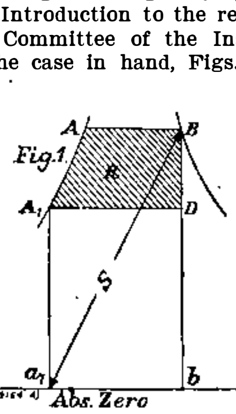
NOTE ON STEAM-TURBINES.

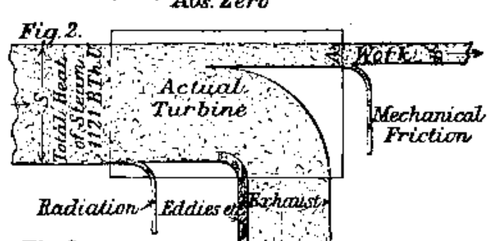
By CAPT. H. RIALL SANKEY, R.E. (ret.), M.Inst.C.E., M.I.Mech.E.

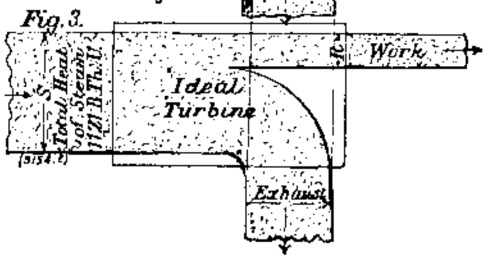
THE following diagrams illustrate the production of motion energy in steam-turbines of various types, and the conversion of this energy into mechanical work; and it is hoped that they may be of assistance to those who are beginning to study the steam-turbine.

The matter is regarded from the standpoint of a flow of energy into, through, and out of the turbine. A portion of the energy flow is converted into work, another portion leaks out during passage through the turbine in the form of radiation and conduction, but by far the greater amount flows away into the exhaust. Even if the turbine were ideally perfect—that is to say, if there were no radiation or conduction losses, and the conversion into work were the maximum theoretically possible—the portion flowing away in the exhaust would still be very considerable. As is well known, for saturated steam the maximum conversion is that of the Rankine cycle, and is exhibited on the energy chart in Fig. 1 by the shaded area marked R, and the area $a_1 A_1 A B b$ represents the total energy flow, or rather, it is the heat energy expended on each pound of steam to raise the pound of water from the exhaust temperature and convert it into steam at the admission temperature. If 100 deg. F. be chosen as the exhaust temperature corresponding to 28 inches of vacuum, or to approximately 1 pound absolute pressure; and if 366 deg. be taken for the admission temperature, corresponding to very nearly 165 pounds absolute pressure, it will be found that $R = 317$ British thermal units, and the heat going away in the exhaust will be represented by the area $a_1 A_1 D b = 804$ British thermal units.

Adapting a diagram originally prepared by the writer for the Introduction to the report of the Thermal Efficiency Committee of the Institution of Civil Engineers to the case in hand, Figs. 2 and 3 are obtained for an actual and an ideally perfect turbine.

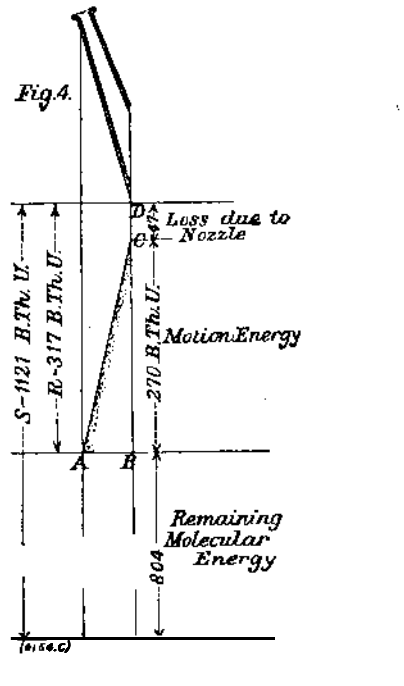






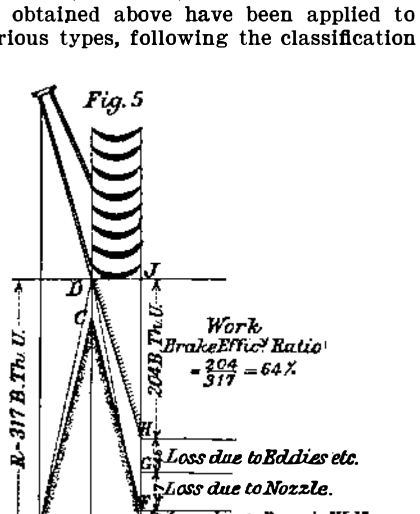
The admission and exhaust pressures and temperatures are taken at the same values as in Fig. 1, and it will be supposed that 1 pound of steam per second is flowing through the turbine, corresponding to about 200 brake horse-power. This is, of course, a very small turbine; but the reasoning is not affected thereby. The width of the stream of energy is S British thermal units per second when reckoned equal to 1,121 British thermal units in the numerical example under consideration from 100 deg. F. The issuing stream, representing mechanical work, is of width R (317 British thermal units) for the ideal turbine, and of width A (220 British thermal units) for the actual turbine. A/S is the thermal efficiency of the actual turbine, and the ratio A/R is the "efficiency ratio" as defined by the Thermal Efficiency Committee. In the numerical example the thermal efficiency is 19.5 per cent, and the efficiency ratio equals 69 per cent. These figures have been reckoned on what corresponds to the indicated horse-power, so that actually A must be further reduced to the width B to allow for mechanical frictional resistances in the turbine, as shown in Fig. 2; the ratio B/R, equal in this case to 64 per cent, might be called the *brake efficiency ratio*, and in the case of a turbine seems to be the best ratio to take.

Directly the steam enters the turbine it is made to acquire a considerable velocity by being expanded through nozzles or blades of suitable shapes. The motion energy thus created is derived from the molecular energy of the steam, which is reduced by the exact amount thus created. Thus in Fig. 4, if A represents the entry to a nozzle, and R is plotted equal to the heat utilization of the Rankine cycle, at B, the exit from the nozzle, the height $B C$ would represent the motion energy of the issuing jet, and the balance $C D$ would be partly in the form of eddies, the remainder lost as radiation. If the nozzle were perfect, the point C would move to D, and the motion energy imparted to the steam would be equal to R, and the ratio BC/BD is the efficiency of the jet. A line, $A C$, would represent the amount of motion energy at every section of the nozzle, and the shape of this line would depend on the shape of the nozzle. If the jet plays on suitably-shaped vanes, the motion energy will be converted into work; and if the steam came to rest on issuing from the moving vanes, the whole of the motion energy would be converted into work. Actually, however, in the case of a single row of moving blades, this velocity of the steam would be about 1,000 feet per second, corresponding to 20 British thermal units per pound of steam; and this energy is represented in Fig. 5 by the height $E F$; then $F G$ is plotted equal to $C D$, and thus represents the loss due to the inefficiency of the nozzle; and the balance $G H$ represents eddies, radiation, etc. The remainder, $H J$, is converted into work, and clearly the ratio $\frac{JH}{JE}$ is the brake efficiency ratio, equal in the numerical example under consideration to 64 per cent. $C F$ gives the reduction in motion energy as the steam passes through the openings between the moving blades, and the dotted lines, $A D$, $D E$, represent the conditions in the ideally perfect turbine.



In Fig. 6 the idea is extended to a turbine having an additional set of fixed and moving blades, as indicated diagrammatically. The issuing velocity from the first row of moving blades will be considerably greater than in the previous case; consequently, a smaller portion of the motion energy will be converted into work in the first row of moving blades. In passing through the fixed blades no work is done, as shown by the horizontal line, but the motion energy will be somewhat reduced, as shown by the sloping line; the motion energy thus lost will reappear as heat. The second row of moving blades converts a further portion of the motion energy into work; and finally, as before, $\frac{JH}{JE}$ is the brake efficiency ratio of the turbine.

Fig. 7 represents an element of the Parsons parallel-flow turbine, drawn to a much larger scale than the previous figures, and it will be noticed that in this case motion energy is produced both in the fixed and moving blades; it is, of course, only in the moving blades that mechanical work is done as indicated in Fig. 7. The curves shown, however, are only diagrammatical. The results obtained above have been applied to turbines of various types, following the classification proposed by Mr. Neilson, in a paper he read before the Manchester Association of Engineers. His Classes I. and III. have already been dealt with in Figs. 5 and 6. The Laval and the single-disk Rateau turbine are practical examples of Class I. Class III. is represented by one type of the Riedler-Stumpf turbine. Figs. 8 to 10 deal with the remainder of Neilson's classification, and the names of some of the actual turbines at present being manufactured are noted against each figure.



In Figs. 8 and 9 the loss due to the nozzles is indicated by the vertical distance between the motion-energy line and the lower chain-dotted line, and the loss due to eddies, etc., is measured vertically from the "work" line to the upper chain-dotted line. The distance between the two chain-dotted lines gives that portion of the utilizable energy in the steam (317 British thermal units) still remaining as molecular energy in the steam at the various stages in the turbine. In Fig. 8 the temperature and pressure are also shown, on the supposition that one-third of the total utilizable energy is dealt with by each of the three sections of the turbine. The rapid drop of pressure in the first section is very noticeable.

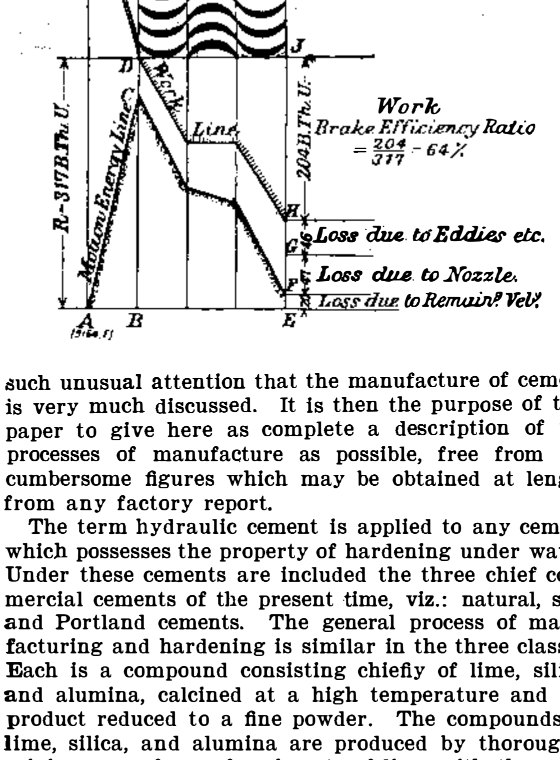
	Neilson's Classification.	Names of Actual Turbines.
Fig. 8	Class II.	Rateau Multicellular. Zoelly. Hamilton Holzwarth.
Fig. 9	Class IV.	Curtis. Riedler-Stumpf.
Fig. 10	Class V.	Parsons.

In the case of the Parsons turbine (Fig. 10) the alternate rows of blades are so numerous (50 to 80) that they cannot be shown to so small a scale; therefore only three sets of fixed and moving blades have been drawn to a larger scale than the rest of the figure. Both the "work" line and the motion-energy line will therefore be in the shape of a saw, following $D H$ and $A F$ respectively. For the sake of comparison the brake-efficiency ratio has been taken as the same as in the case of the other turbines, although for so small a Parsons turbine as 200 brake horse-power this ratio would be less. Similar diagrams can obviously be drawn for any other form of turbine by combining, as may be necessary, the diagrams given in Figs. 5, 6, and 7.—Engineering.

MANUFACTURE OF HYDRAULIC CEMENTS.*

By L. L. STONE.

IN preparing a paper on the subject of cement it is fully recognized that many articles have already been prepared on this subject, and that various descriptions of it have repeatedly been written. Yet, the extensive developments in the cement industry, both from an engineering and financial standpoint, are commanding such unusual attention that the manufacture of cement is very much discussed. It is then the purpose of this paper to give here as complete a description of the processes of manufacture as possible, free from the cumbersome figures which may be obtained at length from any factory report.



The term hydraulic cement is applied to any cement which possesses the property of hardening under water. Under these cements are included the three chief commercial cements of the present time, viz.: natural, slag and Portland cements. The general process of manufacturing and hardening is similar in the three classes. Each is a compound consisting chiefly of lime, silica, and alumina, calcined at a high temperature and the product reduced to a fine powder. The compounds of lime, silica, and alumina are produced by thoroughly mixing some form of carbonate of lime with the exact proportion of clay.

Natural cement was the first cement manufactured in this country, and was extensively used some years ago when nearly all Portland cement was imported from Europe. It is still used to a small extent but only for work of secondary importance. It is made in several places throughout the country from natural deposits of rock containing nearly the same proportions of lime rock and clay as are used to produce Portland cement. If a uniform deposit of rock containing exactly the correct proportions of rock and shale could be found, a natural cement, equal in grade to Portland cement, could be made of it, by simply burning and grinding; but since a variation of a very few per cent in composition is sufficient to destroy or greatly reduce the value of the resulting cement, there never has been found a natural rock deposit sufficiently uniform to produce a cement of this quality. In many cases it is only by the most careful sorting and mixing of certain portions of the raw material that cement can be made from it at all. The process of manufacture is very simple—the rock is quarried and burned at a comparatively low temperature and ground to a powder. It is slower in setting than Portland cement and does not develop as great strength.

Slag cement is made by mixing blast furnace slag with some form of lime, then burning and grinding.

* Read before the University of Michigan Engineering Society.

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It can also be made from the forms of rock discharged from volcanoes, and it is thought that this is the source of the cement used by the Romans in their engineering work. Its manufacture was introduced into this country more to provide a way of disposing of the vast amount of slag accumulating at the larger blast furnaces than for its demand as a cement. The slag as it comes from the furnaces is generally granulated by contact with cold water. It is then mixed with slaked lime and heated and the resulting mass finely ground. A description of the machinery employed in these processes has not been given for it is similar to that used in the manufacture of Portland cement which will be described more in detail.

Portland cement was first made in England about the year 1825. It derives the name "Portland" from Portland Island rock, from which cement was first made. While the essential features of the process of manufacturing were there discovered, cement was not manufactured to any great extent until it was introduced into Germany and Belgium. It is still manufactured in those countries on a very extensive scale, but up to a few years ago little attention was given to improvements of the old system. Its manufacture was not begun in this country to any great extent until about fifteen years ago. Up to 1891 over 80 per cent of the cement used in this country was imported from Europe. It was about this time that engineers began to discover that cement could be produced here as well as in Germany. Improved machinery was devised to compete against the cheap hand labor of the European mills, and as a result cement is manufactured here of equal strength and at far less cost than that of foreign cements. At present practically all of the cement used in this country is American made, except the small percentage used in the few seaboard towns where a high freight makes importation profitable.

In the manufacture of this cement the factories are divided by the nature of the process used in three classes; the wet, semi-wet, and dry processes, all methods being extensively used.

In mills operating under the dry or semi-dry processes, the methods of handling the raw materials are the same. The carbonate of lime is generally obtained from dry lime stone or chalk rock and the silicates from clay and shale. The rock and shale are quarried by the use of air or steam drills and high explosives. Small surface cars are generally used to transfer the quarried rock to the mill where it is crushed in gyratory crushers of various sizes. In quarrying the shale, the fact that it is readily disintegrated by the action of the air is sometimes utilized; large masses of the shale being blasted loose to allow the free action of the air, thus permitting it to be more readily transported. It is then passed through a pulverizer and stored in large bins separately from the rock. The crushed rock has been reduced by this process to such a size that nearly all of it will pass through a one-inch screen and the shale is in the form of a coarse powder.

The materials are then passed separately through rotary dryers where a small percentage of the moisture is removed. A portion of the rock is then taken by weight and mixed with the correct amount of dried shale. It is in determining the proportion of this mixture that the first work of the operating chemist begins. Analyses of both materials are made and the variation in chemical composition is so corrected as to result in a mixture containing the proper elements to produce Portland cement. The materials are then ground to a fineness such that about ninety per cent will pass through a sieve of one hundred meshes per lineal inch. Burr stones were formerly used for this purpose, but they have been replaced by more economical grinding apparatus. A number of different types of mills have been devised for grinding rock, but either a Griffin mill or a combination of a ball and tube mill are generally used in this country.

The Griffin mill operates a revolving vertical shaft suspended from a central point, on one end of which is a fixed round head about eighteen inches in diameter with a six-inch face. This head rotates in a swinging motion inside of a thirty-inch tire, thus generating a centrifugal force which grinds the material between the surfaces of the head and tire. Above the tire is a circular screen through which the rock is thrown by an iron fan on the shaft as soon as it becomes sufficiently fine. It then drops through openings in the bottom of the mill where it is received by suitable screw conveyors.

The ball mill consists of a circular shell about eight feet in diameter by six feet in length lined with perforated steel plates. It contains a number of round steel balls from three to five inches in diameter, which, when the mill is revolved, fall on the pieces of rock and crush them till they pass through the perforated plates and leave the mill. This mill is not suitable for a finishing mill, but is very good to reduce the crushed rock sufficiently to allow about eighty per cent to pass through a twenty-mesh screen.

The tube mill is a steel cylinder twenty-two feet long by five feet in diameter, revolving at about twenty-nine revolutions per minute. It is lined with an extremely hard quartz and loaded with flint pebbles about two inches in diameter. The material is reduced to the required fineness by the pounding and rubbing of these pebbles. It is at this point that the different methods are used which distinguish the mill as being of the dry or semi-dry process. Under the dry process the ground rock is conveyed from the mills and stored in suitable bins from which it is fed by feeding mechanisms into the kilns. If the semi-dry process is used, the powder is mixed with thirty per cent of water making a thin mud or slurry. This slurry is stored in steel tanks and is kept agitated by large revolving sweeps or by blasts of compressed air until it is fed by gravity or pump into the kilns.

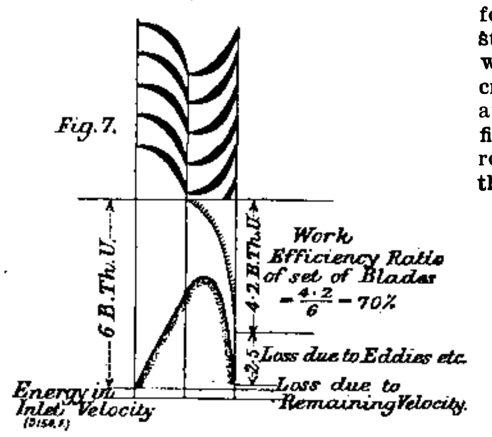
In manufacturing cement under the dry or semi-dry process about six hundred pounds of raw material are required to produce one barrel of cement. It is thus seen that the water added under the semi-dry process must be removed by burning. There is much discussion among cement engineers as to the practical value of this system. While it requires an extra amount of fuel to evaporate the added water, it is claimed that the cost of this difference of fuel is compensated, especially in the natural gas fields, by the power saved in grinding, less wear in the kilns, due to lower temperatures, and greater assurances of uniform cement of the best quality. The raw material is used in the semi-dry process several per cent coarser than in the dry process, and it also allows a further correction after grinding, which cannot be made under the dry process.

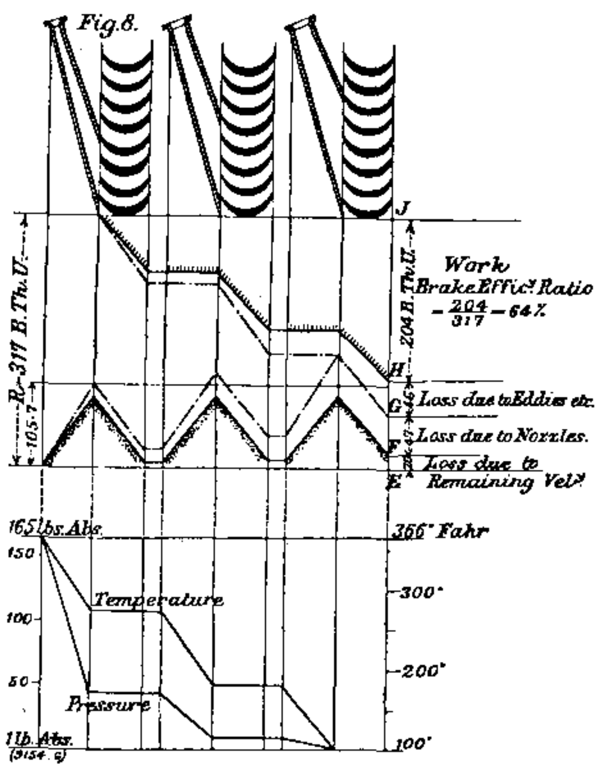
When marl is used to supply the carbonate of lime it is usually found in a swamp or lake and mined by the use of a dredge. It is removed to the plant by tram cars or is pumped by compressed air. The marl, as it is usually obtained, contains between sixty and eighty per cent of water. As four hundred and fifty pounds of carbonate of lime are required for one barrel of cement, this percentage shows that from fourteen hundred to eighteen hundred pounds of water must be evaporated from the marl for each barrel of cement. Due to the close union of the water and marl, no mechanical process has yet been discovered for separating them. The only possible way to remove the water without a prohibitive consumption of fuel is by means of evaporation. The latter process was formerly employed, always accompanied by a high cost of operation, but with the invention of kilns designed to receive the raw material in the form of slurry, the factories using marl are now operated under the wet process. In the marl process the grinding is comparatively simple. The marl is mixed by weight with the proper amount of clay and ground wet, making an exceedingly fine slurry.

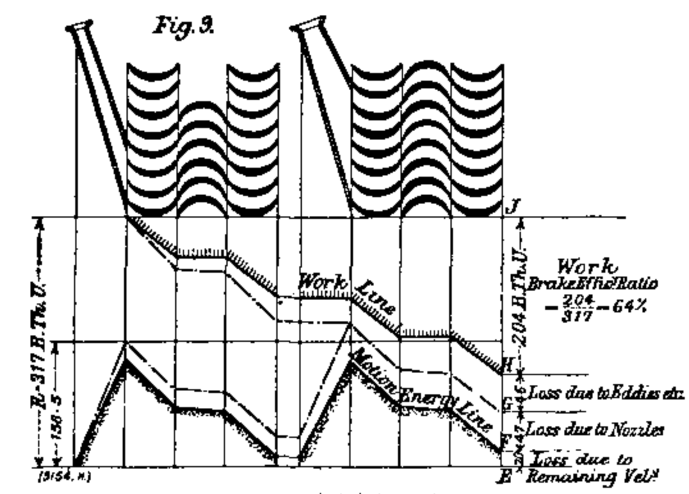
Under the wet and semi-dry processes the slurry is carefully tested before being fed into the kilns. The test is an all-important one and determines almost entirely the quality of cement that will be produced by the mill. The only mix thus far in the operation is the rough or approximate one made when the two materials were first introduced to the mill. The final test is now made and the exact correction made. If the mix runs above the required percentage of rock, enough shale or clay is added to secure the proper composition. The same treatment is made if the mixture runs too high in shale, carbonate of lime being then added to secure the proper composition. These tests are made with the greatest precision on all materials before being allowed to leave the tanks. Any number of corrections necessary are made to secure the correct composition for any particular materials. In the dry process this exact mix is made by weight before the materials are ground, which insures an intimate mix by grinding.

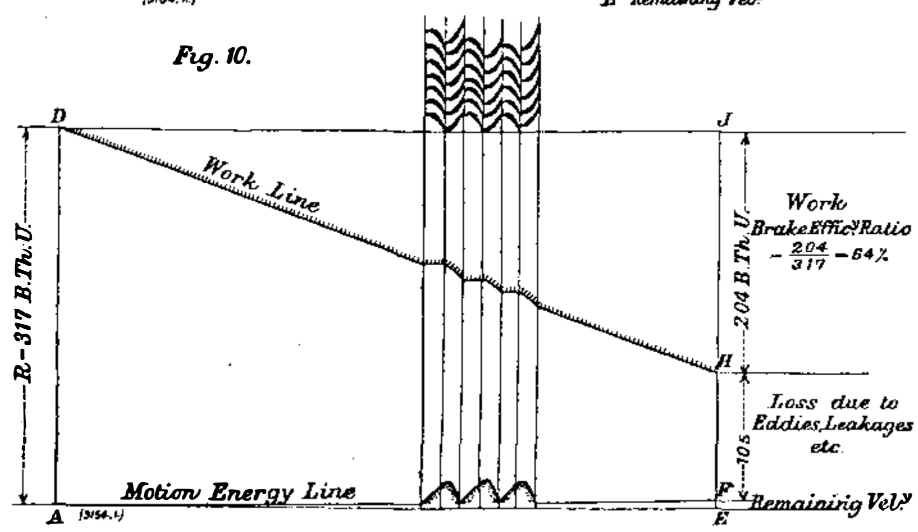
A great number of different kilns or furnaces have been devised for burning cement rock but only two have been extensively used. In the European mills a type of vertical kiln is used. These kilns have a vertical body similar to an inverted cone. The dried slurry is loaded into the kiln in alternate layers with the fuel and fire placed at the bottom. The heat and gases of the fire pass upward through the mass in irregular openings, consequently the resulting clinker is not of a uniform nature, part being overburdened, part being underburdened, and part in the proper condition, and all has to be sorted before being used. The waste gases from the kiln are conducted through long chambers so as to utilize the heat of the kiln during operation for evaporating the moisture from the slurry. When this type of kiln is properly built it is economical in fuel but requires a great deal of hand labor for operation, which is detrimental in this country. These kilns have been placed in but few of the American mills, those being among the first built.

The kilns in which practically all of the cement in this country is burned are known as rotary kilns. They consist of a steel cylinder six to seven feet in diameter by sixty to eighty feet in length, constructed of steel sheets one-half to nine-sixteenths inch in thickness. This shell revolves from one-fourth to one revolution per minute, and is carried by very true locomotive tire steel rings which ride on cast steel rollers. These rolls are so elevated that the kiln is deflected from the horizontal between one-half to three-quarters of an inch per









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foot. The kiln is operated by a large girth gear into which meshes a train of gears that reduce the speed from two hundred to one so as to receive power from an electric motor or line shaft. When this type of fuel was first tried much difficulty was experienced in securing the proper combustion of fuel. Its successful operation was first secured by the use of crude oil, but owing to its cost, a substitute was necessary. Coal was then tried and is now almost exclusively used except where natural gas is found in large quantities. The coal is ground to a fineness of ninety per cent to pass through a hundred mesh screen and is shot into the kiln by a continuous blast of compressed air. The heat is regulated by varying the amount of coal. If gas is used for a fuel it is generally passed through a cast-iron burner which creates the proper mixing of gas and air for complete combustion. To burn or calcine the raw materials, a heat of from twenty-eight hundred to thirty-two hundred degrees Fahrenheit is required. For this reason the kiln is lined for nearly its entire length with from nine to twelve inches of extremely refractory brick. In the process of burning, the dry rock or slurry is fed into the upper end of the kiln and gradually moved toward the lower end by its inclination and revolution. The process is thus seen to be continuous and with the variations in speed of kiln, the amount of raw material fed into it, and the regulation of the amount of fuel, is entirely under the control of the operator. The product thus formed is of uniform grade and all burned to a proper degree of hardness.

The process of burning is a most important one in the manufacture of cement and open to great improvement, consequently this department receives probably more attention than any other of the operations involved. The first successful rotary kiln was five feet in diameter by thirty feet in length, but this size was gradually increased to six feet in diameter and sixty feet in length which was regarded as standard until four of five years ago. While this kiln has a greater capacity and gives more uniform results than the old type of vertical kiln, the amount of fuel required for its operation is much greater than that required by the old system of burning.

The vertical kiln requires about forty pounds of coal to burn one barrel of cement, while it requires from a hundred to a hundred and fifty pounds of coal to burn one barrel of cement in the rotary kiln. But when the vertical kiln is used the raw material must be made up in the form of briquettes and placed in the kiln and after being burned a certain time, taken out. This is all accomplished by hand labor, which prevents the successful use of this kiln in this country.

After the practical success of the rotary kiln was established manufacturers began to modify the kiln in the hope of securing greater economy.

When this kiln is in operation it creates a stack temperature of from seven to twelve hundred degrees F., and the line of improvement has been to endeavor to utilize this waste heat. A number of different methods have been devised, but only two have been developed to a working basis. By one method the waste gases are passed through steam boilers supplemented by direct furnace fire, thus utilizing the waste heat for the generation of power. The chief objections to this system are the excessive cost of the complicated machinery, the difficulty of suitably placing the boilers and furnaces and the presence of more or less dust in the gases which behaves very unfavorably in the furnaces.

The other method is to utilize the hot gases to heat the raw material which is done by increasing the length of the kilns. This idea is the more practicable of the two and kilns were previously developed up to a length of eighty feet beyond which, due to mechanical reasons, it was not considered practical to continue. But this idea was most strikingly developed in a factory designed by Thomas A. Edison where two kilns were built nine feet in diameter by one hundred and fifty feet in length. These kilns produced the most economical results of any rotary kilns yet made and burned cement with from twenty-five to thirty-five pounds less coal per barrel than any kiln of this type up to this time has done. However, a number of mechanical difficulties arose which interfered with the continual operation of the kilns and for these reasons it was not considered by many engineers a complete success. Several modifications of this type of kiln have since been made in the hope of securing an ideal size. In the year of 1902 four kilns seven feet in diameter by one hundred feet in length were designed by the Hunt Engineering Company and installed in the works of the Western Portland Cement Company two years later. These kilns reduced the stack temperature to slightly over four hundred degrees F., and gave such satisfactory results that the same company is now equipping a plant in southern Kansas with ten kilns eight feet in diameter by one hundred and ten feet in length, so installed as to operate under either the dry or semi-dry process.

The product as it is discharged from the rotary kiln is in the shape of small, black, and very hard pellets. It is very hot and must be cooled before grinding. This is usually accomplished by some artificial means. One method is to pass the clinker through a rotary cooler, similar in construction to a rotary kiln with the exception of the lining, from three to five feet in diameter and from thirty to fifty feet in length, through which passes a forced blast of cold air. Another method is by the use of large steel tanks in the body of which are placed perforated cast-iron ducts which divert currents of cold air through the heated mass. In some mills it is cooled by slightly sprinkling with water and in others by letting it lie in large heaps to cool by radiation. About four per cent of gypsum is then mixed with the clinker and it is ground into cement by the same style of mill as is used to reduce the rock.

The cement materials are subjected to chemical and physical tests in all departments. These tests are conducted in laboratories which are found at all plants. In the chemical department all chemical analyses are made and the proportions of rock and shale are here determined. The samples of slurry are here analyzed and the proper amount of correction computed. The clinker is also analyzed to determine its soundness and composition and the quality of burning. Also, a final test is made of all finished cement before shipment. A sample is also kept from each shipment for future reference should any complaint be registered against any shipment of cement.

In the physical laboratory tests of strength, time of setting, and results under accelerated conditions are determined. The cement is molded into small briquettes about four inches long which are of one square inch sectional area in the center and somewhat larger at each end. The briquettes are pulled in two by a testing apparatus and tensile strength per square inch thus registered. Small cubes are also made one inch on edge and the load required to crush them noted. Briquettes made of cement and twenty per cent of water seven days old must test about four hundred and fifty pounds tensile strength. The compressive strength is generally from twenty to twenty-five times the tensile strength.

The setting of cement is in two periods, designated as the initial and final set. The initial set must take place in from twenty-five to forty minutes and this is considered to be acquired when a sample of cement will bear without indentation a wire one-twelfth inch in diameter and loaded to weigh one-fourth of a pound. The final set is considered to have been acquired when the mixture will bear a wire one-twenty-fourth of an inch in diameter, loaded to weigh one pound. The time of setting is regulated by the amount of gypsum ground into the cement. When the clinker and gypsum are ground together every particle of cement is covered with a coating of gypsum which requires a certain length of time for the water to penetrate. It is this required time which delays the action of the cement and water that determines the time of setting and is regulated by the proper amount of gypsum. The accelerated tests are intended to produce in a short time the same effect as that of longer periods under a normal climatic condition. They consist chiefly in placing the hardened cement in cold water, in boiling water and under steam pressure for several hours. The samples must in all cases remain perfectly sound and show no checks or abrasions in the surfaces. These systems of testing serve as a check on the various processes of manufacture, and guarantee to the consumer a product of the best quality.

CEMENT MORTAR AND CONCRETE: THEIR PREPARATION AND USE FOR FARM PURPOSES.*

By PHILIP L. WORMLEY, JR.

INTRODUCTION.

THE many letters received and referred to the Office of Public Roads with reference to the use of cement and the adaptability of concrete for various farm purposes have made it seem advisable to issue a short bulletin on the subject, in which a proper method of mixing concrete is described, together with a few of the many uses for which concrete is well adapted. No attempt has been made to give a technical discussion of the subject, the sole object being to treat in an elementary way those points in concrete construction which are of particular interest to the farmer.

In the appendix will be found the results of tests made to determine the strength of reinforced concrete fence posts, together with tests showing the effect of retempering Portland cement mortar.

CEMENT.

The term "hydraulic cement" is applied to one of the most useful materials of engineering construction and one which in recent years has become widely extended in its field of application. Hydraulic cement possesses the property of hardening, or setting, under water, in which respect it differs from lime, which does not harden except in the presence of air. Thus it is evident that in all places where air is excluded, such as foundations, thick walls, etc., cement mortar should be used instead of lime.

Only two classes of cement will be discussed here—Portland and natural. The difference between these is due partly to the method of manufacture and partly to the condition and relative proportions of the materials employed, which are, generally speaking, limestone and clay. In the manufacture of Portland cement the separate materials are mixed in such proportions as have been found by experience to give the best results. The mixing is done by grinding the materials together in mills, after which the mixture is burned at a very high temperature in kilns, and the resulting clinker ground to an impalpable powder is known as Portland cement. In the case of natural cement the materials used have been already mixed by nature in approximately the correct proportions, being found in the form of a rock which is generally classed as a clay limestone, or a limy deposit technically called calcareous clay. This material is burned at a much lower temperature than Portland cement. When the manufacturer has each ingredient absolutely under control and can adjust the proportions to suit all conditions, it is reasonable to expect that a better and more uniform product will result than when the materials are found already mixed. Portland cement is far more extensively employed than natural cement on account of its superior strength, although the latter is frequently used in cases where great strength is of little importance. The superior strength and durability of cement as compared with lime, together with the low price at which it may now be procured, have caused the former to replace the latter in engineering construction to a great extent.

Storing Cement.

In storing cement care must be exercised to insure its being kept dry. When no house or shed is available for the purpose, a rough platform may be erected clear of the ground, on which the cement may be placed and so covered as to exclude water. When properly protected, it often improves with age. Cement is shipped in barrels or bags, the size and weight of which usually are as follows:

Bulk and Weight of Cement in Ordinary Barrels and Bags.

Kind of Cement.	Per Barrel.		Per Bag.	
	Quantity, Cu. Ft.	Weight (Net), Pounds.	Quantity, Cu. Ft.	Weight (Net), Pounds.
Portland.......... ...	3½	380	⅞	95
Natural*..............	3½	300	⅞	75

* Western natural cement usually weighs about 265 pounds per barrel net.

Cement Mortar.

Cement mortar is an intimate mixture of cement and sand mixed with sufficient water to produce a plastic mass. The amount of water will vary according to the proportion and condition of the sand, and had best be determined independently in each case. Sand is used both for the sake of economy and to avoid cracks due to shrinkage of cement in setting. Where great strength is required, there should be at least sufficient cement to fill the voids or air spaces in the sand, and a slight excess is preferable in order to compensate for any uneven distribution in the mixing. Common proportions for Portland cement mortar are 3 parts sand to 1 of cement, and for natural cement mortar, 2 parts sand to 1 of cement. Unless otherwise stated, materials for mortar or concrete are considered to be proportioned by volume, the cement being lightly shaken in the measure used.

A "lean" mortar is one having only a small proportion of cement, while a "rich" mixture is one with a large proportion of cement. "Neat" cement is pure cement, or that with no admixture of sand. The term "aggregate" is used to designate the coarse materials entering into concrete—usually gravel or crushed rock. The proportion in which the three elements enter into the mixture is usually expressed by three figures separated by dashes—as, for instance, 1–3–5—meaning 1 part cement, 3 parts sand, and 5 parts aggregate.

In the great majority of cases cement mortar is subjected only to compression, and for this reason it would seem natural, in testing it, to determine its compressive strength. The tensile strength of cement mortar, however, is usually determined, and from this its resistance to compression may be assumed to be from eight to twelve times greater. A direct determination of the compressive strength is a less simple operation, for which reason the tensile test is in most cases accepted as indicating the strength of the cement.

Mixing.

In mixing cement mortar it is best to use a platform of convenient size or a shallow box. First, deposit the requisite amount of sand in a uniform layer, and on top of this spread the cement. These should be mixed dry with shovels or hoes, until the whole mass exhibits a uniform color. Next, form a crater of the dry mixture, and into this pour nearly the entire quantity of water required for the batch. Work the dry material from the outside toward the center, until all the water is taken up, then turn rapidly with shovels, adding water at the same time by sprinkling until the desired consistency is attained. It is frequently specified that the mortar shall be turned a certain number of times, but a better practice for securing a uniform mixture is to watch the operation and judge by the eye when the mixing has been carried far enough. In brick masonry the mistake is frequently made of mixing the mortar very wet and relying upon the bricks to absorb the excess of water. It is better, however, to wet the bricks thoroughly and use a stiff mortar.

Grout.

The term "grout" is applied to mortar mixed with an excess of water, which gives it about the consistency of cream. This material is often used to fill the voids in stone masonry, and in brick work the inner portions of walls are frequently laid dry and grouted. The practice in either case is to be condemned, except where the conditions are unusual, as cement used in this way will never develop its full strength.

Lime and Cement Mortar.

L. C. Sabin* finds that in a Portland cement mortar containing three parts sand to one of cement, 10 per cent of the cement may be replaced by lime in the

* Reprint from Farmers' Bulletin, No. 235, issued by the Department of Agriculture.

* Sabin, L. C., Cement and Concrete, 1905.

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