. of cement. The power required for this transfer to section three is furnished by some 20 h.p. giving .2595 h.p. hours per barrel of cement.

Coal received as either run of mine or slack must be put through a rather elaborate process before it is in condition for combustion in the kilns. It is received preferably in Gondola cars and unloaded by a 15 ton locomotive crane, equipped with a 1.5 yard grab bucket. This crane operates about 10 hours per day, handling 8 to 9 cars in that time. The coal cars average 37 tons per car. The storage to which the coal is received is unloaded has a capacity of 3500 tons. The coal from storage or directly from the cars is passed to a 30" Jeffries coal crushed having a normal capacity of 50 tons per hour on run of mine coal. The crushed coal is elevated by a belt conveyor to a 20" screw conveyor. This latter conveyor is reversable and may be run to the left or right filling storage tanks located above the dryers when operating to the right and discharging to a large circular tank holding enough to operate the plant 14 hours when operating to the lef t. An elevator works between this tank and delivers to the above mentioned screw conveyor feeding the dryer bins. These bins hold about two hours supply.

The belt conveyor noted above is worthy of special mention. It is 24" wide and 250 feet center to center of its pulleys giving a rise in this distance of 30 ft. Under the dryer feed tanks and over the dryers themselves are located the feeders for the dryers. Theyrare revolving tables carryinga steady stream of coal regulated in depth by an adjustable knife edge to the dryers. This coal falls into the dryers which are divided into four parts to prevent the coal from forming a mass in one spot and thus retarding the drying process and producing a nonuniform effect. The dryers are rotated in brick settings and are surrounded by the high temperature gases from a gas furnace. Of course, the flame cannot come in direct contact with the crushed coal making this rather inefficient method necessary. The coal leaves the dryers at a temperature not over 220 f. or lower than the temperature necessary to drive off any of the volatile gases. When discharged the coal passes by means of elevators to the storage bins for the Griffin mills where the final pulverization is produced. These tanks are of steel but have alife of only three or four years due to the deteriotating effect of the sulphur in the coal. They should be of concrete similar to the new slufry bins to give more perminant construction. The power for these preliminary steps in the preparation of the coal is about as follows: - The crane carries a 20 h.p. boiler and operates 8 hours per day or nearly .039 boiler h.p. hour per barrel of cement.

The Jeffries crusher 20 h.p. motor takes .0390 h.p. hours per barrel of cement. The inclined belt takes the same amount and the reversible screw conveyor 10 h.p. for a 16 hour day or .0390 h.p. hours per barrel of cement. The dryers are operated two at a time from a 35 h.p. motor and require about 17 h.p. each and operate for a 24 hour day thus requiring .1525 h.p. hours per barrel of cement. The screw conveyors and elevators for distributing the coal to the Griffin mills are operated from the mill line shaft and the power consumption is included in that for the operation of the Griffin mills.

The mill room for the finish Griffin Mill contains 12 - 30" mills with 50 mesh screens, operated under the old conditions by a 500 h.p. Westinghouse gas engine and later by an electric motor. Tests for power consumption were run with both drives with good results. The data for the indicator tests in the gas engine must again be supplimented by the correction of the speed to an average of that at all loads due to the fluctuation due to poor governing. This average is taken as 148 and is also applied to the motor calculations due to the fact that at light loads the controlling apparatus would not hold down the motor speed. This is of no great importance as the line shaft is always loaded with a large part of the mills available and the change at near full load conditions is negligible.

The data for these two tests follows and from it the close agreement of the two tests is evident. The average power consumption less the outside load on the motor giving 31.3 h.p. per mill against 29.7 h.p. per mill when this section is driven by the gas engine. Assuming 30.0 h.p. as an average the actual power on the basis of output is 1.615 h.p.hours per barrel of cement.

Under each of the Griffin mills is a cross conveyor discharging to a long screw conveyor extending the length of the batteries. This main conveyor discharges to another short conveyor and thus to an elevator which in turn delivers to a cross conveyor discharging to the coal tanks in front of the kions. These final conveyors and elevators are driven by 10 h.p. motors requiring as an average load about 5 h.p. each. The power being .06 h.p. hours per barrel of cement.

SUMMARY FOR COMPLETE PLANT.

	h.p. hours / bbl. cement.	
Bucyrus steam shovel, rock quarry	.1365	(boiler h.p.)
Marion steam shovel, shale quarry	.0682	(" ")
Locomotives in rock quarry	.1273	(" ")
Locomotives in shale quarry	.0776	(" ")
Drilling blast holes rock quarry	.0370	
Shale crushers	.1260	
Quarry incline, rock	.0718	
Fairmount rock crusher	.2573	
Elevator, Fairmount crusher	.0412	
Williams crusher	.2565	
Elevator, conveyor, etc. Williams crusher	.0616	
TOTAL actual h.p. hours to get raw material into storage, exclusive of moving in and from quarries.	.8514	

	Old Process	New Process
Electric cars feeding dryers	.0937	.0585
Dryers	.0540	.0000
Griffin mills	4.6200	.0000
Slurry pumps	.1250	.0000
Pug mills	.2995	.0000
Ball mills	.0000	1.7230
Tube mills	.0000	2.9180

Slurry aggitators	.0000	.2952
Feed tank aggitators	.1490	.1490
Kilns	1.0700	1.0700
TOTAL Actual h.p. hrs. to get from storage to and through the kilns.	6.4112	6.3137

The above figures , except as noted, are all for the power consumtion in the various departments on the basis of the method of manufacture used in the plant before the change in the manner of preparing the raw material from dry grinding by Griffin mills to wet grinding in ball and tube mills , was made. The double column of results as given on page ______ show the actual difference in the power consumption for the two methods. However, several very important features are not shown by these figures alone. And while the actual saving in power as there shown is insignificant, the true conditions and conclusions are markedly different.

First, the fineness of the pulverization as secured by the old process, Griffin mills, was 92% through a 100 mesh sieve. While the fineness as now secured by the ball and tube mills averages 97% through a 100 mesh sieve. The fact that the power consumption goes up materially with the fineness is well known by cement manufacturers. To determine what this increase might be in this particular case, a ten hour run was made with the fineness reduced to 92% on the new mills. Careful preparations had been made to produce as nearly normal conditions as possible and although the time thus operated was too short to make positive statements as to the resulting values and percentages they are undoubtedly very near the true conditions.

During the test period the tube mills consumed a total of 1,890 k.w. hours and the kominuters, ball mills, consumed a total of 1,857 k.w.hours and the output equivalent in barrels ofccement was 1,524. The above data gives 1.2 k.w. hours per barrel of cemtnt for the tube mills, and 1.22 k.w. hours per barrel of cement for the kominuters, or a total of 2.46 k.w. hours which equals 3.3 h.p. hours per barrel of cement.

The power consumption of these same mills when grinding to a fineness of 97% through a 100 mesh sieve was as follows. Tube mill 1.286 k.w.hours per barrel of cement. Ball mill 2.175 k.w. hours per barrel of cement or a total of 3.461 k.w. hours = 4.641 h.p. hours per barrel of cement.

The conclusions from the above data when expressed in percent is about as follows; That there was a total increase in power consumption of 1.3 h.p. hours which is 39.4%. As there was a total difference in the fineness of 5% the tests show an increase of approximately 8% increase on power consumption forneach 1% increase in the fineness factor.

That this increased fineness is very desirable goes without question and although the power consumption on the raw grinding might be materially reduced if the old figure of 92% was adherred to, the production in the kilns would thereby fall off. Where the most economical point between these two variables is located, cannot be stated, but that high fineness is desirable both on the basis of output and quality is undisputed.

To further emphasize and substantiate the above statements as to the effect of fineness and that the power figures given in the summary of the power requirements in the mill under discussion doe not in themselves show the true conditions we quote briefly from the discussion of Mr. H. Stuckmann, Vol. 33, Proceedings of the American Society of Mechanical Engineers. "- - - - -. Experiments carried on for long periods with varying fineness of the raw material showed an average of 56 cu.ft. of gas for each per cent of greater fineness between 88 and 96 per cent through the 100 mesh sieve. In other words, each percentage of finer raw material affected a saving of about 47,000 B.t.u. per barrel of clinker produced. Besides this saving in fuel, it was found that the capacity of the kilns, which were 7 ft. 6 in. by 125 ft., was greatly increased, the output per 24 hours being as follows:

88.5 per cent fineness -	454 bbl. per day
90.0	534
92.5	591
94.0	600
96.0	620

It, therefore, seems just that the item (6.4112 h.p. hours per barrel of cement) of power required for raw grinding on page 22 should for the old Griffin mill method, be increased some 40% to make it truly comparable with the value (6.3137 h.p. hours per barrel of cement) given for the same steps by the ball and tube mill process. If we make such a change adding 40% to the figure for Griffen mill grinding only as the other items would remain materially unchanged, we have for the Griffen mill process 8.2592 h.p. hours per barrel of cement produced and for the ball and tube process 6.3137 h.p. hours per barrel of cement or a decrease of 23.5 % . This in contrast to the apparent decrease of 15% as shown by the figures when no account is taken of the fineness factor.

APPENDIX

POWER DATA FOR VARIOUS MILL UNITS.

Electric load on coal room motor. Engine No. 10.

Time	Volts	Amperes	Speed.	K.W.	H.P. Basis actual speed.	H.P. Basis 148 r.p.m.	Out-side load.
12 Mills Full Load.							
12.00	240	1400	152				
12.02	239	1420					
12.04	230	1440					
12.06	231	1380					
12.08	233	1340					
12.10	233	1320					
	234.3	1383.3		324	435	423	376
8 Mills-2/3 Load.							
12.12	235	1200	168				
13.14	236	1200					
12.16	235	1180					
12.18	232	1160					
	234.5	1185		278	373	329	282
4 Mills-1/3 Load.							
12.20	232	900	190				
13.22	234	900					
12.24	234	880					
12.26	235	860					
12.28	235	860					
	234	880		206	276	215	168
0 Mills No Load-Line shaft and outside load on line.							
12.30	237	380	200-340				
12.32	237	300					
12.34	235	360					
12.36	235	360					
12.38	235	360					
12.40	235	380					
	235.6	356.6		84.1	112.5	75.7	29
Coal motor off- Outside load only.							
12.42	239	140					
12.44	239	140					
12.46	239	160					
	239	146.6		35.1	47		

H. P. per Mill by Motor reading,-31.3; by cards from engine,-29.7.

Electric load on Engine No. 9 Mills (operates Griffin Mills)

Time	Volts	Amperes	Speed	K.W.	H.P. Basis actual speed	H.P. Basis 148 r.p.m.	Out-side load
	12 Mills						
3.00	229	1410-30	604				
3.02	228	1410-35	600				
3.04	228	1400-20	600				
3.06	235	1360-80	600				
3.08	235	1370-1400					
3.10	235	1410-30					
3.12	239	1430-60					
3.14	236	1400-20					
3.16	235	1370-1400					
3.18	235	1390-1410					
3.20	235	1350-80	127				
3.22	235	1360-90	128				
3.24	234	1350-80	126				
3.26	235	1360-90	126				
	235.4	1390.5	126	327	439	516	
	10 Mills						
3.34	235	1220-50	130				
3.37	237	1230-40	130				
3.38	237	1230-50					
	236.2	1236.6	130	292	392	446	
	No load-Clutches out						
9.00	239.5	170-180	148				
9.02	239.5	170-180	146				
9.03	239.5	170-180	146				
	239.5	175	146.5	41.85	56.2	56.8	
	Two Mills						
9.10	239.0	430-450	148				
9.12	238.5	420-440	148				
9.14	239.5	430-450	147				
9.16	239.5	440-460	147				
	239.1	440	147.5	105.3	141.5	142	
	Four Mills						
9.27	243.0	720-740	146				
9.29	236.5	730-750	148				
9.31	236.0	730-750	147				
9.33	235.0	750-770	148				
	237.6	742.5	147.5	176.2	236.2	237	

Time	Volts	Amperes	Speed	K.W. Basis Actual speed	H.P.	H.P. Basis148 R.P.M.	Out-side load.
	Six Mills						
9.40	235.0	1130-70	146				
9.42	237	1130-60	150				
9.44	236	1100-50	150				
9.46	237	1090-1120	148				
	236.2	1131.2	148.5	267.5	359	358	
	Eight Mills						
9.55	234	1390-1410	146				
9.57	232	1430-1460	147				
9.59	233	1430-50	147				
10.02	233	1430-50	147				
	233	1431.2	147-	334	448	450	
	Twèlve Mills.						
10.15	231	1470-1500	126				
10.17	230.5	1480-1510	126				
10.19	231	1490-1510	126				
	230.8	1493.3	126	345	463	544	
	Ten Mills						
10.30	235	1280-1300	127				
10.32	234	1290	128				
10.34	236	1300-1310	127				
	235	1295	127.25	304	407	474	
	Eight Mills						
10.40	234	1090	128				
10.42	233.5	1080-1100	128				
10.44	233	1070-90	128				
10.46	233.3	1090	127				
	233.5	1088.75	128-	254	340	393	
	Six Mills						
10.50	237	820-40	127				
10.52	237	820	128				
10.54	237	810-830	128				
	237	823.3	127.75	195	262	304	
	Four Mills						
10.57	239.5	600	127				
10.59	239.5	610	127				
11.01	239.0	610	128				
11.03	239.0	610-630	127				
	239.25	610	127*	146	196	228	
	Two Mills						
11.05	241	370-90	126				
11.07	241.5	370-90	126				
11.09	241	370-90	126				
	241.16	380	126	91.7	123	144.5	

Time	O Mills Volts	Amperes	Speed	K.W. Basis actual speed	H.P.	H.P. Basis 148 r.p.m.	Out-side load
11.16	239	155	126				
11.18	239	155	126				
11.20	238.5	158	126				
	238.8	156	126	37.3	50	58.7	

Power consumed by mills, deducting the "no-load" power.

2 Mills----	85-86
4 "	180-169
6 "	301-245
8 "	393-334
10 "	415
12 "	485

Production of Cement and Power during 12-day period
K. W. Hours.
Basis 1" slurry= 1.4 bbl. clinker, 1" should=1.47 bbl.

March	Cement BBls.	Ball mill & Centrifugal	Tube mill & Slurry agitators.
31	3890	5830	10270
30	4037	5530	8100
29	3897	5500	9100
28	3991	5320	9280
27	3918	3850	6900
26	3860	5150	9370
25	3831	5400	9330
24	3918	5440	8860
23	3969	5520	8980
22	3788	5220	9040
21	3752	5610	9320
20	3987	5010	8560
	46838	12) 63380	12) 107010
		5275	8925

$$\frac{46838 \times 1.47}{1.40 \times 12} = 4.098.32 \text{ BBL per Day.}$$

$$\frac{5275}{4098.32} = 1.286 \text{ K. W. hrs. per bbl.}$$

$$\frac{8925}{4098.32} = \frac{2.175}{3.461} \text{ K. W. hrs. per bbl.}$$

Averages for Month of March.
Kominuters- 1.405 K.W.hrs per bbl. equiv of cememt

Tube Mills-

$\frac{2.469 \text{ K.W.hrs. per bbl. equiv. of cement}}{3.874 \text{ K.W.hrs. per bbl.}}$

No. of cars of clinker on 3D, No. 9 engine, K.W.hrs. same period.

March 20-31 (Mill Hour)

Date	Day	Night	Total	Day	Night	Total.	K.W.Hrs Warehouse inc.	
20	385	400	785	95	129		6840.	
21	500	475	975	129	124		7910	
22	520	540	1060	134	132		8520	
23	595	520	1115	143	144		8650	
24	530	510	1040	141	140		8430	
25	555	505	1060	144	132		8040	
26	475	455	930	125	144		7640	Sunday
27	575	455	1030	142	134		7990	
28	565	440	1005	143	144		8350	
29	530	450	980	144	134		8260	
30	577	510	1087	144	144		8450	
31	506	485	991	135	138		8050	
			12058					

K.W. Hrs. Less Warehouse,

6010
7080
7690
7820
7600
7210
7320
7160
7520
7430
7620
7220
87680

							Warehouse	
1	515	590	1105	141	144	7280	317	Sunday
2	455	490	945	139	135	7360	742	
3	425	480	905	142	142	7400	856	
4	455	575	1030	144	144	7580	886	$\frac{3321}{4}$=830
5	505	540	1045	142	141	7400	837	
			5030			37020		

12 Days $\frac{87580}{12058}$= 7.275

5 " $\frac{37020}{5030}$ = 7.375

17 " $\frac{124700}{17088}$ = 7.325 K.W.hrs. per car clinker.

= $\frac{7.325}{\cancel{1EX}\ 1.6}$ = 4.575 K.W. hrs. per bbl. cement

\- 6.13 H.P. hrs. per bbl. cement.

Dryer No. 2   Load that No. 3 would usually have.

Time	Amps.	Volts
11.45	88-97	230
11.50	90-96	232
	Shut Down	
12.30	88-103	230
12.35	90-100	228
12.40	88-98	226
12.45	96-105	225
	94.9	228.5 = 21.7 K.W. = 29.1 H.P.

Dryer No. 1 & 2
7700 x 82.5 = 635,000 H.P.hrs.

Dryer No 3
7680 x 29.1 = 223,500 H.P.hrs.

About 94 amps. is a good average load. The peaks came when the car of rock was dumped in elevator.

Pug Mill No. 1.

12.55	27	233	Running light
1.00	33	228	
1.05	34	230	
1.10	34	230	
1.15	33	228	
1.20	34	230	
1.25	34	230	
1.30	34	230	
1.40	34	233	
1.45	35	224	
1.50	34	232	
	33.33	229.8 = 7.66 K.W. = 10.25 H.P. for 6 mills	
		29.06 " 17 "	

Hrs. run by Pug mills,
Pug mill No. 1 ran 7700
" 3 7680

34 amps. is a close average.

Power readings taken April 6-7 on No. 1 pug mill represent load on No. 3 Pug. mill, but are not representative of ordinary load condition on No. 1 because on above date only 6 mills were in operation and ordinarily this mill and pump handles material from 17 mills.

$$\frac{10.25}{6} = 1.708 \text{ H.P. per Mill}$$

Pug mill No. 1 = 7.700 x 29.06 = 223,800 H.P. hrs.
" No. 3 = 7680 x 10.25 - 78,750
302,550 H.P.hrs, for Pug Mills.

Therefore for 1916 these mills consumed .2995 H.P. hrs, bbl. of cement produced.

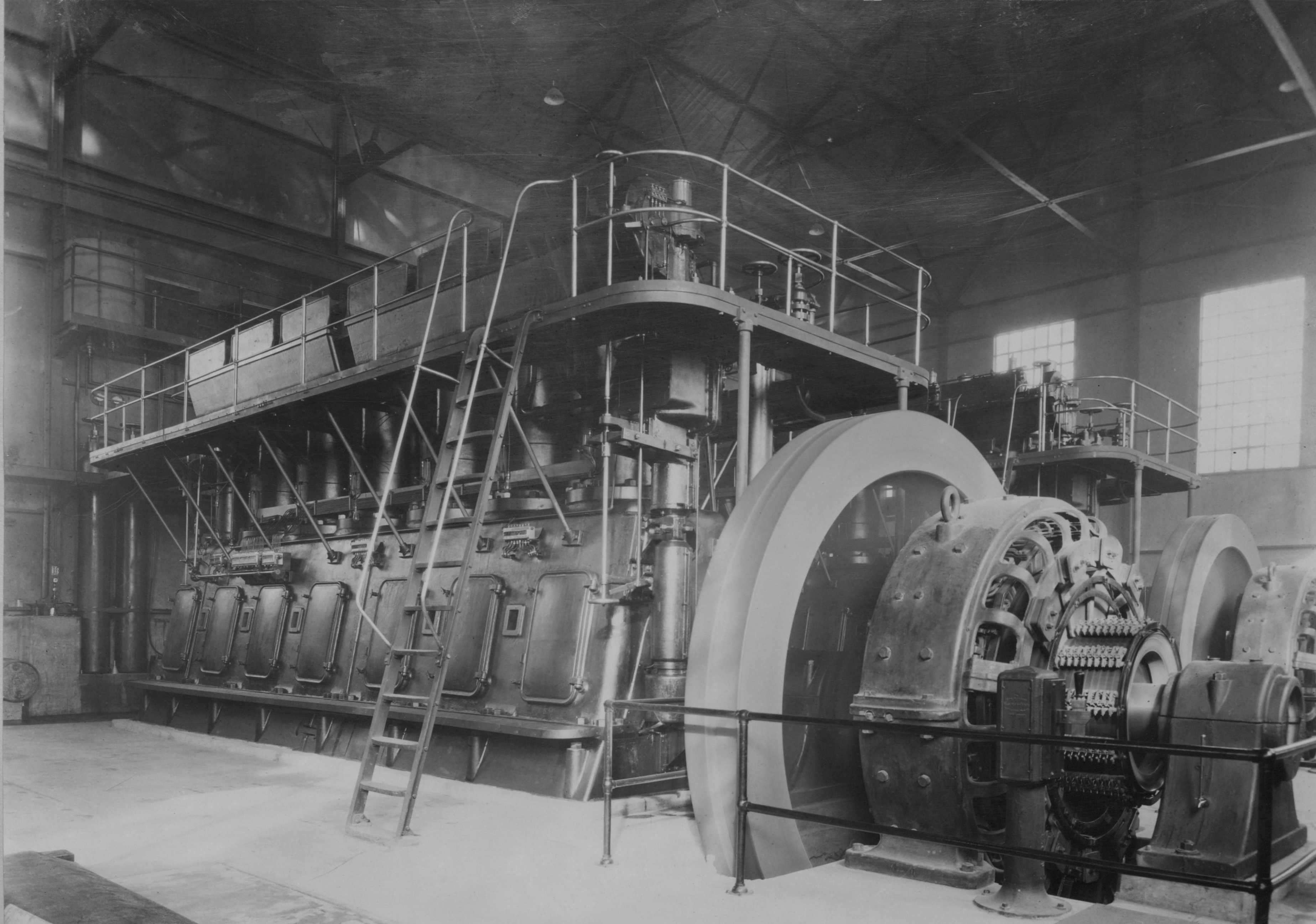
McCaslin conveyor	.0595
Coolers	.4470
Small conveyor	.0595
Large conveyor	.2083
Griffin mills	7.6200
Conveyors & elevators to 3D	.2595
Storage conveyors	.1990
	8.8528
TOTAL Actual h.p.hrs. to get from kilns into final storage.	
Unloading coal-locomotive crane	.0390 boiler h.p.hrs.
Jeffries crusher	.0390
Incline belt	.0390
Reversable screw conveyor	.0390
Elevator	.0098
Dryers	.1525
Griffin Mills	1.6150
Elevator kiln room	.0304
Screw conveyor kiln room	.0304
Fan, kiln room	.5940
Hopper conveyors, coal	.0893
TOTAL actual h.p.hrs. to unload coal and deliver to the kilns.	2.6384
Air compressors	.3655
Water pumps	.7620
Machine shop	.2130
Misdellaneous	1.3405

Department

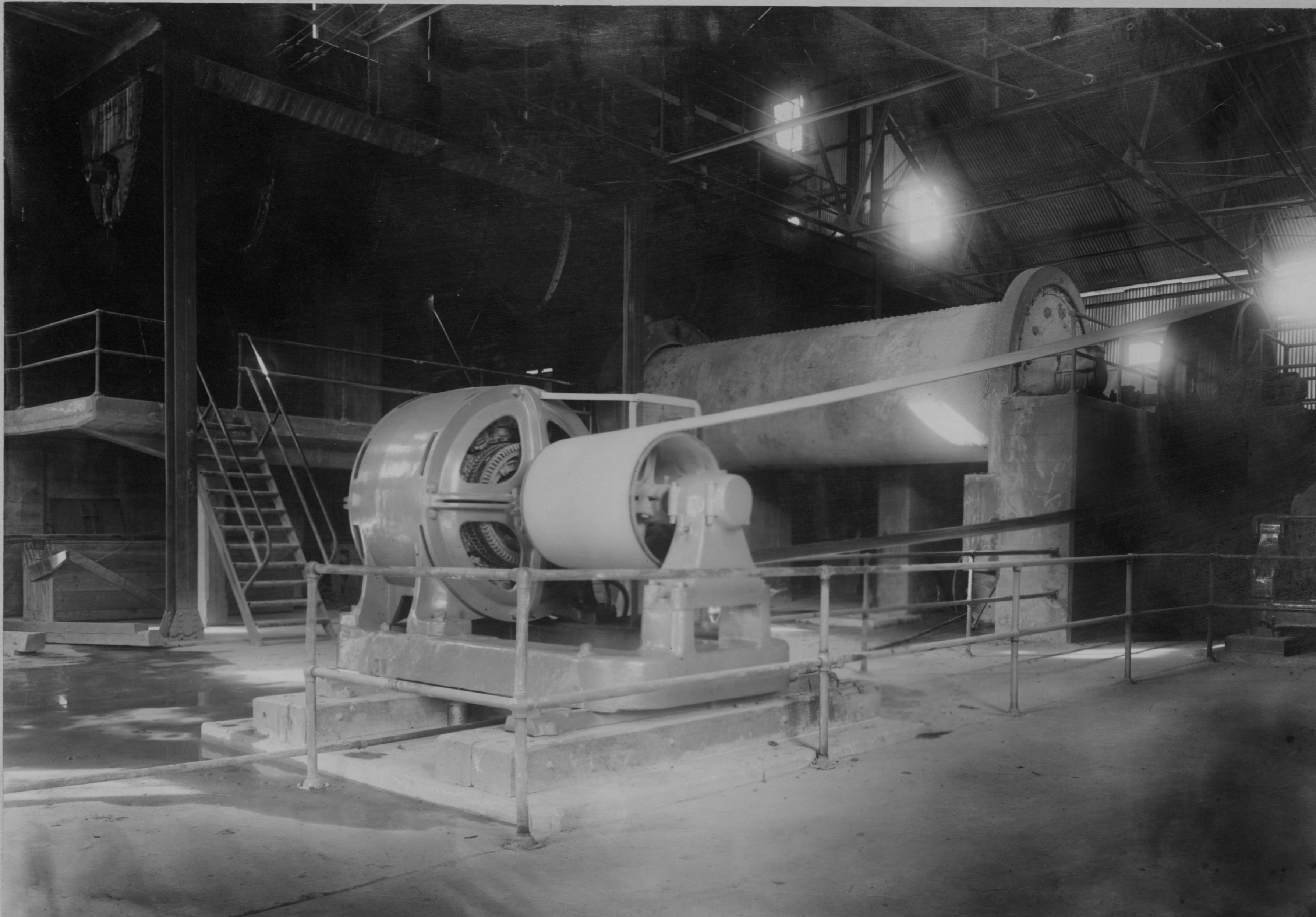
a. Quarry
b.1 Preliminary crushing, secondary breaking down and storing of raw material.
b.2 Drying, grinding and pulverizing of raw material.
c. Burning the raw material to cement clinker and cooling it.
d. Crushing, grinding and pulverizing the cement clinker.
b. The raw end complete.

	H.P. hrs. per bbl. Cement	% of Total
a		
b_1	.8515	5.3
b_2	5.3412	33.1
b	6.1927	38.4
c	1.5765	9.8
d	8.3463	51.8
	16.1155	100.0

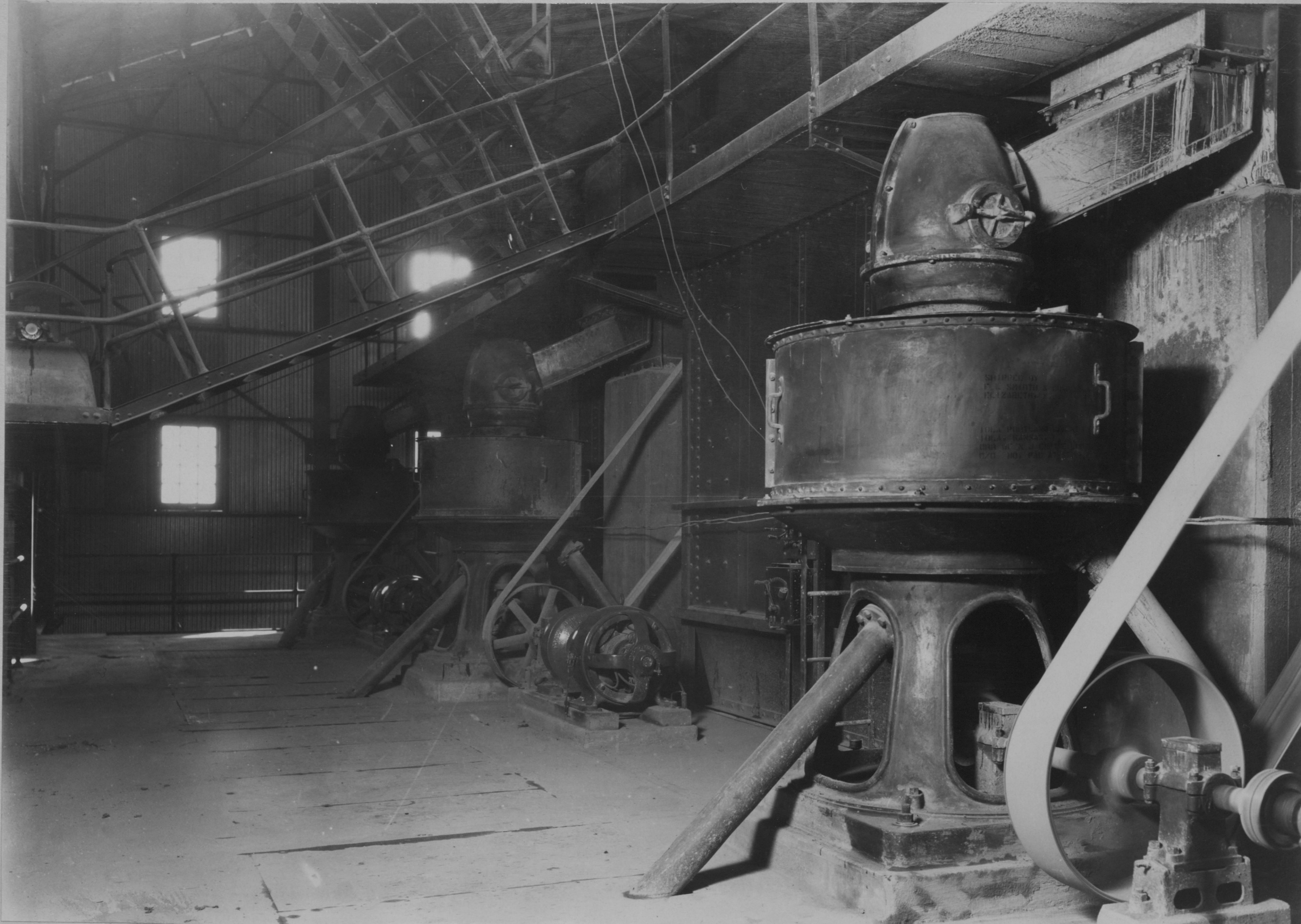
b	6.1927	30.9
c	1.5765	7.8
d	8.3463	41.7
Coal	2.6384	13.1
Aux.	1.3405	6.5
	20.0944	100.0



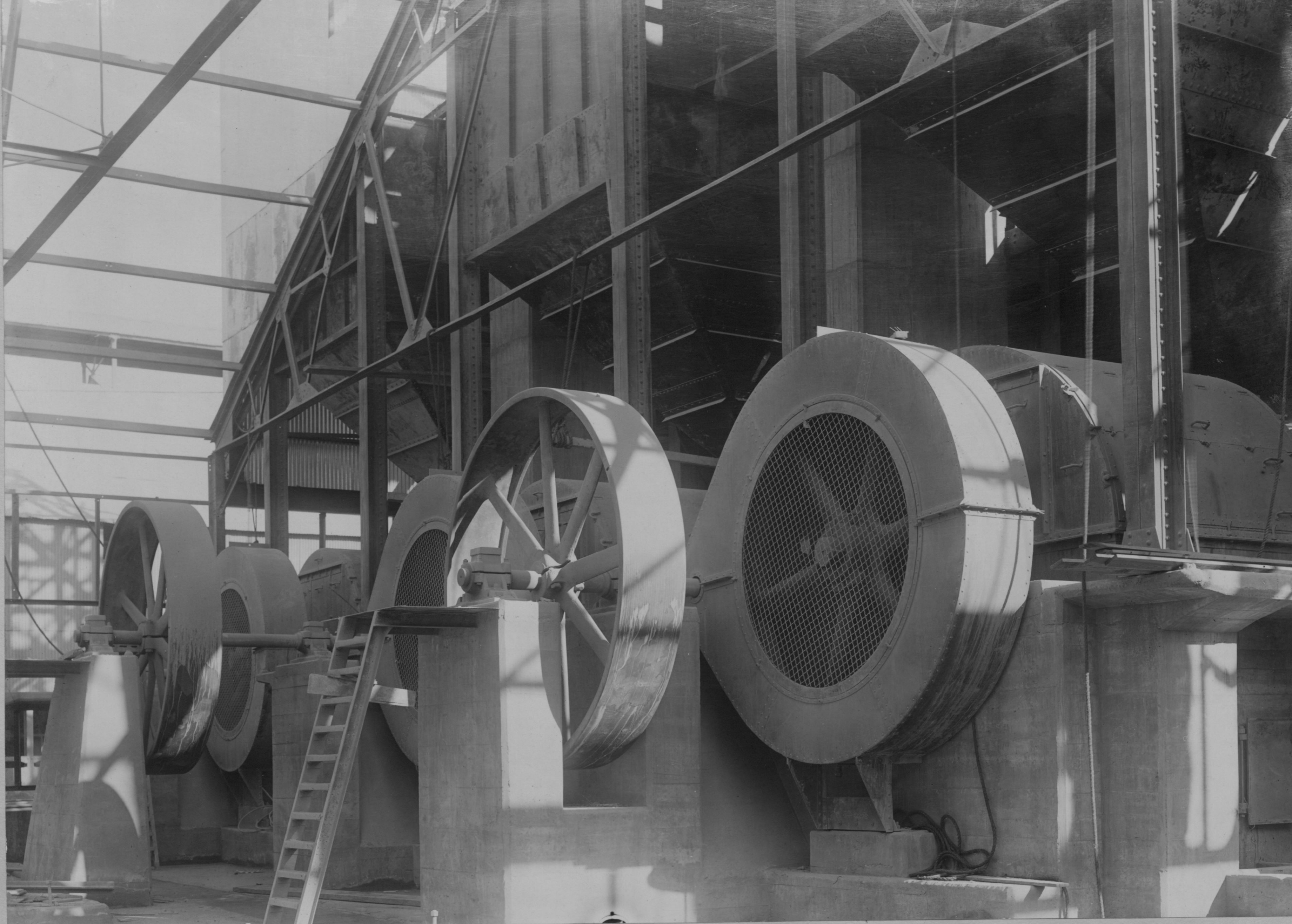
250 H.P. WESTINGHOUSE GAS ENGINE IN OLD PROCESS PLANT



MOTOR DRIVEN TUBE MILL



PUG MILLS



BALL MILLS

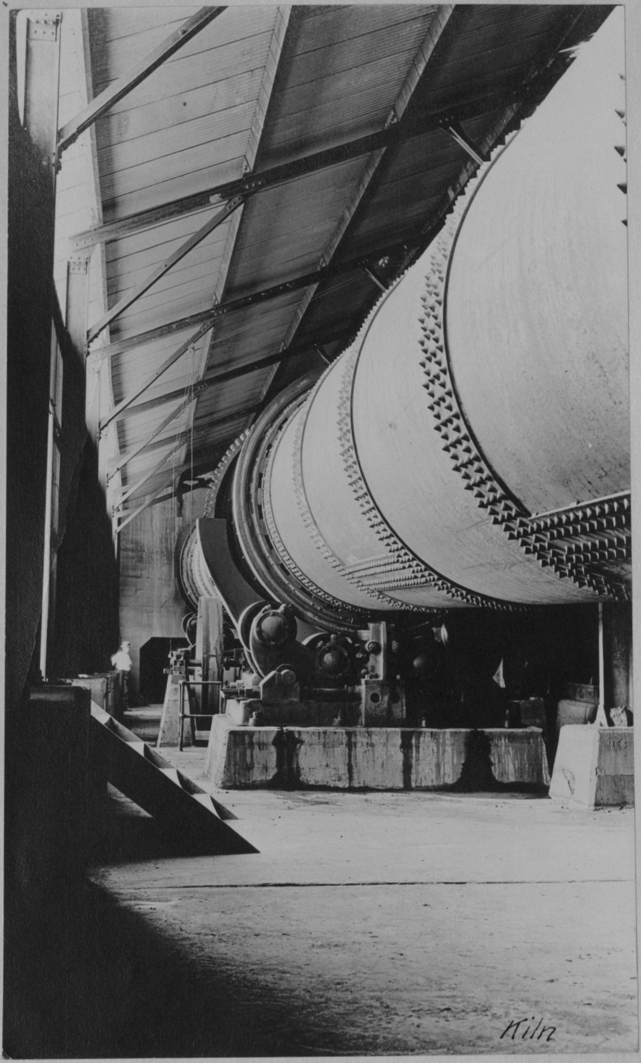
TUBE MILLS

THE QUARRY

THE STEAM SHOVEL

Steam Shovel.

Steam shovel - Quarry



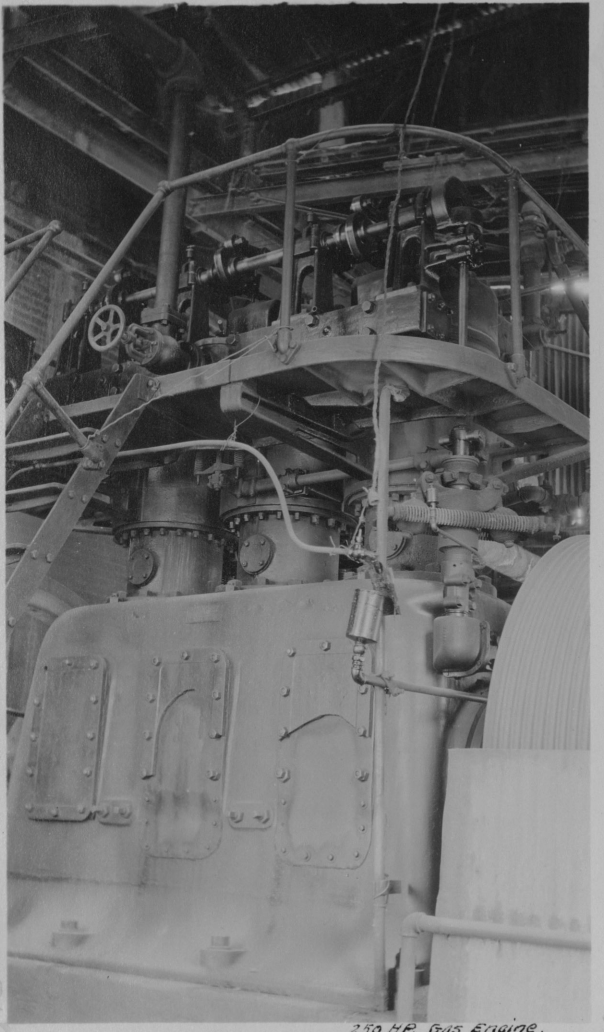
Kiln

Griffin Mills.

Clinker Cooler

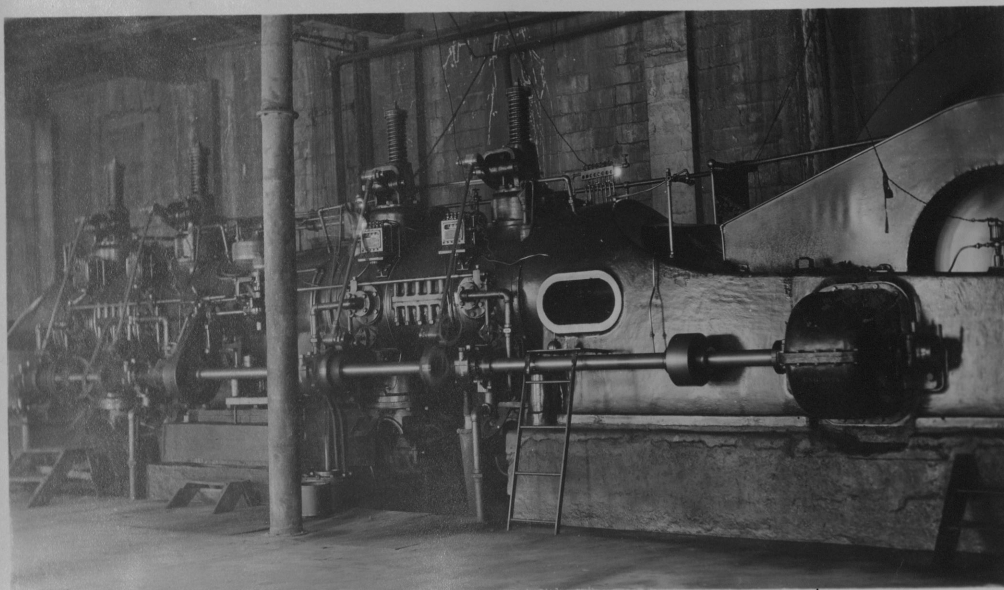
Storage Bins.

250 H.P. Gas Engine

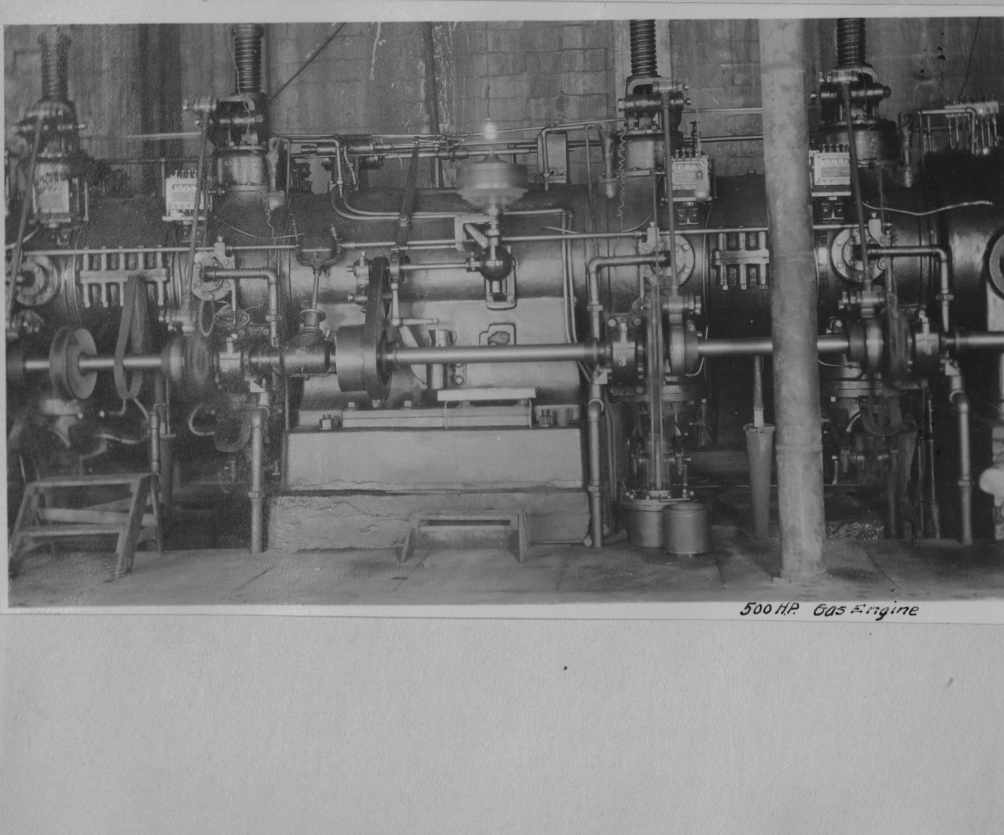


250 H.P. Gas Engine.

500 H.P. Gas. Engine

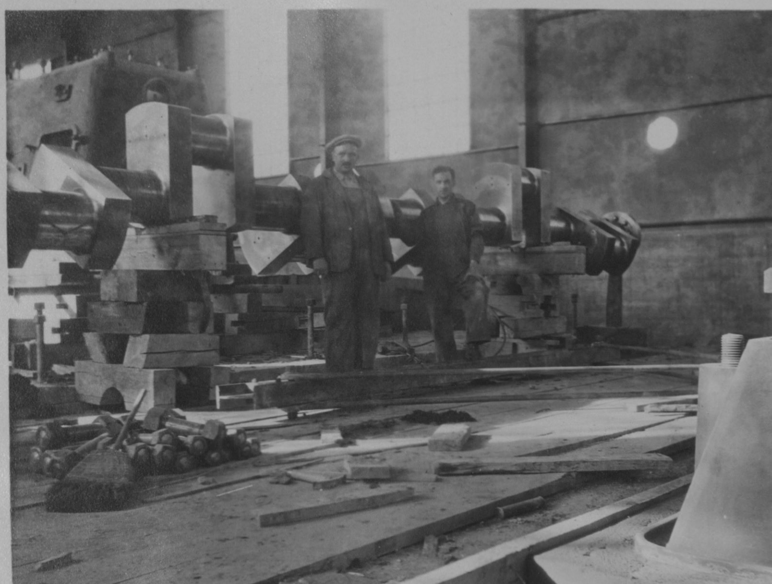


500 H.P. Gas Engine

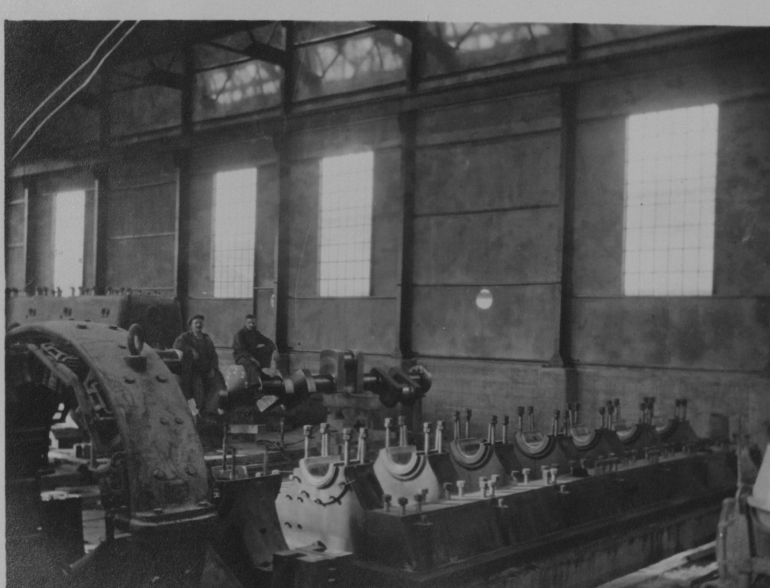


500 H.P. Gas Engine

Crank Shaft and Bed - 1000 H.P. Diesel Engine



Crank Shaft - 1000 H.P. Deisel.



Bed - 1000 H.P. Diesel.

Cylinders - 1000 H.P. Engine

Cylinders - 1000 H.P. Eng.