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The Wisconsin Engineer

DECEMBER, 1911

Volume 16 Number 3

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The Wisconsin Engineer

VOL. XVI DECEMBER, 1911 No. 3

A SURVEY OF THE CONCRETE AGGREGATES OF WISCONSIN.

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It is the purpose of this paper to describe the methods employed at this University in testing the sands, broken stones and gravels of Wisconsin in order to ascertain their respective merits as aggregates for making mortar and concrete.

Concrete may be defined as a mixture of inert particles of sand and gravel, sand and broken stone, or similar substances (called aggregates) and a binder which, mixed with water, possesses the property of hardening and cementing together the inert materials into a stonelike, monolithic mass. Mortar is a like substance made from a smaller aggregate, such as sand or broken stone screenings, and a cement. At the present time Portland cement is the material most used for a binder in concrete. It is obvious that the cement should be of good quality if a strong and durable concrete is to be made. Consequently, engineers have adopted certain specifications which the cement must pass before it will be accepted for use. Many engineers have long appreciated the necessity for specifications concerning the general character of the sand, gravel and broken stone, but rigid tests of these aggregates have seldom been specified. The conviction, based upon credible experimental data, is now quite firmly fixed that certain classes of aggregates should not be employed to make concrete. The causes of many failures at first attributed to poor cement have later been traced to the use of a sand or aggregate wholly unfit for such a purpose. In as much as the determination of the suitability of various aggregates is often times a long and somewhat costly process and requires a large equipment of apparatus, it is only within the province of the larger laboratories to attempt such tests.

During the past seven years the United States Geological Survey has been conducting some very elaborate tests on materials found in different parts of this country and has issued bulletins containing accounts of its methods of testing and some of the results obtained. Two years ago the Mechanics Department of this University started on a program of tests

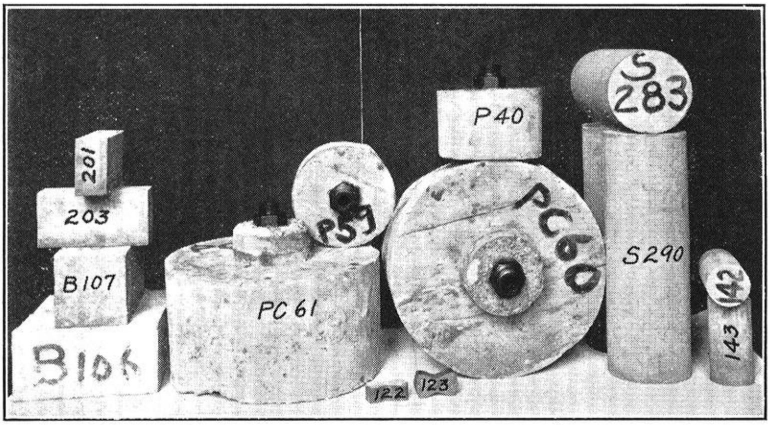

Fig. 1. *Specimens Used in Different Tests.*

which will be followed in analysing the aggregates found near the larger cities of this state.

The method of carrying out the program follows. Arrangements for securing material are made by a member of the laboratory force who, in general, inspects the deposit and determines the amount of the various aggregates needed for the tests. In order to make all the tests outlined in the present schedule, about 3000 pounds of sand and 4000 pounds of broken stone, or the equivalent of other aggregates, is freighted into Madison in cement sacks. The effort is always made to secure a sample which will represent the average out-put of each pit or quarry.

If a complete sample of material is obtained, it is subjected to the series of tests outlined below. These tests are made by paid assistants who have shown themselves accurate and painstaking and who follow carefully prepared instructions concerning the methods of handling the details of the different tests. Hitherto most of the work has been done during summer vacation, but with a recently obtained increase in the department force it is now possible to carry on the work continuously, and to much better advantage.

OUTLINE OF TESTS FOR STUDYING THE MATERIALS OF WISCONSIN WHICH ARE SUITABLE FOR MAKING CONCRETE OR MORTAR.

I. (a) Physical Tests on Aggregates.
1. Weight per cubic foot, measured loose.
2. Percentage of voids.
3. Specific gravity.
4. Granulometric (sieve) analysis.
5. Percentage and character of silt.
6. Percentage of moisture.
7. Character of aggregate.

(b) Chemical Tests (when necessary).

II. Physical Tests on Mortars Made with a Standard Mixture of Portland Cements and Sands, Screenings, or Other Material Smaller than One-Quarter Inch in Diameter.
1. Tensile tests on standard briquettes (Fig. 1, Nos. 122 and 123). Mixes employed are 1:2, 1:3, 1:4, and 1:5. Four briquettes of each mix are tested at the following ages: 1:2 mix at 7, 28, 60, 180, and 360 days; 1:3 mix at 7, 28, 60, 180, 360 days, 2 yr., and 5 yr.; 1:4 and 1:5 mixes at 7, 60, and 360 days.
2. Compression tests on 3x6-in. cylinders (Fig. 1, Nos. 142 and 143). Mixes employed are 1:2, 1:3, 1:4, and 1:5. Three cylinders of 1:2 and 1:3 mixes are tested at 7, 28, 60, 180, and 360 days; three cylinders of 1:4 and 1:5 mixes at 7, 60, and 360 days.
3. Yield tests—two trials on each mix used in 1.

4. Absorption tests on 2, 2¼x4x8-in. specimens (Fig. 1, Nos. 201 and 203) from each of the above mixes.
5. Freezing tests on specimens similar to those in 4.
6. Fire tests on specimens similar to those in 4.
7. Permeability tests on four cylinders 8 in. in diameter and 5 in. high (Fig. 1, P 40 and P 59; and Fig. 5) from each of the above mixes. The shortest path for water flow is 2 in.

Tests Nos. 4, 5, and 6 are made at 60 days; No. 7 at 28 days.

III. Physical Tests on Concrete Made with a Standard Mixture of Portland Cements and Both Fine and Coarse Aggregates.

1. Compressive strength of 6x18-in. cylinders (Fig. 1, S283 and S290). Mixes employed are 1:2:4 and 1:3:6, proportions by volume; 1:6 and 1:9, proportions by weight. The last two proportions are determined by a combination of the mechanical analysis and yield test methods. Tests will be made whenever possible using materials from the same locality. In studying some of the broken stone aggregates, tests will also be made using Janesville sand for the fine material. Three specimens of each of the first two mixes are broken at 7, 28, 60, and 360 days. A like number from the other mixes are broken at 7 and 60 days.
2. Yield of concrete from each of the mixes in 1.
3. Absorption tests on 2, 5x5x10-in. specimens (Fig. 1, B106 and B107), same mixes as in 1.
4. Freezing tests on specimens similar to those in 3.
5. Fire tests on specimens similar to those in 3.
6. Permeability tests on 4 cylinders 16 in. in diameter and 9 in. high (Fig. 1, PC 60 and PC 61) from 1:2:4, 1:6, and 1:9 mixes. Specimens are similar to mortar permeability cylinders except that the distance from embedded opening in casting to surface of concrete, shortest path for water flow, is 6 in. in concrete specimens.

Tests Nos. 3, 4, and 5 are made at 60 days; No. 6 at 28 days. Lack of space prohibits a detailed explanation of the methods employed in making these tests and only the general method of making the more important ones will here be considered. The general purpose of making physical tests is to ascertain what relations exist between these various physical properties and the physical properties of mortars and concretes made from the material under consideration. Some of these tests can be easily and quickly made, and afford valuable indications of certain properties which the corresponding mortar or concrete will possess. For instance, the weight per cubic foot, measured loose, is of importance in determining the percentage of voids, or space not occupied by solid aggregate. A knowledge of the percentage of voids is an aid in judging how much cement or mortar is required to fill up these spaces and produce a dense mixture. The weight per cubic foot is found by means of the apparatus shown in Fig. 2A. Sun-dried material is allowed to fall through the trap door, *d*, of the hopper, *h*, at such a rate that the cubic foot measure, *m*, is filled in one minute. The measure is then struck off even full with a straight edge and the material weighed.

The percentage of voids is found by pouring, very slowly, about three-fourths of a cubic foot of sun-dried material into the voidmeter, Fig. 2B, which contains about one-half cubic foot of water. Before and after the material enters the voidmeter, the height of the water column in the glass tube, *t*, is read on the scale, *s*, to .001 cu. ft. By correcting for the contained moisture in the sun-dried material, and the absorption after entrance into voidmeter, both percentage of voids and specific gravity can be computed.

The granulometric, or sieve, analysis is made by screening a representative sample of sand, gravel or broken stone over sieves of different mesh and determining the weight of material caught upon each sieve. By plotting a curve with percentage of sample (by weight) less than a given size of mesh as ordinates, and diameter of mesh as abscissae, the graduation of the material can be observed. Such curves may be seen in Fig. 3.

From elaborate experiments by Feret, Fuller, Thompson, and others, laws have been deduced from these mechanical

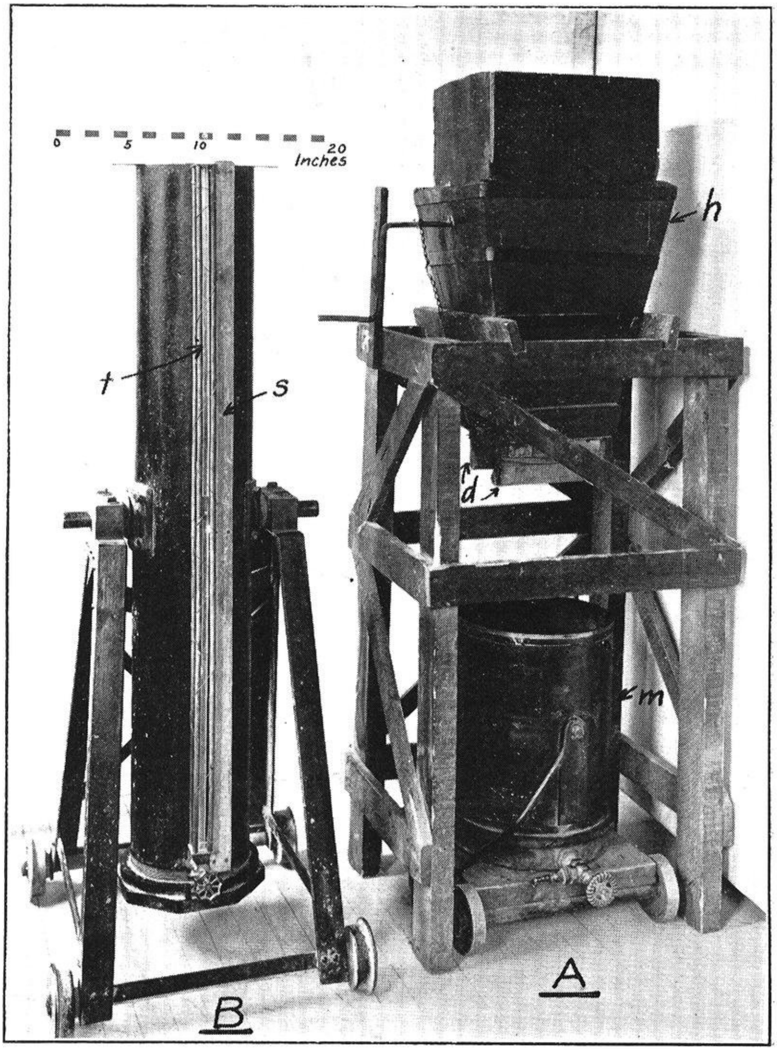

FIG. 2. *A—Weight per Cubic Foot Apparatus. B—Voidmeter.*

analysis curves which are of considerable importance in estimating the value of aggregates. Consider curve I, Fig. 3; this represents a very fine sand which will make a mortar easy to work with a trowel, but which will be neither strong nor impermeable. The sand corresponding to curve II is well-graded and will make a very strong, dense, and impermeable mortar; but the mortar will not be so easily worked as that made from

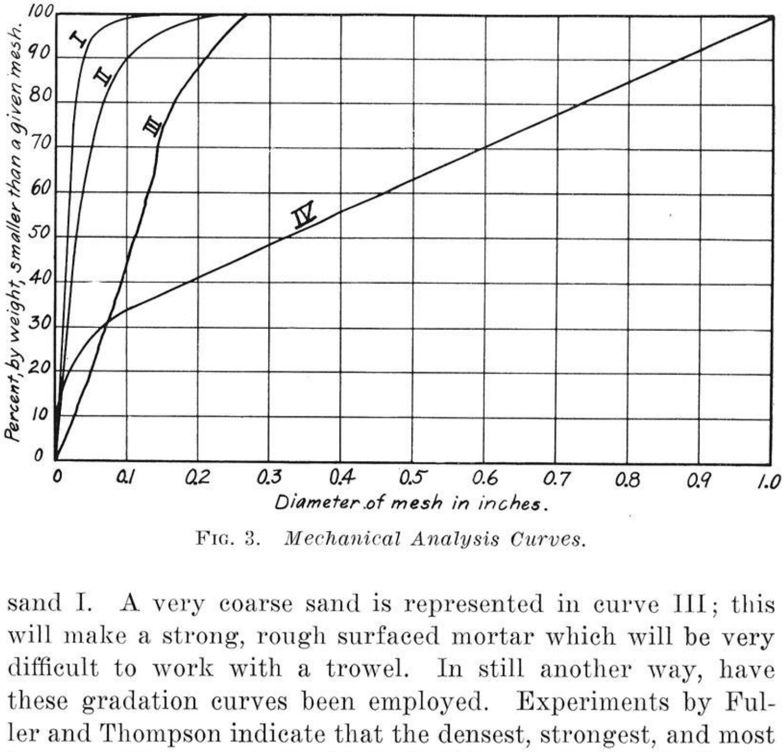

FIG. 3. *Mechanical Analysis Curves.*

sand I. A very coarse sand is represented in curve III; this will make a strong, rough surfaced mortar which will be very difficult to work with a trowel. In still another way, have these gradation curves been employed. Experiments by Fuller and Thompson indicate that the densest, strongest, and most impermeable concrete is obtained if the gradation of all particles, including the cement, conforms to a definite curve formed by an ellipse and straight line tangent. Their curve for a mixture of gravel, sand, and cement, in which the diameter of the largest particle is less than one inch, is shown in curve IV. Similar curves to no. IV are used in this survey in determining the 1:6 and 1:9 proportions for concrete.

Next consider the test to determine the percentage of silt. Silt is the name given to the very finely subdivided material of earthy or organic origin which is often present in aggregates, especially in sands and gravels. It has been found that certain kinds of impurities such as mica, loam, organic matter, or clay

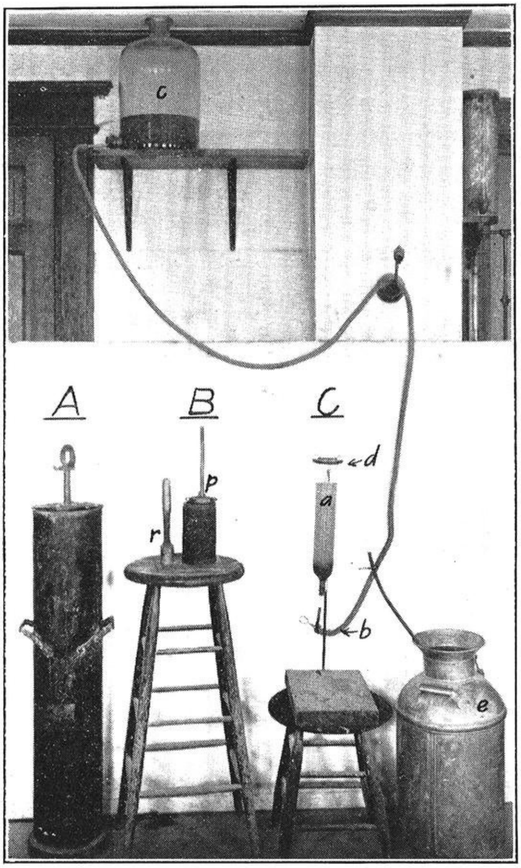

FIG. 4. *A—Yield Test Apparatus for Concrete. B—Yield Test Apparatus for Mortar. C—Apparatus for Determinig Silt.*

are undesirable elements in aggregates. Consequently, since these impurities are frequently in the silt, it is important to determine the amount and character of this finely subdivided material in order to estimate the value of an aggregate. In making the test, a 200 gram sample of the material is carefully weighed and placed in the percolator, *a*, shown in Fig. 4 C.

A piece of No. 200 wire cloth placed over the opening in the stopper prevents the fine material from descending into the pipe, *b*. Clean water is admitted from the aspirator bottle, *c*, and flows away from the percolator carrying the silt through the syphon, *d*, into the large can, *e*. At one minute intervals the material is thoroughly stirred. The process is discontinued when the water clears immediately after stirring, thereby showing an absence of silt in the percolator. The solution in can, *e*, is evaporated in a large evaporating dish and the residue scraped out, weighed, and preserved for chemical analysis. The percentage of silt and its character can then be determined.

Thus these tests, in conjunction with other physical properties, such as percentage of moisture, percentage of absorption, chemical composition, the shape of particles, appearance of surfaces, and the strength of broken stone or gravel, furnish valuable indications of the properties of mortars and concretes made from a given material.

In order that a minimum variation in the cement might obtain, it seemed advisable to mix different brands to form a standard Portland cement. It is hoped that, in this way, the variations in quality of the individual brands purchased from time to time will be neutralized in the mixture; and that a cement will thus be secured which will have more uniform properties than could be obtained by purchasing any one brand. The different brands are purchased in the open market and subjected to the standard tests of the A. S. C. E., and in addition, strength and soundness tests are carried on for a period of one year. After the 28 day strength tests have been made, the different brands are thoroughly mixed and stored in large galvanized iron tanks, the covers of which are hermetically sealed with modelling clay. Samples of this mixture are subjected to the same tests as the individual brands. About 20 pounds of each brand or mixture is preserved in fruit jars for future tests, or for any check tests which it may seem desirable to run.

The aggregates are arbitrarily divided into two classes, fine and coarse, by screening on a ¼-inch sieve. The fine aggregates are subjected to series of tests no. II; the fine and coarse aggregates to series of tests no. III.

All mortar specimens are mixed by hand. The briquettes are hand molded in accordance with the A. S. C. E. standard specifications. The small cylinders and brick shaped specimens are mixed by hoe on a small metal mixing pan. A quantity of dry cement and sand sufficient to make a complete set of specimens is mixed for about four minutes until the mass appears uniform in color. A sufficient amount of water is then added to form a medium wet consistency, and the material is mixed

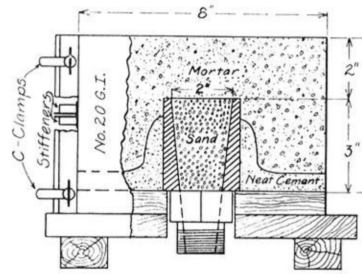

FIG. 5. *Method of Casting Permeability Specimens.*

for four minutes longer. The molds are then filled in layers two inches deep, and tamped with the cast iron tamper shown in Fig. 4 B. Wooden molds are used for all brick shaped specimens and cast iron or steel molds for the cylinders. Specimens are kept in molds for two days; then they are cured in water. Brick specimens are removed from the water bath at 14 days and allowed to cure in the air of the laboratory until tested. Mortar cylinders are also cured in water. Those untested at 28 days are removed and allowed to stay in air in the laboratory until 60 days old. The cylinders remaining after the 60-day tests are placed out of doors in a wire cage. The mortar for the permeability specimens is mixed in the same way as that used in making brick specimens or cylinders. The specimens are molded with the end which is the bottom during the test (Fig. 7) uppermost. Neat cement mortar is placed in the bottom of the mold and around the casting, as shown in Fig. 5, to prevent water leaking through along the sides of the casting. Then mortar of wet consistency is put into the molds and tamped. The castings are filled with wet sand to keep the mortar from entering them. On the following day, the surfaces of specimens uppermost in the molds are cleaned with a stiff wire brush to remove the thin layer or nearly impervious matter, called laitance, which appears on the top surface during the process of setting. After six days in the molds, the specimens are removed and sprinkled twice a day until two days before testing. The sand is then washed out from the insides of the castings, and the mortar surfaces within the castings are chipped off with a chisel to remove any mortar richer than that in the specimens proper which might segregate there during the molding process. The insides of the castings are thoroughly cleaned with a hose and filled with fresh coarse sand to act as a filter. The specimens are then immersed in a water bath until tested.

Concrete specimens for the compression and permeability tests are made from machine mixed concrete. The required quantities of the different materials are placed in turn in a hopper car and weighed on a triple-beam scales. All materials are mixed dry in a no. 0 Smith mixer for 3/4 min., and wet for 2 1/4 min. A wet mix is employed for all specimens. The entire contents of the mixer are then emptied into wheelbarrows. Next each mold is filled one-third full from the first wheelbarrow, two-thirds full from the second wheelbarrow, and is completely filled from the last wheelbarrow. During the process of filling the molds, the concrete is puddled with a rod to get rid of the entrained air and to prevent pocketing of the aggregate. The cylinders are allowed to stand about four hours with an excess of material on top; the tops are then floated smooth and level with a mason's trowel. After two days in the molds the cylinders are weighed and measured. They are then sprinkled twice a day for two weeks, after which those not registered for the early time tests are cured in the air of the laboratory until 60 days old. After the 60-day tests the remaining cylinders are placed in the cage out of doors.

The concrete permeability specimens are molded, cured, and tested like the mortar permeability specimens. For the fire, freezing and absorption tests on concrete, specimens resembling small blocks are molded from the hand mixed concrete used in the yield tests. The dimensions of these specimens are made 5x5x10 in., so that they are comparable to small blocks sometimes employed in construction. They are removed from the molds after one day and then cured and tested like the mortar brick specimens.

Fig. 6 B shows a briquette being subjected to a tensile test in a Riehlé-automatic-shot-briquette-testing-machine. In starting the test, sufficient fine shot is placed in the bucket, *b*, to counter balance the weight, *w*. After the briquette is adjusted in the grips or clamps, *g*, the trigger, *t*, at the top of the bucket is released; this opens a piston valve which allows shot to flow down into the cup, *c*. As the shot flows from the bucket the weight, *w*, moves downward; and, through the lever system, a strain is produced upon the briquette which is proportional to the shot lost. To keep the beam in the central position, the crank, *k*, is turned in the clockwise direction. When the briquette breaks, the bucket moves upward but the piston is held by the rod, *r*, so that the valve is immediately closed and the flow of shot stopped. The spring balance is graduated to read the load on the briquette to the nearest five pounds.

At A, Fig. 6, is shown a concrete compression cylinder with its lower end resting on a block having a spherical seat. The purpose of this block is to provide against an eccentric load, due to non-parallelism of the ends of the cylinder, by permitting adjustment between the upper head of the testing machine and the top surface of the cylinder. Blotting paper is placed at the top and bottom of the cylinder to fill up slight inequalities in the surface and to equalize the pressure over the cross-section. The upper head of the teesting machine is lowered at the rate of .015 in. per min., thus producing a strain on the specimen which finally causes rupture.

The method of supporting and loading the brick and block specimens which are tested transversely is shown at C, Fig. 6. The supporting knife edges, *s*, are provided with spherical seats to eliminate as far as possible any tendency to twist the specimen, or any end restraint tending to prevent the lower side of the beam from lengthening. The apparatus is placed in a testing machine and the specimen loaded through the up-

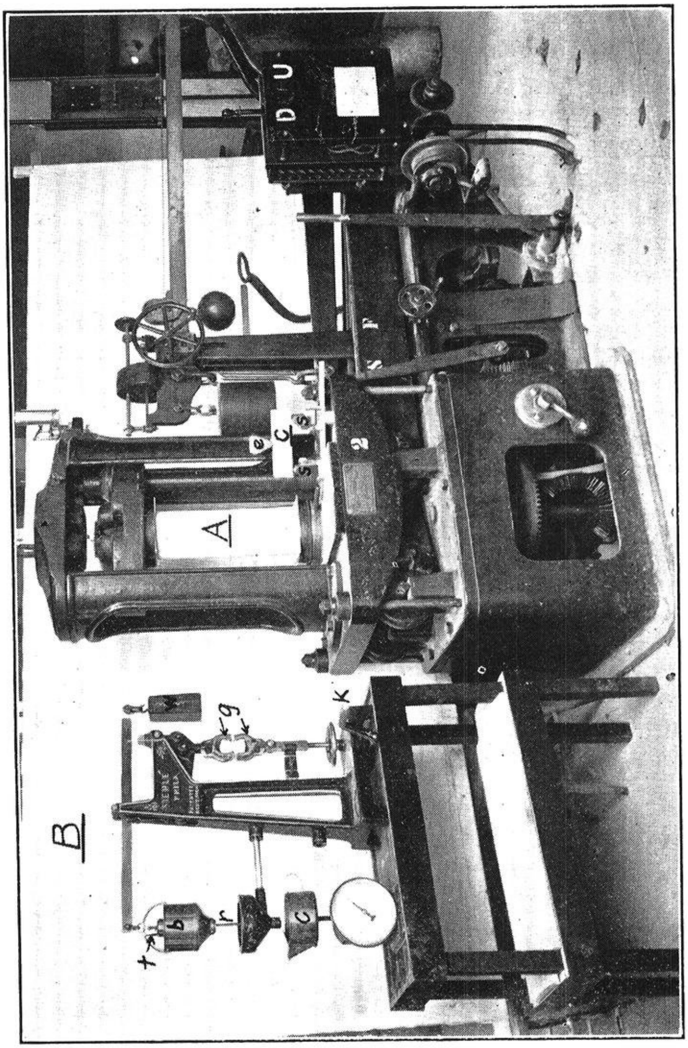

FIG. 6. *A—Concrete Compression Cylinder Ready to Be Tested. B— Briquette Ready to Be Tested. C—Method of Loading Brick Specimen.*

per knife edge, *e*. The load is applied very slowly by hand until the specimen fails. The breaking load and appearance of fractured section are noted.

The apparatus used in making the permeability tests and the method of attaching specimens is shown in Fig. 7. After the specimens have been coupled onto the outside ¾-inch pipes, by unions, *u*, fitted with rubber gaskets, the pipes and glass tubes, *t*, are filled nearly full of water. An air pressure of 40 lb./in.^{2} is then admitted from the tanks, *r*, and readings of the heights of the water columns in the glass tubes are taken on the scales, *s*. Observations of pressure on the gage, g, of the heights of the water columns, of the time, and concerning the behavior of the specimens are taken twice a day for three days; then the pressure is reduced to 10 lb./in.^{2} and readings taken for four days when the test is discontinued. After the test, the specimens are broken open and their appearance carefully noted. The tubes are all calibrated so that the quantity of water entering the specimens can be readily determined.

The yield test is used primarily to determine the volume of concrete or mortar which will be obtained if a given proportion of cement to aggregate is used. It is also possible to determine the density of the mix, and the relation between maxium density and ratio of volume of cement or mortar to voids in aggregate. Since the strength and impermeability vary with the density, this test is of importance. The yield test on a mortar is made by mixing a sufficient quantity of mortar of medium wet consistency to nearly fill the small cylinder shown at B, Fig. 4. The material is tamped into the cylinder in four layers by the rammer, *r*. The piston, *p*, with rod graduated to read to .0001 of a cu. ft. is lowered into the cylinder and whirled about to level the surface of the mortar. The spider, supported on the top of the cylinder and through which the piston rod slides, carries a mark from which readings are taken of the volume of the material in the cylinder. The weight of the materials before mixing, the weight of the cylinder, and the weight of the cylinder and mix are all taken. Consequently, if the weight per cu. ft. and the specific gravity of the different materials is known, the yield, or ratio of volume

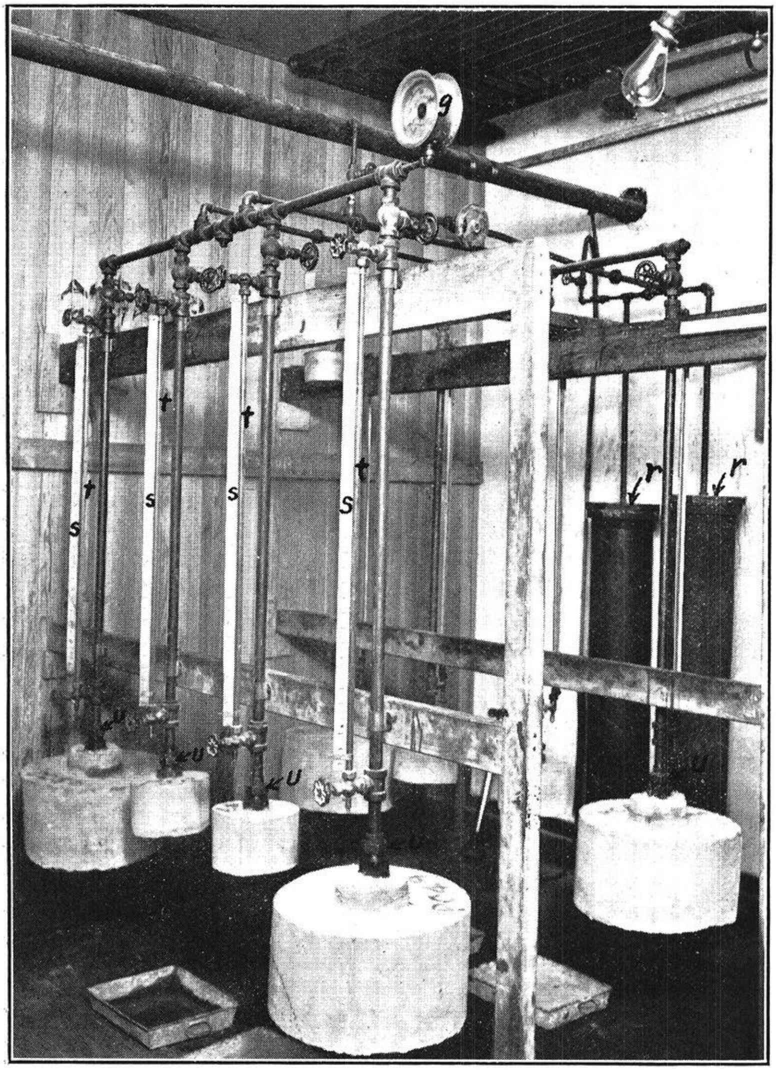

FIG. 7. *Apparatus Used in Making Permeability Tests.*

of mortar to volume of aggregates, and the density, or ratio of absolute volumes of cement and aggregate of total volume of mortar, can be computed. The yield test on concretes is made in a similar way by making use of the large cylinder, Fig. 4 A.

Two of the bricks, or block specimens, from each mix are subjected to an absorption test. After drying to constant weight at a temperature above 250° F., the specimens are put into pans containing water two inches deep. They are surface dried and weighed at the end of 30 min., 4 hrs. and 48 hrs. From these data the percentage and rate of absorption can be determined.

The same specimens employed in the absorption test are used in the freezing test. If the bricks have dried out they are again soaked in water for four hours and then placed in a refrigerator in which the temperature is kept below +15° F. After twelve hours or more in the refrigerator they are removed and plunged immediately into a tank of water in which the temperature is maintained above 150° F. Then they are soaked in hot water for one hour and put back again into the refrigerator. This cycle of operations is carried out ten times. Following the last soaking in hot water the specimens are weighed, allowed to dry out, and are then tested in cross-bending.

Two of the bricks, or block specimens, from each mix are subjected to a fire test. The specimens are placed in a cold gas-furnace, gradually heated to 1700° F, and then kept at this temperature for at least 30 minutes. Temperatures are measured by four thermo-couples placed in different parts of the furnace. Upon removal from the furnace, one specimen of each kind is immediately plunged into cold water and the other allowed to cool in the open air. Both are subsequently tested in cross-bending, and the results noted. The remainder of the brick and block specimens are tested in cross-bending. Thus a relation between the normal strength and the strength of the brick after being subjected to the freezing or fire test is obtained.

Careful records are kept of all data taken, or connected with any of the tests, on blanks specially prepared for the purpose. To insure that the tests or changes in curing conditions will be made at the proper time, cards are made out as soon as the specimens are made and filed in chronological order. An assistant makes it his first duty each day to look at this card index and follow the instructions given therein. The results of the tests are filed in an index and the major portion of the data is computed as soon as it is determined, in order that errors in the method of making the tests or discrepancies in results may be observed and corrected before other tests are made. Whenever an amount of data has been compiled sufficient to warrant publication, a bulletin will be issued.

It is hoped that two things may be accomplished by this survey of aggregates, first, that more complete knowledge of the properties of the larger sources supplying such material may be obtained and published, thus benefiting the people of the state directly; and second, that the results obtained may be of value in advancing general knowledge concerning the properties of mortar and concrete.

LOCOMOTIVE SUPERHEATERS.

L. V. Ludy.

Acting Professor of Steam and Gas Engineering.

One of the principal losses occurring in the cylinder of a steam engine is that due to "cylinder condensation." The steam entering the cylinder may contain a small amount of suspended moisture. Its capacity for holding this moisture decreases with the temperature. When steam is admitted to the cylinder it meets the cylinder walls, the temperature of which is less than that of the entering steam, and there results an interchange of heat. The fact that the steam gives up a aportion of its heat to the cylinder causes some of the steam to condense. As the piston proceeds on its stroke and expansion occurs, some of the steam initially condensed will be re-evaporated. It is thus seen that in the operation of a simple steam engine the cylinder goes through a process of alternately cooling and reheating, resulting in cylinder condensation and re-evaporation. There is always a net loss in the process.

In order to reduce this loss to a minimum, a number of schemes have been employed, chief among which may be mentioned the following:

(a) By providing the cylinder with a jacket in which steam or furnace gases circulate and maintain the cylinder at a comparatively high temperature.

(b) By compounding, thus reducing the temperature range in any particular cylinder. In this case the cylinders are frequently provided with steam jackets.

(c) By the use of superheated steam.

Steam in contact with water, under constant temperature conditions, obeys the laws of vapors. The pressure remains constant during volume changes so long as the changes occur at constant temperatures.

If steam is not in contact with water, its temperature may be raised, resulting in what is known as superheated steam.

Steam thus heated becomes more like a gas and possesses a comparatively large amount of heat energy which is available for doing work. In many cases this additional heat energy is secured from the waste gases. One point which commends the use of superheated steam in steam engines and especially steam turbines, although seldom brought out, is the fact that steam, when once superheated, becomes a poor conductor of heat.

The economic advantages of the use of superheated steam have been known for nearly one hundred years. It is only within the more recent years, however, that it has been used for practical purposes to any great extent. The time when superheated steam was first used in locomotives dates from the year 1898. At this time two experimental locomotives were equipped with steam superheaters and placed in service upon the Prussian State Railway. A great many difficulties were at first encountered with proper lubrication of the valves, piston and valve rod packing, etc., but these difficulties one by one were overcome. Since that time development in locomotive superheaters has been rapid, with the result that now a great many locomotives, both at home and abroad, are fitted with superheaters.

In adapting superheating apparatus to locomotives, the principal problem involved has been the design and construction of apparatus in such a way as not to interfere with the efficiency of the boiler and the ease with which cleaning and repairing may be carried out. In most cases the superheating parts are placed in the front-end, or smoke-box, which occasionally is made somewhat larger than would otherwise be required. In certain types superheating tubes extend into the boiler tubes, which usually must be made larger. In one or two instances the superheating chamber is placed entirely within the boiler. Of the different types of locomotive superheaters which have been developed and successfully used, the following makes are presented as being typical.

THE COLE SUPERHEATER.

The Cole, or Schenectady superheater as it is sometimes called, was developed by the American Locomotive Company. It has been successfully used in recent years and has had a

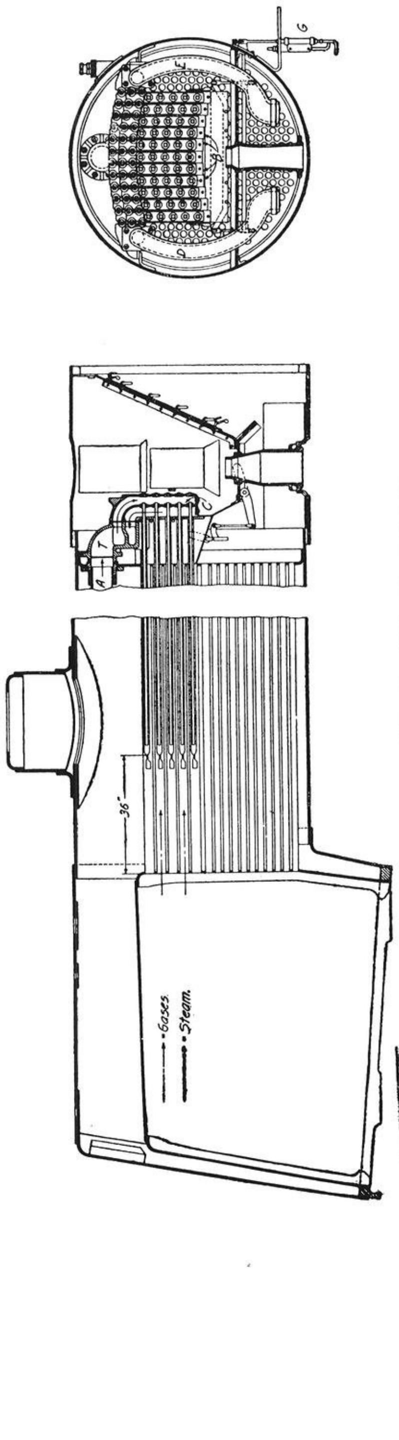

Fig. 1. Cole Superheater.

large application. In the Cole superheater it is necessary that the upper rows of boiler tubes be larger than the others. Into each of these large tubes extend two concentric tubes connected respectively to two chambers in the header casting.

The construction and scheme of application of the Cole superheater is illustrated in Fig. 1. It is seen that the dry-pipe A delivers steam to the upper compartment of the T-pipe. In front of the T-pipe are connected a number of header castings, the joint being made steam-tight by the use of copper gaskets. As shown by a vertical cross-section at C each header casting is divided into two compartments by a vertical partition. Of the two concentric tubes referred to above, the smaller one being 1 1/16″ outside diameter is expended into the vertical partition and communicates with the front compartment; the larger tube is 1¾″ inside diameter and communications with the back compartment. Five sets of these concentric tubes are connected to each header casting, each set being encased by a regular 3-inch boiler tube which is expanded into the front and back tube sheets in the usual way. The back end of the inner superheating tubes are left open and the back ends of the outer tubes are closed. These tubes extend to within about 36 inches of the rear tube sheet. They are prevented from resting on the bottom of the 3-inch tubes by shoes attached to the ends of the outer tubes, thus leaving a clear space below. The arrangement of the three tubes is clearly shown in the figure. In this particular illustration, fifty-five 3-inch tubes are employed, thus displacing as many smaller tubes as would otherwise occupy the same space.

When in operation steam from the dry-pipe enters the upper space in the T-pipe and passes to the forward compartments of the header castings. From these compartments it passes through the superheating tubes, going back through the central tubes then forward through the annular spaces between the two tubes, to the rear compartments of the header castings. From here the steam flows to the lower space in the T-pipe, thence downward around the outer walls of the smoke-box to the steam chests. The steam as it flows through the various channels is superheated by the hot gases, the extent of superheating depending upon the rate of steam flow and the draft conditions.

On account of the excessive heat it is necessary to protect the various parts of the superheater when steam is not passing through them. This is accomplished by an automatic damper which is operated by means of the steam cylinder shown at G. The entire portion of the superheater parts in the smoke-box are completely enclosed in a metal box in the lower part of which is located the large damper. When the throttle is opened and steam is admitted to the engine cylinders, steam also enters below the piston of the automatic damper cylinder G, and forces it upward and the damper is held open. When the throttle is closed, a coiled spring above the piston of the automatic damper cylinder G forces it downward, closing the damper and preventing the hot gases from being drawn through the 3-inch tubes.

Objections are sometimes raised against this type of superheater because of the fact that the heating surface of the boiler is decreased slightly by the 3-inch tubes which have replaced a portion of the smaller tubes, also that the draft is slightly impaired.

THE SCHMIDT SUPERHEATER.

The first locomotive superheater built was used on the Prussian State Railway and was invented by Herr Wilhelm Schmidt. The original Schmidt superheater was of the smoke-box type, many of which are now in use in Germany. The introduction of the Schmidt fire-tube type has proved so successful that the manufacture of the earlier types has been discontinued. Its construction is based on the same general principles as that of the Cole superheater. The two differ in details of construction only.

THE PIELOCK SUPERHEATER.

The Pielock superheater is constructed upon an entirely different principle from that of the Cole and Schmidt superheaters, the essential difference being that the superheater proper is fitted into the barrel of the boiler in such a manner that a portion of the heating surface of the boiler tubes is

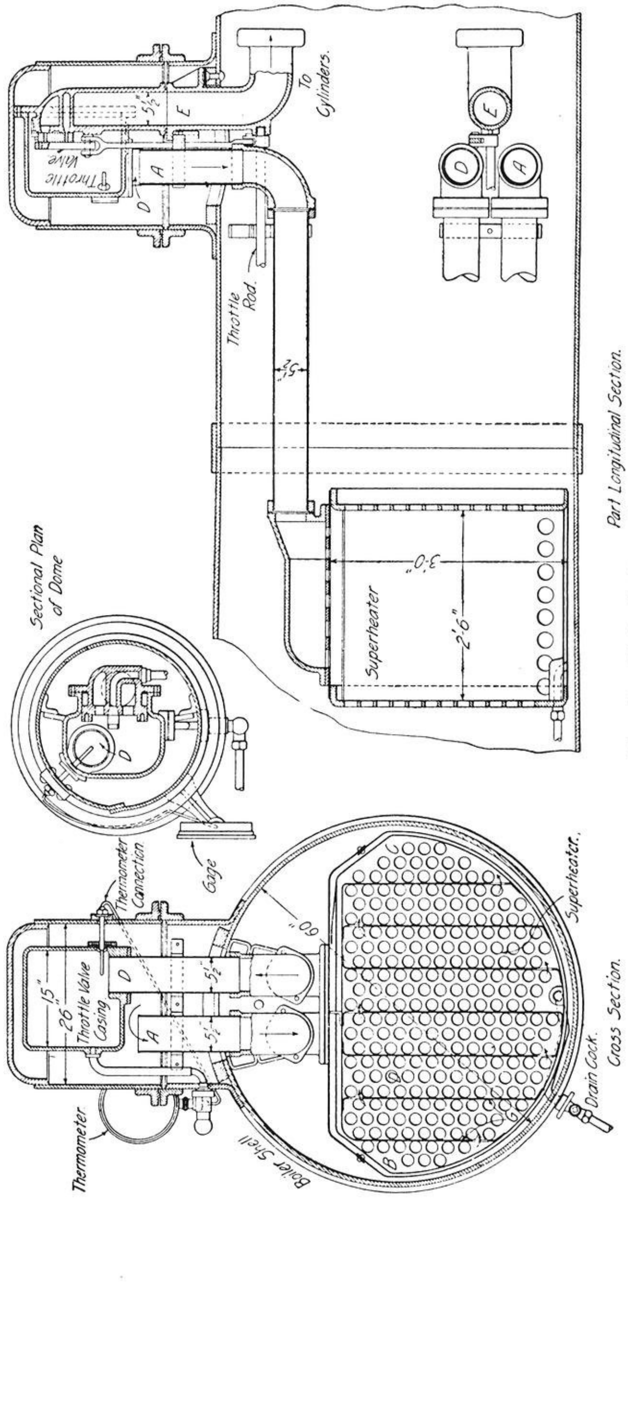

FIG. 2. *Piclock Superheater.*

employed as superheating surface. It is located far enough ahead of the back tube sheet to prevent the tubes from becominb overheated when steam is not being used.

The construction and location of the Pielock superheater is illustrated in Fig. 2. As can be seen it consists of a box containing tube sheets corresponding to those of the boiler, the box being set so that the tubes pass through it. The box contains vertical baffle plates G between different rows of tubes, which causes the steam when passing through to follow a broken path passing up and down between the tubes. When in operation steam from the dome enters the open pipe A passing to the chamber B on the left. From here the baffle plates causes it to take the circuitous path indicated by the arrows, to the chamber C on the right. From the chamber C the steam flows up through the pipe D to the throttle valve casing, from which it passes through the pipe E on its way to the engine cylinders.

In constructing the Pielock superheater it is built to suit the boiler in which it is intended to be used. In fitting the superheater the box is first put into the boiler before the front and rear tube sheets are placed in position. After the front and rear tube sheets are riveted in place, the tubes are inserted and first expanded into the rear tube sheet then the plates of the superheater, and lastly, the front tube sheet. In expanding the tubes in the superheater plates a specially constructed mandril is used. In order to facilitate the removal of the tubes the holes in the different sheets slightly increase in diameter from the rear tube sheet to the front tube sheet. Ordinary tightness of the tubes in the superheater box is sufficient as the pressure on the inside and outside of the box is the same. A small leak would do but little harm. A drain cock is provided which can be used to ascertain if the box is watertight. It is claimed that any degree of superheat desired can be secured up to a temperature about 650° F., depending on the position of the superheater and its dimensions.

THE BALDWIN SUPERHEATER.

The Baldwin superheater which is found in use to a limited extent in the United States is unlike any of the superheaters yet described in that it is found entirely within the smoke-box.

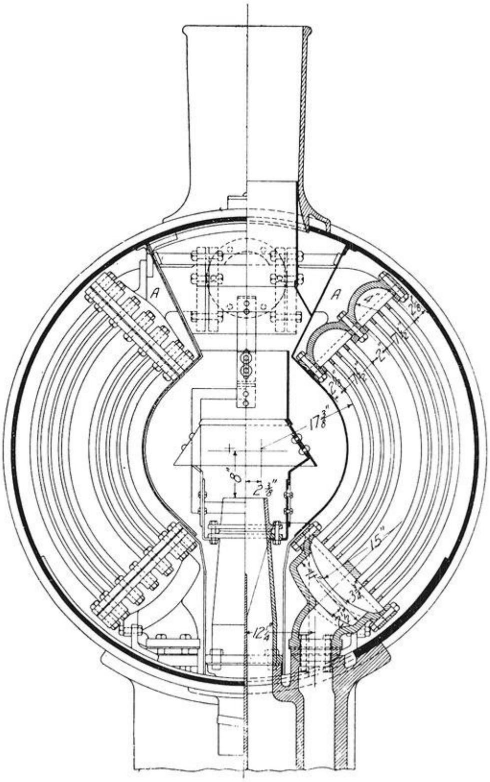

FIG. 3. *Baldwin Superheater.*

It can be applied to any locomotive, and its application does not in any way reduce the heating surface of the boiler, or does its action in superheating the steam, take any heat which would otherwise be used in vaporising water.

A typical illustration of a Baldwin superheater is shown in Fig. 3. As can be seen, the superheater uses only such heat as would otherwise be wasted through the stack, and whatever is gained in superheat is clear gain. It is composed of two cast-steel headers, shown at A, which are connected to the T-head which in turn is bolted to the dry-pipe. A large number of superheating tubes expanded into plates bolted to the upper headers, follow the contour of the smoke-box and are connected to headers in the lower part of the smoke-box. The tubes are divided into groups, the arrangement being such that when steam enters the T-head it passes to either side, first down through the group forming the outer four rows of this rear section of tubes, then crosses over in the lower header and passes up through the inner group, then crosses over to the upper header of the middle section it passes down the inner group of the tubes and up the outer group, then crossing over to the forward section and passing down through both the inner and outer group of tubes to the passageway in the saddle leading to the steam chest.

As previously stated the superheating tubes are heated by the waste gases as they are passing through the smoke-box to the stack. Suitably arranged deflector plates cause the gases to circulate around the tubes on both sides to the front end of the smoke-box, then back through the central portion to the stack. The entire front-end is heavily lagged at all points to prevent, as far as possible, loss of heat by radiation.

RESULTS OF TESTS OF SUPERHEATERS.

Of recent years much experimental work has been done to ascertain the relative increase in economy obtained by the use of locomotives equipped with superheaters and to determine the increase, if any, in the maintenance of locomotives so equipped. In many instances the published data on the subject is presented in such a manner as to make comparisons rather difficult. The work which has been conducted at Purdue University on locomotive superheaters in recent years has been of much interest to railroad men. In 1910 Dean W. F. M. Goss presented the results of experiments on the Purdue experimental locomotive equipped with a Cole superheater, to the Carnegie Institution of Washington. The machine on which the work was conducted is a simple American type locomotive, having a boiler designed to carry a working pressure of 250 pounds per square inch. The results obtained are very briefly summarized in Tables I and II.

TABLE I.—*Steam per Indicated Horse Power per Hour. Cole Superheater.*

Boiler Pressure Lbs. per Sq. In. Gage.	Superheat in Degrees F.	Pounds Steam per I. H. P. Per Hour.		Saving in Per Cent by use of Superheated Steam
		Saturated Steam	Superheated Steam	
240	139.6	24.7	22.6	8 50
220	145.0	25.1	21.8	13.14
200	150..3	25 5	21.6	14.51
180	155.6	26.0	21.9	15.77
160	160.8	26.6	22.3	16.16
140	166.1	27.7	22.9	17.32
120	171.4	29.1	23.8	18.21

Tests of the Prudue locomotive fitted with a Schmidt superheater, the results of which were reported to the American Railway Master Mechanics Association in June 1911, are briefly summarized in Tables III and IV.

The above comparisons of tests of the locomotive using superheated steam with both the Cole and Schmidt superheaters were made at a constant speed of 30 miles per hour. An examination of the preceding date discloses the following facts:

TABLE II.—*Coal per Indicated Horse Power per Hour. Cole Superheater.*

Boiler Pressure Lbs. per Sq. In. Gage.	Pounds Dry Coal Per I. H. P. Per Hour		Saving in Per Cent by use of Superheated Steam.
	Saturated Steam	Superheated Steam	
240	3.31	3.12	5.74
220	3.37	3.00	10.98
200	3.43	2.97	13.41
180	3.50	3.01	14.00
160	3.59	3.08	14.21
140	3.77	3.17	15.91
120	4.00	3.31	17.25

(a) With the locomotive equipped with a Cole superheater a saving was effected, over values obtained with saturated steam, in steam used per I. H. P. per hour of from 8.5 to 18.21 per cent, and in coal per I. H. P. per hour of from 5.74 to 17.25 per cent.

(b) With the locomotive equipped with a Schmidt superheater a saving was effected, over values obtained with saturated steam in steam used uer I. H. P. per hour of from 21.05 to 29.60 per cent, and in coal per I. H. P. per hour of from 20.54 to 30.24 per cent.

TABLE III.—*Steam per Indicated Horse Power per Hour. Schmidt Superheater.*

Boiler Pressure Lbs. per Sq. In. Gage	Superheat in Degrees F.	Pounds Steam per I. H. P. Per Hour.		Saving in Per Cent by use of Superheated Steam
		Saturated Steam	Superheated Steam	
240	222.2*	24.7	19.5*	21.05
220	226.5*	25.1	19.0*	24.30
200	230.8	25.5	18.9	25.89
180	235.1	26.0	18.7	28.08
160	239.4	26 6	18.9	28.94
140	243.8	27.7	19.5	29.60
120	248.6	29.1	21.0	27.83

*Results estimated for making comparisons.

(c) The degree of superheat in the branch-pipe before entering the cylinders, when the Cole superheater was employed, varied from 139.7 to 171.4 degrees F., and with the Schmidt superheater from 222.2 to 248.6 degrees F.

TABLE IV.—*Coal per Indicated Horse Power per Hour. Schmidt Superheater.*

Boiler Pressure Lbs. per Sq. In. Gage.	Pounds Dry Coal Per I.H.P. Per Hour		Saving in Per Cent by use of Superheated Steam
	Saturated Steam	Superheated Steam	
240	3.31	2.63*	20.54
220	3.37	2.57*	23.74
200	3.43	2.55	25.65
180	3.50	2.51	28.28
160	3.59	2.55	28.97
140	3.77	2 63	30.24
120	4.00	2.89	27.75

*Results estimated for making comparisons.

The increase in efficiency of the Schmidt superheater over that of the Cole superheater is partially accounted for by the fact that the total superheating surface of the Schmidt amounted to 325 square feet, while that of the Cole was only 193 square feet.

In 1905 the Pennsylvania Railroad Company published the results of tests conducted on the Company's testing plant at the Louisiana Purchase Exposition, of a locomotive fitted with a Pielock superheater. The locomotive was an Atlantic type, four-cylinder balanced compound and was built in Germany. The superheater contained a total superheating surface of 283.79 square feet. In all, ten tests were conducted, at boiler pressures varying between 187.0 and 204.2 pounds gage, and speeds of 80 to 280 R. P. M., corresponding to 18.57 and 65.05 miles per hour, respectively. The range of superheat in the superheater for the different tests varied between 160.9 and 192.0 degrees F. The degree superheat at the cylinders would undoubtedly be less than this amount since the dry-pipe is surrounded by saturated steam which has a temperature much lower than that in the superheater. The best performance of the engine was obtained under a boiler pressure of 200 pounds gage, and a speed of 37 miles per hour, and a superheat of 180.9 degrees F. Under these conditions the consumption of superheated steam per I. H. P. hour was 16.6 pounds. The dry coal consumed under the different conditions varied between 2.27 and 4.19 pounds per I. H. P. hour.

CONCLUSION.

Many complaints have been made by operators relative to difficulty experienced in securing proper lubrication of the piston and valve when using superheated steam. It has been demonstrated, however, that this difficulty can be overcome by the exercise of good judgment in the use of the proper amount and grade of lubricating oil.

The superheating simple locomotive will reduce the steam and coal consumption to that required by the compound locomotive. The reduced consumption of water affected by superheating is a factor worthy of consideration in sections where the water is not suitable for boiler use. The superheating locomotive will operate efficiently on comparatively low steam pressures and its maximum possible power is considerably beyond that of the simple engine.

A TRIP THROUGH THE INDUSTRIAL PLANTS OF GERMANY.*

A. G. CHRISTIE.
Assistant Professor of Steam Engineering.

On Tuesday Mr. Orrok and the writer called on Herr Direktor Datterer of the Berliner Electricitats Werke and through an interpreter had a very interesting talk with him, discussing the past and present tendencies in power house development. We were provided with passes and started out to see their various power plants under the guidance of one of their Electrical Engineers who is an American citizen and an ex-officer of our navy.

The Schiffsbaudame, the oldest of the company's central stations, now only used as a reserve, was first visited. It contains five Görlitzer compound engines, all with poppet valves. The engines, are small, ranging from 1000 to 2000 K. W. Three of the generators were direct current and two alternating, one of the latter being of the inductor type, such as the Stanley Electric Co. used to build in the United States. The boiler room contained hand fired Borsig boilers, and was on the same level as the engine room.

The next station visited was "Louisenstrasse," and this proved to be a very interesting plant. The engine room contains three 4000 H. P. vertical quadruple expansions, two crang Sulzer engines. The high pressure cylinder is placed above the first intermediate and the second intermediate above the low pressure cylinder. The valve gear resembled the American Nordberg, all valves being of the poppet type as superheat is used. The cylinders were lubricated by Sulzer oil pumps which resembled very closely our well known Richardson pumps. The remarkable and very fascinating feature of these engines was the complete balance of moving parts obtained in the design. The writer climbed to the very top of one that was carrying full load and

* In the October issue Mr. Christie discussed various manufacturing plants of Germany, which discussion is here continued with special reference to power plants.

found so little vibration that it was scarcely noticeable. These were built just before the advent of the steam turbine, and may be considered as embodying the last refinement in steam engine design.

As this plant is located near the center of Berlin, land is very expensive and hence the boilers were placed on two floors directly above the engine room. These boilers are of the German B. & W. type, which differs in details from our B. & W. They were equipped with B. & W. chain grate stokers. A separately fired Borsig superheater is used. Ados CO_2 recorders are operated on

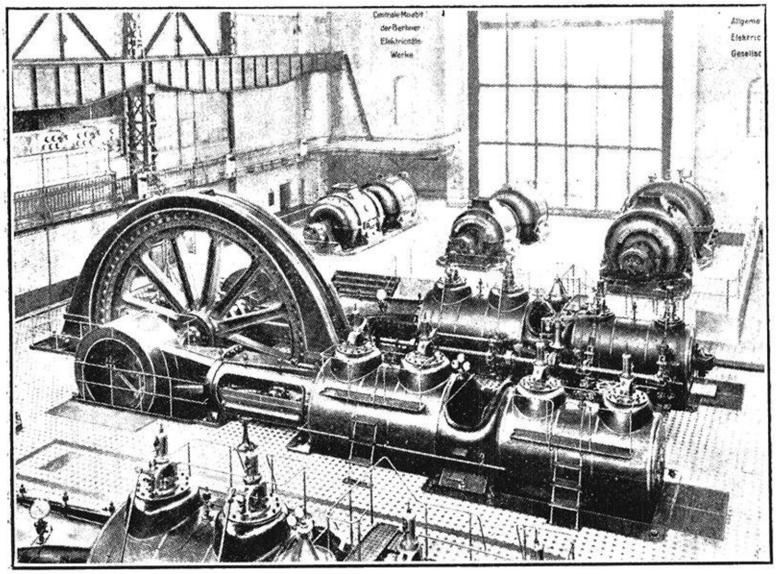

FIG. 1. *Moabit Central Station, Berlin Electricity Works.*

the flue gases of each boiler and we were told that they were quite reliable and need little care.

The third and largest plant visited was that of Moabit, which is situated in the industrial section of Berlin. There are two stations at this plant. The old station contains five 4000 K. W., A. E. G. steam turbines and one 6000 K. W. unit. It also contains seven 3000 K. W. horizontal quadruple expansion Sulzer steam engines. We noted that the bearings on the steam turbines ran very warm, 165° F. by thermometer, and were at the same time water-cooled. This would seem to indicate that a greater supply of cool oil and an alteration of the method of supplying this oil is desirable. The excuse offered, that this temperature gave the least friction loss, did not justify so high temperature, as the bearing friction loss is very small in any case, while oil will certainly evaporate more rapidly and break down sooner under these conditions than when kept at a more moderate temperature. Fig. 1 shows a portion of the interior of this station.

The boiler room is equipped with Borsig water tube boilers fitted with internal superheaters and with stokers. The smoke consuming devices which were installed formerly in this plant did not prove successful and were thrown out. Their experience seemed to show that smoke could be avoided only by fire brick enclosed combustion chambers and by careful firing.

In the new station there are two 6000 K. W., A. E. G. steam turbines already installed. These run at 1050 R. P. M. but also have very warm bearings. None of the turbines in either station had any appreciable vibration even at their high speed. There was no provision for altering the speed of the turbines from the switchboard, which is always provided in our large central stations.

This plant is notable for the extensive use in its interior decoration of soft-glazed brick. We were interested to learn that the installation of steam turbines in this plant reduced the operating force from 189 to 70 men. This reduction took place principally in the engine room and in the repair gang, though the decreased steam consumption also made a great reduction in the boiler room.

The Rummelsburg station embodies the latest ideas in power plant design. It contains three 4000 K. W., A. E. G. steam trubines and two 6000 K. W. units, giving a maximum load of 24000 K. W. It cost complete $1,250.000, or about $50 per K. W. maximum output. But since the installation of steam turbines at Moabit and the fact that the Rummelsburg end of town has not built up as fast as anticipated, the plant is not needed except for heavy peak loads. The station is built of red brick with salt glazed trimmings. The engine room ceiling is made of red cedar with a natural finish and is very pretty.

The condensing plant is also of A. E. G. design. As river water is used for cooling in the surface condensers, and as condensed steam is used for boiler feed, the two cannot be mixed. Hence it was found necessary to install an auxiliary cooler to cool the water from the hot well that is used in the ejector nozzles of the rotary air pump. This scheme has given entire satisfaction and a vacuum of 725 mm. or 28.5 inches of mercury was noted.

The boiler plant is practically the same as at Moabit. They are using turbine driven centrifugal pumps for boiler feed purposes. These were the first we had seen in Europe, though they are quite common in America. These pumps are of the two stage type with 10 inch diameter impellers about 1¼ inches wide at the circumference. The iron diffuser vanes are cast integral with the casing. The pumps run steadily at 2800 R. P. M. and each delivers 2000 cu. m., or about 530,000 gal. per hour against a head of 225 pounds. The coal burned at this plant is principally Cardiff coal from Great Britain and also some Westphalian coal. It is brought up the River Spree in barges and unloaded by modern hoisting and conveying machinery.

On Wednesday we went out to the Bergman Electricitats Werke to see the steam turbines which they manufacture. We were received by Herr Bergman, and then motored out to the turbine plant in a car of the company's own manufacture. Their steam turbine is of the same general type as the A. E. G. with Curtis high pressure and Zoelly low pressure, but differs in details. The diaphragms between stages are all in halves, and in the low pressure sections the guide blades in these diaphragms are made of nickel steel and cast in place, thus requiring no machining. The same scheme is used by the Brittish Thomson Houston Co. The labyrinth packing is made of babbitt on the low pressure diaphragms and of brass on the high pressure.

The most interesting and novel feature of the machine was the revolving buckets on the Zoelly section. These are stamped out of extruded nickel steel strips and are drop forged to shape. There is no fattening in the middle of the blade when one looks at it endways. The front and back faces are exactly parallel. One would think that this would cause considerable loss from eddying, but it apparently does not judging from the results obtained on test. The distance piece between blades is made of brass and is drop forged hot. These are drilled in jigs and riveted together on the wheel rim, thus making an exceptionally light and neat construction. The wheel discs are very heavy at the shaft, but taper towards the blades. The shroud ring in the outside is simply a plain band. The last two blades next to the ends of the shroud rings are silver soldered to it. Speed regulation is obtained by throttling the steam to the nozzles by means of an oil relay governor of almost exactly the same construction as that used on the Allis-Chalmers turbines in this country, even to the details. Some of the turbines have hand operated valves for opening or closing of nozzles, while others have none at all.

Their direct current turbo generators are provided with interpoles, but, in common with all this type of machine, are quite noisy. Their turbo-alternators are not as well constructed as ours. In fact, the electrical machinery in general in Germany did not impress the writer as being superior to ours, at least not in construction.

The company has built 40 turbines to date, ranging from 100 to 6000 K. W., but have only been in the business a couple of years. We visited their electrical shops and saw them rolling and polishing copper, but their methods seemed somewhat out of date. The same was true of their hydraulic machine for making extruded metal, and their punch shops with their sheet mills are very poor. Their machine shops contained large tools of the German Niles Co. These buildings are well lighted and arranged; they are built of a highly colored yellow pressed brick.

At their main plant they have a large shop devoted to the manufacture of automobiles. The engines are standard four cycle units and for test are hitched up to generators on the test floor.

In the afternoon we took the train to Eberswalde, about 30 miles north of Berlin, in order to visit the power plant of Hegermuhle Electricity Works, of which we had heard a great deal. By a curious coincidence, we met on the train a representative of the A. E. G. and two English engineers bound for the same place. Eberswalde is still a summer resort for Berlin people but the writer cannot see what attractions it affords, as it is located among the sand hills which cover the whole of North Germany, and some of the roads we had to drive over on our return would have shamed a western trail. It is situated on the Pinow Canal, one of the most important in Northern Germany. Of recent years it has developed very rapidly as a manufacturing center. Manufacturers have been forced to leave the large cities on account of labor troubles, high taxes, etc. The Eberswalde power plant was built to supply the growing demand for electricity in the surrounding country and also for street car and electric light service. We had a drive of several miles through interesting country to the plant.

The plant is one of the neatest that the writer has ever seen and contains some decidely unique features. At present only about one half of the ultimate capacity of the plant is installed. There are three 650 H. P. Babcock and Wilcox marine type boilers in the boiler room. These are enclosed entirely in a carefully assembled sheet steel casing lined inside with asbestos blocks. This casing almost entirely overcomes the boiler loss due to air leaks through the setting. This loss does not seem to be appreciated by our power plant designers in the United States. The writer was told by the Assistant Chief Engineer in the Carville Station at Newcastle, England, that they always figured on 5% higher boiler efficiency with a steel encased B. & W. marine boiler than with a standard B. & W. boiler with a brick setting, other things being equal. A saving of this amount would certainly pay high interest on the extra cost of the steel casing.

The stokers are B. & W. chain grates and are placed entirely under the boiler. The roof of the furnace is of fire brick, thus obtaining all the advantages of the Dutch oven in the complete combustion of the coal and volatile gases. At the sides and rear there are doors as shown, through which any chunks can be broken up, and glass covered peep holes are provided, through which the condition of the fire and the location of holes can be noted without opening doors. Dump grate bars are also placed at the rear of the chain grates to hold and thoroughly burn out the excess air enteerng through the burnt out ash. With this arrangement of stokers, the boilers are necessarily somewhat higher above floor level than with the ordinary setting.

Coal is delivered in barges on the canal adjacent to the plant and unloaded outside the power plant by a regulation clam-shell bucket. It is conveyed to the bunkers above the boilers by two sets of bucket conveyors, which pass under this storage pile in concrete tunnels. These conveyors are remarkable for making several quarter turns on their way to the boilers from the coal piles.

The ashes are collected in cars run under the ash pits. They are elevated to the ground level by a hoist and emptied into carts. At present the ash is used for filling in ground.

The boiler itself being of the marine type, it has only one drum at the front. There is, however, a second dry steam drum placed directly above this one. From this upper drum the dry steam passes down to the superheaters, which are standard B. & W. and built into the setting in the usual way.

Green's economizers are placed directly on top of the boilers, thus making another large saving in floor space.

The novel part of the plant is the chimney and draft apparatus. As one approaches the plant the two steel chimneys sticking out above the roof about 40 feet and formed like large Venturi meters, holds one's attention and makes one wonder what new scheme has been devised here.

As the gases have passed through an economizer, their temperature on reaching the breeching is quite low, probably about 300° F. Hence it would be necessary in order to obtain the required draft to burn coal to build an extremely high chimney or to provide mechanical draft. In this plant the latter method was chosen and a new system of induced draft, the invention of Dr. Hans Cruse, has been installed. The chimney is nothing more than a gas ejector. A small motor attached to a Sirocco blower and built on a platform by the breeching delivers cold air at the pressure of three or four inches of water into a pipe which passes up the center of the chimney about 40 feet to the narrow neck part. As it passes up this pipe it is heated by the surrounding flue gases and its volume and velocity increased. The discharge of this air in the narrow throat of the chimney creates an ejector action and produces a drop in pressure in the lower part of the chimney. Thus any draft desired can be obtained by regulating the speed of the fan by a rheostat.

The advantages claimed for this system of induced draft are as follows: The fan is not touched by the hot flue gases and is not subject to corrosive actions if coal containing sulphur is burned. Hence it is of almost unlimited durability. The fan is also of very efficient design. The bearings do not need water cooling, as is usual with ordinary fans. It is said that this arrangement only uses about 1 to 1½% of the power developed, which is certainly a low figure. The chimney is built of boiler plate, and hence is of cheap construction. Including patent royalties, this equipment is said to cost about the same as the regular induced draft equipment, but is much simpler and more satisfactory to operate.

There are installed in the boiler room, besides the CO_2 recorders, recorders to indicate the difference of pressure between the ash pit and the chimney flue. The use of these recorders discourages the firemen from operating with their dampers almost closed to get high CO_2.

The feed water is supplied by either of two Curtis turbine driven centrifugal pumps running at 1500 R. P. M. and forming a very fine unit. The water is regulated on the boilers by automatic feed water regulations. The level of the water in the drums is shown by Klinger gage glasses, which shows the water portion black and the steam portion white. These have not been adopted very largely in this country, though they are extremely serviceable. Another improvement in water gage glass construction, which is very common all over Europe, consists of enclosing the gage glass itself by glass screens so that in the event of a glass breaking the firemen are not likely to be injured by the flying glass.

In common with all the power plants visited in Europe, the steam piping systems were very poor. The pipe at Eberswalde is all made with welded steel flanges, but is not provided with proper bends to take up expansion, and, in consequence leaked badly in places. In fact, some of the poorest arrangements the writer ever saw for taking up expansion have been installed in this plant. One of these consists of two swivel expansion joints, while the other consists of half a goose neck with right angled ells and nipples in place of the other half. It was also surprising to find globe valves used on the main steam lines.

In the engine room there were two 4000 K. W., A. E. G. steam turbines and condensers with A. E. G. turbine driven circulating and rotary air pumps. The units are of standard construction and need not be described. Instead of the regular mercury columns on the exhaust to read vacuum, these units were supplied with direct reading absolute pressure mercury indicators.

All the air entering the generators is carefully filtered through bags. The hot air leaving the generators is piped outside the engine room, thus preventing undue heat in this building. The electrical equipment is very extensive and represents the latest practice of A. E. G., among other machines including the "rain-storm" lightning arrestor, etc. The bus-bars, switches and cut-outs were very fine.

From our observations, power plant practice in Germany may be summarized as follows: Water tube boilers with internal superheaters and with chain grate stokers and fire brick arches are used almost universally. Economizers are installed instead of feed water heaters. Great attention is paid to automatic recording instruments for steam pressure, CO_2, draft, etc. Coal and ashes are generally handled by conveying machinery. Economy in the boiler room, both in coal consumption and in labor, is demanded. Steam turbines of the impulse type are most popular, while surface condensers along with water softeners are in universal use. Cooling towers are frequently resorted to. All auxiliaries are usually motor driven. The electrical equipment is much the same as is common in America. Great attention is paid to attractive interior construction and to harmonious effects in interior decoration, while both engine and boiler rooms are usually models of cleanliness.

NOTES ON THE CALCULATION OF HEATING VALUE OF COALS FROM THEIR ANALYSES.

O. L. Kowalke.

Assistant Professor of Chemical Engineering.

The heating value of a coal may, in general, be obtained by two methods: (1) By actual combustion in a calorimeter, (2) By calculation from the analysis.

There seems to be little doubt that the calorimetric test on a coal is the best, and for all tests of importance, this method is in general use. The cost of a calorimetric equipment seems somewhat high to those who have only occasional determinations to make, and who desire only an approximate estimate of the heating value.

The calculation of the heating value from the analysis may be performed in two ways: (1) An ultimate analysis of the coal may be made, which gives the proportions of carbon, hydrogen, oxygen, nitrogen, sulphur, and ash. The heating value may then be computed from the known heats of combustion of carbon and hydrogen, according to various formulae. (2) An approximate analysis may be made which gives the moisture, volatile matter, fixed carbon, and ash. By means of emperical formulae or curves the heating value can be deduced.

The ultimate analysis of a coal is a difficult and tedious process and requires long practice for its accurate execution. There have been various formulae proposed for obtaining the heating value from this analysis, and there is considerable difference of opinion as to the correct method.

In view of the complexity of the ultimate analysis, several methods have been proposed for calculating the heating value from the proximate analysis which is not difficult to make. In 1902, E. Goutal published a formula (*Comptes Rendus*, Sept. 1902; *E. C. & M. I.*, April '07) for calculating the heating value from the proximate analysis, the formula being based on a large number of tests on French coals. The formula, in English units, is as follows: B.T.U.=14760 C+aV. Where the

B.T.U. refers to coal as received, (C) the percentage of "fixed carbon" expressed as a decimal, (V) the percentage of "volatile matter" found expressed as a decimal, and (a) the constant. A table of values of (a) was constructed in terms of

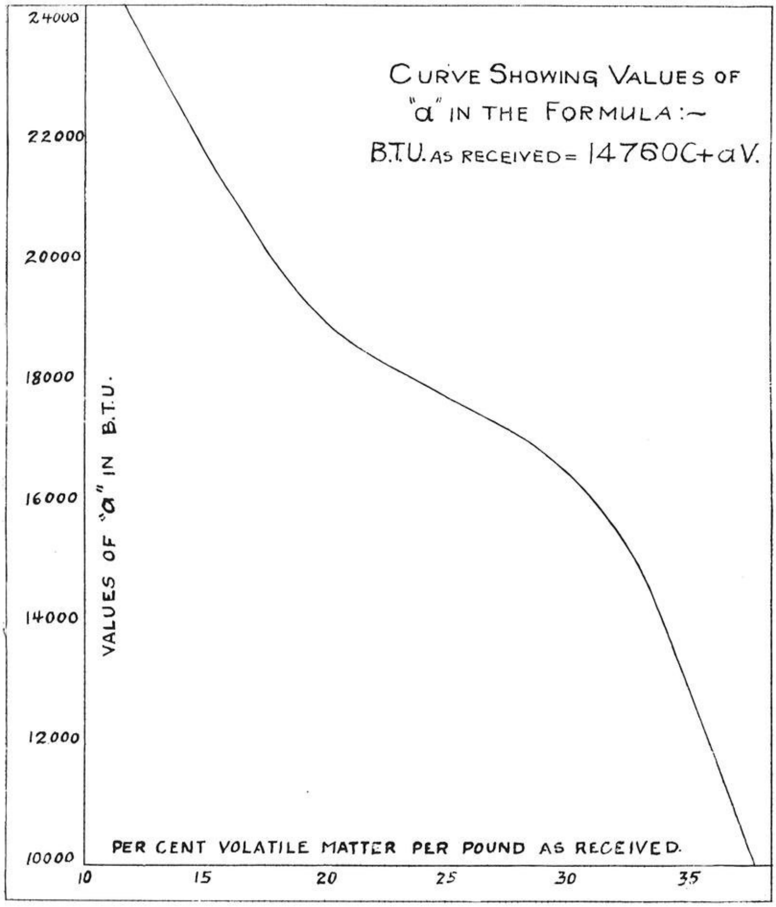

PLATE I.

the volatile matter (V′) in the combustible. The heating value is computed by multiplying the fixed carbon, in decimal form, by 14760, and the volatile matter (V) actually found by constant (a) corresponding to the volatile matter (V′) in the combustible, and adding these two products.

Since the formula and values of (a) were determined on French coals, it seemed desirable to evolve a set of values for (a) from American coals. It also seemed desirable to retain the formula:—B.T.U. /# as received =14760 C+aV, but to give (a) directly in terms of volatile matter percentage (V) as found. Accordingly about 200 analyses of American bituminous and semi-bituminous coals were used to compute a set of values for (a), and these were plotted in the form of a curve, Plate I, with values of (a) as abscissae and values of (V) as ordinates. The heating value of the coal as received is then the sum of the products of:—14760 times the "fixed carbon" (as a decimal), and (a) times the "volatile matter" (V) (as a decimal) as found. This method and the values of (a) will give a result approximating the calorimetric determination within 1% or 2%.

The following is an example:—

Moisture	11.58	B.T.U. /# as rec'd=14760 C+aV/.	
Volatile Matter..	34.00	For 34%, (a) from curve is 13850	
Fixed Carbon...	40.63	Computed B.T.U.=10706.0	
Ash	13.79	14760×0.4063=	5997.0
	———	13850×0.3400=	4709.0
	100.00%	Calorimetric=	10840.0
		Difference=	134.0

It should be noted that this formula does not hold for anthracites low in volatile matter. Below 12% volatile matter this method does not seem to hold true, but it does appear to give results approximately correct for coals having higher than 12% volatile matter.

The Under-Feed Stoker Co. of Chicago has worked out a curve, Plate II, by means of which the heating value as received can be determined from the proximate analysis to an accuracy of about 2%. Numerous checks with this curve against the calorimetric determination prove it to be substantially correct.

In this curve the percent of fixed carbon per pound of combustible is plotted as abscissae, and the B.T.U. per pound of combustible plotted as ordinates. The fixed carbon as found is re-computed on the basis of a pound of combustible, i. e. moisture and ash free coal. The B.T.U. on this curve corresponding to the re-computed value of the fixed carbon in the combustible, is then multiplied by the sum of volatile matter and fixed carbon as found. The product is the heating per pound as received.

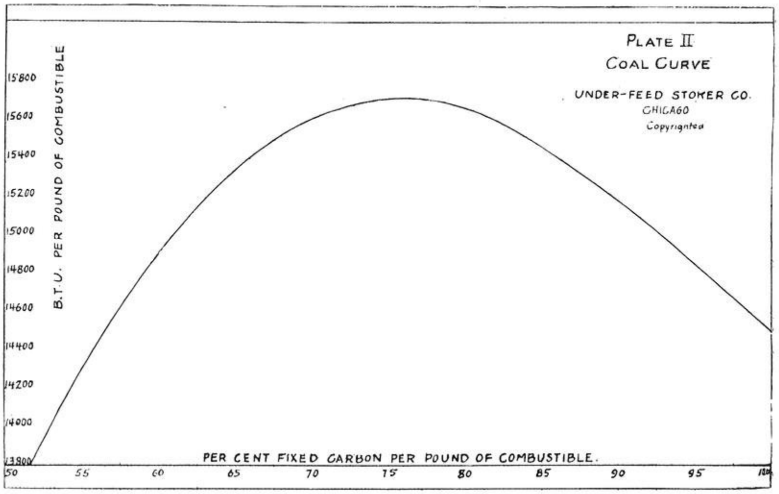

PLATE II.

The following is quoted from the published account:—

Moisture	5.78	Volatile Matter	30.69
Volatile Matter	30.69	Fixed Carbon	55.03
Fixed Carbon	55.03		
Ash	8.50	Combustible in Coal	85.72%
	100.00%		

0.5503÷0.8572=0.643 or 64.3% fixed carbon per pound combustible. The B.T.U. per pound of combustile from the curve, corresponding to 64.3% is 15300 B.T.U. Then 15300×0.8572=13156 B.T.U. /# as rec'd.

The curve above referred to appeared in the March 1911 issue of the *"Publicity Magazine"* of the Under-Feed Stoker Co. and is here reprinted by their permission.

The Wisconsin Engineer.

EDITORIAL.

The article by Professor Withey, appearing elsewhere in this issue, incidentally furnishes an illustration of work done in our College for the direct benefit of an extensive industry. This work is a fine example of one line of service which Dean Turneaure is promoting as rapidly as the facilities of the College permit.

We are pleased to call attention to other recent examples of such service. The following are some of the more notable ones recently published in university bulletins or engineering journals: Nickel and Copper Alloys with Electrolytic Iron; Long Distance Transmission of Steam and its effect on Power Plant Economics; The Specific Heat of Steam; Losses in Steam Turbines and Gas Engines; Reinforcement of Concrete Structures; Waterproofing of Concrete; Water Power Resources of Wisconsin; Rainfall and Stream Flow in Wisconsin; Air-lift and Centrifugal Pumps; Friction Losses in Water Pipe; and Effect of Rapidly Moving Trains on Bridges.

Our faculty is engaged quite extensively in the State service. Professor Pence is engineer for the State Railroad and Tax Commission, Professors Mack and Burgess serve on the joint engineering staff of the two commissions, and others are called in from time to time to render special assistance. Professor Smith has served as State Sealer of weights and measures for a long time, and rendered much assistance in establishing our new weights and measures regulations. Considerable assistance has been given from time to time by members of the faculty to the State Geological and Natural History Survey, especially to the highway division. Dean Turneaure is a member of the newly created State Highway Commission. All departments of the College are called upon more or less frequently for special help by citizens, firms, municipalities, etc. A notable example was the recent call from flood-stricken Black River Falls, responded to by Professor Mead.

The various departments of the College are busily engaged now in many lines of experiment and study which will yield results of scientific interest and practical value. One of the most fruitful fields is that of the materials of construction, their properties and economic uses. In this field of study the opportunities in our College are excellent by reason of the well developed laboratories in Chemical Engineering, Metallurgy, and Applied Mechanics.

* * *

The forthcoming alumni directory of the College of Engineering will contain interesting and significant data on the distribution of its graduates among the various lines of engineering work. It is found that about 92.5 per cent of the engineering graduates remain in engineering work and that a small part of 1 per cent are unemployed. Of the civil engineers about 23 per cent are in the employ of some branch of the government, 20 per cent in the engineering professions of consulting and contracting, 12 per cent in manufacturing plants, 12 per cent in steam railroad work, 6 per cent in teaching and the remainder is divided among mining, power plant work, irrigation and electric railways. Of the electrical engineers 26 per cent are in electrical manufacturing as engineers, salesmen or managers, 15 per cent in central stations, 8.6 per cent in telephone work, 8.4 per cent in teaching, 7.5 per cent in manufacturing plants, 5.7 per cent in the employ of the government, and the remainder is divided among railways, transmission, consulting and contracting. Of the mechanical engineers 50 per cent are claimed by industrial manufacturing plants, 13 per cent by public utility companies, 4 per cent by the government and 5.8 per cent by consulting and contracting while 8 per cent are teaching.

In addition to the classified summary by occupation the directory will give the address and occupation of every person who has ever received an engineering degree from the University of Wisconsin. It will also show the distribution of the graduates from the College of Engineering in the various states and cities in which they are domiciled at the present time. The directory is the most nearly complete publication of its kind ever complied by the college and should therefore be of interest to every alumnus and student of the College of Engineering.

DEPARTMENT NOTES.

HYDRAULIC AND SANITARY ENGINEERING.

A seminary in experimental hydraulic engineering has been conducted during the past four years by Mr. Davis and Mr. Weidner. Attendance at the meetings is required of all students having experimental theses in hydraulic engineering. These men present papers during the first semester describing the methods of work which they propose to employ in the prosecution of their experiments, while during the second semester the papers discuss the methods of computing and analyzing the results. The students' general knowledge of the methods of hydraulic experimental work is thus broadened by being made familiar with all lines of work in progress in the laboratory. The discussion which developes after the presentation of the papers clears up many doubtful matters and often leads to improvements in apparatus and methods, and avoidance of errors and unnecessary work. The program for the first semester of this year is as follows:

Dec. 9. Ort and Scudder; Experiments to determine the effect of variation of centrifugal pump design.

Dec. 16. Davis, Grimmer, Reilly, and Smith; Investigation as to the action of valves in reciprocating pumps.

Jan. 6. Jessup and Scheiber; Experiments to determine the effect on the efficiency of a turbine of installing it below tail water level.

Jan. 13. Simon and Vroman; The determination of the effect of variations in the length of the drive pipe on the capacity and efficiency of a hydraulic ram.

Jan. 20. Hewitt and Mears; The effect of distorted velocity curves on the coefficient of a Pitot tube.

MINING AND METALLURGY.

The advanced course in metallurgical by-products is being given by Mr. Havard for the first time this semester. This is a required course only for students in the professional course in mining and metallurgy, but it is intended to be of especial value to industrial chemists and for advanced geological students. Geological research has passed the era of pure speculation and further advance requires quantitative methods and a knowledge of thermal chemistry. The work on slags, chemical heat equivalents, mass action, etc., taken up in this course should have direct application to the magmatic problems of the geologist.

The mining laboratories are gradually being put into operating condition and several ore dressing investigations of practical importance will shortly be begun. Two furnaces will be added to the metallurgical equipment during the year and pyrometers and accessory apparatus is also to be provided.

BOOK NOTICE.

"ADDRESSES TO ENGINEERING STUDENTS."

Edited and published by Waddell & Harrington, Consulting Engineers, Kansas City, Mo.

Messrs. Waddell and Harrington have done a great service to students and young engineers in bringing together a large number of addresses delivered to engineering students by prominent engineers and educators. The book includes more than 40 selected addresses on various phases of student and professional life and from various standpoints. Among the selected list are addresses by our former Dean, J. B. Johnson, President Charles W. Elliott, of Harvard University, President Alexander C. Humphries of Stevens Institute, Mr. Walter C. Kerr of Westinghouse, Church, Kerr & Company, Professor George F. Swain of Harvard University, Professor D. C. Jackson, formerly of this institution and now at Massachusetts Institute of Technology, and several from Mr. Waddell himself.

The collection and publication of these lectures are due to the great interest which Mr. Waddell has always taken in young engineers and in engineering education in general. The books are sold to students at 75 cents each, which hardly covers the actual cost of printing and binding. The work contains very much of interest and value to the engineering student, and the very low price should enable everyone to own a copy.

ALUMNI NOTES.

The University has conferred one degree in Sanitary Engineering, in 1904. It was conferred on Joseph I. Bingham. Mr. Bingham is with the D. L. & W. R. R. as assistant engineer. He is at present engaged in reconstruction work at Analomink, Pa.

Two recent graduates in Chemical Engineering are employed in research and experimental work; F. F. Farnham, '09, with the National Tube Co., McKeesport, Pa., and W. C. Andrews with the B. F. Goodrich Rubber Co., Akron, Ohio. C. A. Hansen, '05, is with the General Electric Co., and is at present the assistant in charge of research work in electrical furnace construction.

Arden Richard Johnson who graduated in the electro-chemical course in 1906, is the director of the Engineering College of De Paul University, Chicago.

Several of 1910 class in chemical engineering have found positions with large companies; O. W. Storey with the National Metal Moulding Co., of Economy, Pa.; R. C. Downing with the La Clede Gas and Light Co., of St. Louis; A. B. Chadwick with the North Shore Consolidated Gas Co., of Waukegan; and W. B. Schulte with the Northern Chemical Engineering Laboratories of Madison, Wis.

John E. Cleary, '07, and Jesse A. Davidson, '04, are with the Western Electric Co., Chicago. They are both engaged in telephone engineering work.

Two chemical engineering graduates have taken up Forestry work at Madison, J. H. Thickens, '08, and G. C. McNaughton, '09, at Wausau, Wis.

It is interesting to hear about some of the men who graduated from the course in Metallurgy and Mining which the University offered some years ago. The first graduate whom we have record of is Geo. Haven, '76. He is with the Crow Wing Lumber Co. of Waterloo, Iowa. Wm. A. Hover, '77, is in the wholesale drug business, in Denver, Colo. Magnus Swenson, '80, has offices in the Carroll Block, Madison. Wm. N. Merriam, '81, is with the Oliver Iron Mining Co. as Geologist. A. F. Rote, '82, is a lumber merchant in Monroe, Wis. O. J. Frost, '82, is located in Denver as a custom assayer and Chemist. H. B. Smith, '85, is the vice-president of the First National Bank of Colton, California. N. M. Thygeson, '85, is with the Twin City Rapid Transit Co., of Minneapolis. Walter Parmley, '87, is in the firm of Parmley and Nethercut, New York City. J. R. Thompson, '87, is the general manager of the American-Boston Mining Co., Ishpeming, Mich. Herbert J. Harris, '93, is the assistant superintendent of the O. S. L. R. R., Salt Lake City.

D. M. Grant, Mining '11, is in the geological department of the E. J. Longyear Co., Crystal Falls, Mich.

Quite a few mechanicals are now teaching in various parts of the country. Their names and the colleges they are now as follows: Mm. Wipperman, '08, University of Pennsylvania; F. B. Rowley, '05, University of Minnesota; Arthur B. Richter, '89, University of Montana; W. A. Richards, '99, University of Chicago; Lewis Moore, '00, Massachusetts Institute of Technology; F. W. Ives, '09, Ohio State University; A. J. Hoskins, '90, Colorado School of Mines; F. W. Greve, '09, Oregon Agricultural College; D. E. Foster, '06, Washington State College; C. L. Dean, '01, University of Nebraska; J. E. Boynton, '05, University of Iowa; F. W. Buerstatte, '01, Missouri School of Mines; E. S. Burnett, '05, Cornell University; and E. H. Whittaker, '09, in the Worthington, Minn., high school.

Julian D. Sargent, '07, has gone into newspaper work. He is now with the St. Paul Despatch.

Geo. G. Throp, M. E. '91, is second vice-president of the Illinois Steel Co. and vice-president of the Indiana Steel Co. His offices are in the Commercial National Bank Building, Chicago.

Carl A. Johnson, the president of the Gisholt Machine Co., graduated in the mechanical engineering course in '91.

E. J. McEachron, '04, and W. L. Woodward, '94, are with the Fuller and Johnson Co. of this city.