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MOLDING SANDS OF WISCONSIN

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Status of Industry in Wisconsin

Though Wisconsin had 323 foundries in 1925, it does not rank among the leading producers of molding sand in the United States. In 1924 it was one of the 25 states which collectively produced but 9 per cent of the total.[1] Table I (p. 8) gives the distribution of the foundries and producing pits.

Table II (p. 9) gives the production of molding sand in Wisconsin since 1904.

An analysis of these figures gives a very interesting insight into the molding sand production in Wisconsin. The average yearly production from 1904 through 1926 was 84,225 short tons. This material had an average total yearly value of $63,009, an average price per short ton of $0.748, and an average relative or true price of $0.579. The production in general rose until 1908 when it declined to 41,687 short tons, the lowest recorded production up to that time. In 1911 a high point of 90,723 short tons was reached, after which the production gradually dropped off to 37,528 short tons in 1914. The production reached its highest recorded level in 1923, 140,995 short tons, and its lowest recorded level in 1921, 17,972 short tons.

The low production years, 1908, 1914, and 1921, reflect the general industrial conditions of our country at that time, especially the iron and steel industry.

It will be interesting to the producers to study the data found in Table III (p. 9).

These figures show the following interesting facts: (1) that the average price of molding sand in Wisconsin for the last seven recorded years has fallen below that for the United States with the exception of 1919, when it surpassed it by $0.21; and (2) that the average of these averages for Wisconsin for the last seven recorded years is $0.202 above the average from 1904 through 1926.

[1] Phillips, Estelle R., Sand and gravel: U. S. Dept. of Commerce, Mineral Resources of the United States, 1924, Part II—Nonmetals, p. 265, 1927.

TABLE I

DISTRIBUTION, BY COUNTIES, OF FOUNDRIES; PRODUCING MOLDING SAND PITS; AND SAMPLES COLLECTED AND TESTED[1]

County	Number of foundries	Number of producing molding sand pits	Number of samples collected and tested
Ashland	3	--	--
Barron	1	--	--
Brown	4	2	2
Buffalo	--	--	2
Calumet	3	--	--
Chippewa	2	--	--
Columbia	2	2	6
Dane	8	--	3
Dodge	7	--	--
Door	1	--	--
Douglas	7	--	--
Dunn	3	1	--
Eau Claire	6	1	5
Fond du Lac	5	--	2
Grant	2	--	--
Green Lake	4	7	29
Iowa	--	--	1
Iron	2	--	--
Jefferson	8	--	--
Kenosha	10	1	3
Kewaunee	2	--	--
La Crosse	7	1	2
Lincoln	5	--	--
Manitowoc	7	--	--
Marathon	4	--	--
Marinette	1	--	--
Milwaukee	107	--	1
Monroe	--	--	1
Oneida	2	--	--
Outagamie	9	--	1
Ozaukee	8	--	--
Pierce	--	1	--
Portage	2	--	--
Racine	24	1	4
Rock	15	2	4
Sauk	--	2	13
Sheboygan	12	--	1
Walworth	--	--	1
Washington	5	--	1
Waukesha	10	--	2
Waupaca	2	--	2
Waushara	--	--	1
Winnebago	14	--	11
Wood	9	--	--
Illinois	--	--	4
Total	323	21	102

[1] Foundries are from Penton's Foundry List. 1925 Edition; producing pits are from lists furnished by the United States Geological Survey and other data.

TABLE II

QUANTITY AND VALUE OF MOLDING SANDS PRODUCED IN WISCONSIN

Year	Quantity[1] Short tons	Value[2]	Average price per ton	Index No. average prices[3]	Relative or true price
1904	53,585	$26,478	$0.49	85.6	$0.572
1905	52,279	27,412	0.53	86.2	0.614
1906	55,973	33,907	0.61	88.6	0.688
1907	72,348	42,683	0.59	93.5	0.631
1908	41,687	32,806	0.79	90.1	0.876
1909	[a]84,381	[a]63,915	[a]0.76	96.9	[a]0.784
1910	[a]87,786	[a]54,732	[a]0.62	100.9	[a]0.614
1911	90,723	59,009	0.65	93.0	0.698
1912	77,026	49,599	0.64	99.1	0.645
1913	76,537	37,432	0.49	100	0.49
1914	37,528	21,303	0.57	98.1	0.581
1915	126,675	50,661	0.40	100.8	0.396
1916	84,597	56,606	0.67	126.8	0.528
1917	97,674	53,846	0.55	177.2	0.310
1918	107,782	90,658	0.84	194.3	0.432
1919	121,742	159,106	1.31	206.4	0.634
1920	128,742	137,646	1.07	226.2	0.473
1921	17,972	17,553	0.98	146.9	0.667
1922	81,516	61,532	0.76	148.8	0.510
1923	140,995	124,980	0.89	153.7	0.579
1924	81,337	64,803	0.80	149.7	0.534
1925	[b]102,990	[b]83,587	0.81	158.7	0.510
1926	[b]115,321	[b]98,953	0.86	151.0	0.569

[1] Figures are from Mineral Resources which was formerly issued by the United States Geological Survey but subsequent to 1923 has been issued by the United States Department of Commerce.

[2] Idem.

[3] Wholesale prices 1890–1926: U. S. Dept. of Labor, Bureau of Labor Statistics Bull. No. 440, p. 9, July, 1927.

a Includes glass sand.

b Figures obtained from manuscript data.

TABLE III

AVERAGE PRICE PER SHORT TON

Year	Average price		Relative or true price	
	United States	Wisconsin	United States	Wisconsin
1918	$1.04	$0.84	$0.535	$0.432
1919	1.10	1.31	0.532	0.634
1920	1.46	1.07	0.645	0.473
1921	1.29	0.98	0.878	0.667
1922	1.17	0.76	0.786	0.510
1923	1.21	0.89	0.787	0.579
1924	1.13	0.80	0.754	0.534

These facts may indicate three things: (1) that the Wisconsin producer is not making the profit that is due him; (2) that the cost of production of molding sand in the state is much lower than in other states, due to the methods used; or (3) that the large proportion of low priced core sand produced has a tendency to lower the average price of the total.

The General Problem

During the past few years the properties of molding sands and their relations to the use of the sand in foundry practice have been carefully studied. These investigations have been carried on in part by a few foundry organizations and in part by a few individuals who have recognized the importance of this matter. The American Foundrymen's Association, realizing the importance of the foundry sand problem, has established several standard tests which are applicable to molding, steel, and core sands, and also to foundry control work. To create further interest in the testing of the various properties of the molding sands, the American Foundrymen's Association is at present maintaining an official testing station at Cornell University, Ithaca, New York. The Wisconsin Geological and Natural History Survey sensed the need of this testing work in Wisconsin and cooperated with the Foundrymen's Association.

Purpose of the Investigation

The investigation of the molding sands of the state had a threefold purpose: (1) to study the properties of Wisconsin sands, (2) to locate new deposits of sand near the foundry centers if possible, and (3) to study the geological occurrence of the sands.

By a study of the properties of the sands which are now being produced, the foundrymen of the state may get a clearer conception of the sands which are available in Wisconsin and the type of work for which they can be used. The demand for new deposits near the foundry centers is a just one because a large quantity of the sand is now shipped from without the state at high freight rates. A study of the geological occurrence of the existing deposits gives data which may be used at a subsequent time in further prospecting for new sands.

Method of Work

Field Work

During the months of July and August, 1924 the author visited producers of molding sands and many of the leading foundries of the state. Every producing pit visited was sampled, and in cases where more than one grade of sand was being taken from the same pit, samples of each were taken (Table IV, pp. 78–91). The author made no attempt to grade the sands in the field but obtained notes of the occurrence and also the grade number applied to the sand by the producer. In all cases where it was possible the type of work for which the sand was used was noted. It was hoped that by visiting the foundries and finding out the class of work being done and the sands which were being used, some suggestions might be made whereby the foundrymen might profit by using Wisconsin sands.

Laboratory Work

The testing of the samples collected was carried on at Cornell University, Ithaca, New York.

Geographical Distribution of Molding Sand Deposits

The deposits of molding sand are, in general, found in the southeastern counties of the state with the exception of those in Monroe, La Crosse, Buffalo, and Eau Claire counties. This distribution is well brought out by the map, figure 1, which

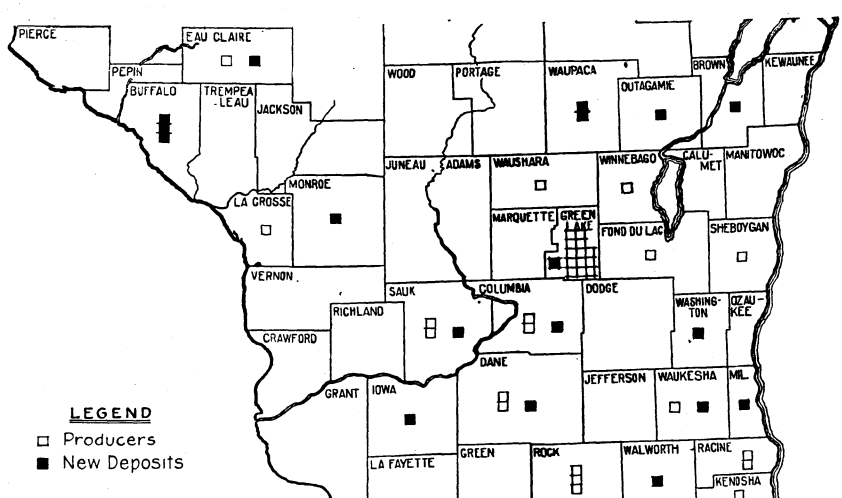

Figure 1.—Distribution of molding sand deposits by counties.

shows by counties the number of producers and new deposits. The majority of these deposits are on railroad lines or a very short distance from them. Proximity to transportation facilities is a requisite of any sand deposit worth developing.

Molding sands are sold on an F. O. B. basis at the loading point; consequently any sand which is some distance from the foundry trade of the eastern counties sells at a lower price to meet the competition of the producers which are nearer the trade.

General Characteristics of Molding Sand Deposits

Molding sand deposits may be classed into three general types according to the quantity of clay material which they contain. The molding sand deposits which contain 5 to 30 per cent of clay material usually occur in almost flat or slightly undulating country and only in exceptional cases reach a thickness of more than 3 feet.

The core sand deposits, which usually have less than 5 per cent of clay material, show a wide variation of characteristics according to their mode of occurrence. They vary in thickness from a few feet to 15 feet and may be exposed on the surface as well defined ridges, nearly flat deposits, mounds, or as sand along the present lake shores, or in river channels.

The steel sands which contain little or no clay material are found in the partially consolidated sandstone formations. These deposits are quarried and the height of the quarry face depends entirely on the regularity of the grain size of the material. In general, it is not economical to quarry a face much higher than 25 feet.

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The author wishes to thank the molding sand producers and the foundrymen of the state for the interest which they have shown in the investigation of the molding sand resources of the state, and also Drs. H. Ries and C. M. Nevin, and Mr. T. C. Adams for their assistance in the interpretation of some of the data obtained from the sand tests.

CHAPTER I

PROPERTIES OF MOLDING SANDS

General Statement

A sand to be of value for foundry work must possess certain properties. These are texture, permeability, bond strength or cohesiveness, refractoriness, and proper life. Chemical composition is in most cases of little commercial value. The mineral composition is important to consider in connection with the refractoriness.

Texture

The texture of the sand is determined by the fineness test prescribed by the American Foundrymen's Association. This test is discussed in detail in a publication of the Joint Committee on Molding Sand Research of the American Foundrymen's Association.[1] The test consists of determining the clay substance in the sand by decantation after the clay has been suspended by shaking in water to which 25 cubic centimeters of a standard solution of sodium hydroxide[2] has been added. The grains are screened dry, and the quantity retained on sieves with the following number of meshes to the inch, 6, 12, 20, 40, 70, 100, 140, 200, 270, and Pan, is noted.

Methods of Expressing Fineness

General.—In the past fifteen years several methods have been devised for expressing texture of molding sands instead of using the ordinary method of stating and analysis (columns 7–17, Table IV, pp. 78–91). Though this method shows the relative abundance of the different grain sizes, there are many who believe that some shorter mode of expression would be more useful.

The methods devised for the statement of the mechanical analysis of a sand fall into two classes: (1) those using some type of

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[1] Standard and tentatively adopted methods of testing and grading sands: Am. Foundrymen's Assoc., Chicago.

[2] The standard solution is made by dissolving 10 grams of sodium hydroxide in 100 cubic centimeters of water.

curve, and (2) those using a figure to express the grain size. A recent paper by C. M. Nevin discusses the two classes mentioned above and presents a unique method for the classifying of sands by their mechanical analysis. Nevin's method, briefly stated, consists in plotting the percentage weights taken from the fineness test when the clay substance is neglected. The screen openings are plotted horizontally on logarithmic coordinates and the percentage weights are plotted vertically on rectangular coordinates. A set of limit grade curves, based on sands from the Albany, New York district, has been prepared for grading sands. A second method, recently devised by C. A. Hanson of the General Electric Company, consists of plotting the cumulative percentage curve, and from this differentiating the probability curve. This method gives a smooth curve which is very easy to interpret. The only objection the author has to this method is that it is somewhat complicated for general use.

Each of the two methods has its merits. The statement of the mechanical analysis by means of a curve shows the relative distribution of the different grain sizes. The statement of the mechanical analysis by a figure is very simple and shows the relative coarseness or fineness of the sand. At present the question: "Which method will best serve the foundrymen and sand producers?" is open to debate. The author, however, feels that the simpler method of stating the analysis by a figure is all that is needed provided the results of further tests accompany the figure.

Coarseness figure.—Many determinations of the fineness of molding sands have been made and in most of these determinations a proposed relation to the permeability of the sand has been suggested. The relation in every case has been shown to be only approximate. The method used by Ries and Rosen for the determination of the fineness of molding sands is very similar to the one the writer wishes to propose except that it requires a few more detailed and not really necessary manipulations.[1]

The coarseness figure here described has been determined from the mechanical analysis of sands tested by the method prescribed by the American Foundrymen's Association in which screens with the following number of meshes to the inch were used, 6, 12, 20, 40, 70, 100, 140, 200, 270, and Pan. To determine the coarseness figure the percentage weight of the sand retained on any screen is divided by the number of meshes to the inch of that screen, using 410 for the material retained in the pan. The figure

[1] Ries, H., and Rosen, J. A., Foundry Sands: Michigan Geol. and Biol. Survey Ann. Rept., 1907, pp. 41–79.

410 was calculated with the aid of a microscope from the average size of the grains retained on the pan. The sum of all the quotients obtained in the above mentioned divisions gives the coarseness figure which is a decimal for sands of fine texture and grades up to a whole number in the sands of coarser texture (column 18, Table IV, pp. 78–91).

SAMPLE No. 871

Screen size	Percentage retained	÷	Number of meshes per inch		
6					
12					
20					
40	0.60	÷	40	=	0.015
70	1.00	÷	70	=	0.014
100	29.02	÷	100	=	0.290
140	24.14	÷	140	=	0.172
200	13.72	÷	200	=	0.069
270	8.30	÷	270	=	0.031
Pan	12.72	÷	410	=	0.031
Coarseness figure					0.622

It is very evident that the coarseness figure has a direct relation to the established grade of the sands. It was thought best to base any system of grades which might be made from the coarseness figure on those already established in the Albany district and also to make the system applicable to core sands as well as sands used for molds. With this in mind the writer computed the coarseness figure for the fifty-seven selected sands used by Nevin in his revision of the grades of the sands produced in the Albany district. The limits established by Nevin were used as a basis for drawing the curve, figure 2, page 18, which shows the limits of the coarseness figure for each grade.

This method of grading molding sands by means of coarseness figures eliminates the element of judgment which has to be used in grading sands by a series of limit curves. This is an important factor because it is almost impossible to draw limit curves which would be of universal use. The first time a sand is encountered which does not exactly fit the limit curve, the judgment has to be brought into play.

The question of permeability is solved by suggesting that every sand that is given a coarseness figure be also given a permeability figure as determined by the prescribed test of the American Foundrymen's Association. It is suggested that the figure for maximum permeability be used for this purpose. If the permeability figure accompanies the coarseness figure, it will guard against the possibility of adding too much fine material to blended sands.

The writer has confidence in this method of grading because it has been applied with very good success to 128 molding sands from New York, New Jersey, Pennsylvania, Michigan, and Wisconsin, and to 202 core sands from New Jersey, Pennsylvania, Maryland, North Carolina, Virginia, Tennessee, Michigan, Wisconsin, and California. In establishing the limits of the coarseness figure for the curve, figure 2, only 15 out of the 50 sands graded by Nevin were changed and these were so near the

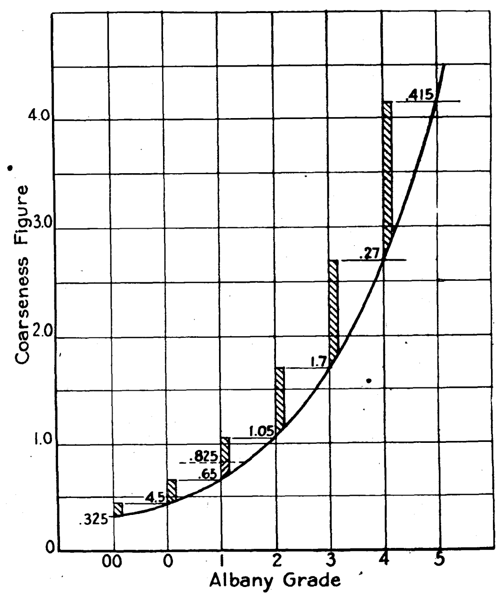

Figure 2.—Curve showing upper limit of coarseness figure for each grade.

limits as to be questionable. Probably the most important thing that the coarseness figure can do to promote the universal grading of molding sands is to help in putting the whole system on a simple mathematical basis.

Grain class.[1]—The Sub-Committee on Grading of the Committee on Sand Research of the American Foundrymen's Association has recommended a tentative standard grading classification for foundry sands. This method, of course, can not be considered a standard one until it is accepted by the Executive Committee of the American Foundrymen's Association.

[1] Standard and tentatively adopted methods of testing and grading sands: Am. Foundrymen's Assoc., Chicago.

The figure by which the sand is classified according to grain is to be known as the "grain class" and is obtained from the fineness test in the following manner. The percentage weight of the grains retained on each screen is multiplied by a factor known as the "fineness factor". In this computation the clay substance is neglected. The sum of the numbers obtained from these multiplications is divided by the sum of the percentage weights. The figure obtained by this calculation is to be known as the "grain fineness" and represents approximately the average screen size of the sand particles. Limits have been designated for the "grain fineness" in order to establish the "grain class".

An example will best illustrate the method as it is used.

SAMPLE NO. 871

Screen size	Percentage retained	×	Fineness factor		
6					
12					
20					
40	0.60	×	20	=	12.00
70	1.00	×	40	=	40.00
100	29.02	×	70	=	2,031.40
140	24.14	×	100	=	2,414.00
200	13.72	×	140	=	1,920.80
270	8.30	×	200	=	1,660.00
Pan	12.72	×	300	=	3,816.00
Totals	89.50				11,894.20

$$\frac{11{,}894.20}{89.50} = 132.896 \text{ grain fineness} = \text{No. 3 grain class}$$

The fineness factor for each screen number is given below:

Screen number	Fineness factor	Screen number	Fineness factor
6	3	100	70
12	5	140	100
20	10	200	140
40	20	270	200
70	40	Pan	300

The limit for grain fineness for the different grain classes is listed below:

Grain class	Grain fineness limits	Grain class	Grain fineness limits
1	200–up	6	40– 49
2	140–199	7	30– 39
3	100–139	8	20– 29
4	70– 99	9	15– 19
5	50– 69	10	10– 14

The grain fineness and grain class have been calculated for the sands collected for this investigation and these figures are given in columns 21 and 22, Table IV (pp. 78–91).

It must be kept clearly in mind that the grain class describes a sand only so far as grain fineness is concerned and carries no information regarding clay content and other characteristics of the sand. Complete grading involves other classifications; hence the numbers 1, 2, 3, etc. denote the grain class and not the complete grade.

Clay content classification.—Besides the "grain fineness classification" the committee has included in its tentative standard for grading a clay content classification. A sand is in the clay content class in which its percentage of clay substance falls according to the following clay content zones.

Clay class	Clay content zone Per cent
A	0.0 to but not including 0.5
B	0.5 to but not including 2.0
C	2.0 to but not including 5.0
D	5.0 to but not including 10.0
E	10.0 to but not including 15.0
F	15.0 to but not including 20.0
G	20.0 to but not including 30.0
H	30.0 to but not including 45.0
I	45.0 to but not including 60.0
J	60.0 to but not including 100.0

Summary.—All the sands which were collected in the field have been given the fineness test which was described briefly above. The author computed the coarseness figure for all the sands in order to make a clearer comparison with sands from other states and also to establish a grade for the sands of the state which are now sold without any grade number.

Molding Sand

The fineness tests of the molding sands which were collected during the investigation are listed in Table IV (pp. 78–91). Column 20 gives the Albany grade number. Where the producers are giving their sands a grade number, this is also noted (column 20, Table IV, pp. 78–91). The sands which have been given grade numbers are principally from the Berlin district. There seems to be a slight discrepancy in these numbers at Berlin, but this general statement may be made in regard to the grades as they exist at present: the 3 of the Berlin district represents a coarse 0 and a fine 1 of the Albany district; 2 corresponds to 1 of the Albany district; 1 is similar to 1½ and the finer 2 of the Albany district. The author does not wish to suggest any change in the system which is now being used at Berlin, but it is worthy to note here that a confusing difference exists and that in the future the sands shipped should conform as nearly as possible to the grades already established. The molding sands collected throughout the state may be grouped into four divisions based on the fineness tests and the work they will do in the foundry. These divisions are: (1) those sands which reach a coarseness of 0.45 as determined by the author's method, (2) those which range in coarseness from 0.45 to 0.825, (3) those which range in coarseness from 0.825 to 1.70, and (4) all the sands of greater coarseness (column 18, Table IV, pp. 78–91). The sands of the first three groups are rarely used with a facing mixture and the finish of the casting depends to some extent on the grain of the sand. Group 1 is used principally for fine castings of brass, bronze, or aluminum. Group 2 is used for light gray-iron and malleable iron work where a smooth finish is desired. These sands might be termed a fine grade of bench sands; the finer ones are used for bench work. They are also used in casting sanitary fixtures, automobile cylinder blocks, and other iron work up to one hundred and fifty or two hundred pounds. The coarser sands of this group, which represent the upper limits of the group, are used as floor sands for heavy iron work. The sands of group 4 which are used with facing mixtures have a wide use in the casting of heavy machinery.

Steel Sand

There are no pits or quarries which are producing steel sands in Wisconsin at the present time, but several samples of sand were collected, tested, and considered for this type of work.

The fineness tests of these sands are given in columns 7–22, Table IV (pp. 78–91) and are accompanied by the coarseness figure and the corresponding Albany grade number. From a study of the sands which are now being used in the large steel foundries, it would seem that the sands that are most desirable are those that have 75 per cent of their bulk coarser than the 70 mesh screen and the greater part between 20 and 70 mesh. These specifications in general give a sand that is fairly uniform in grain size. A natural clay bond is not desirable for steel casting because it is usually not refractory enough, and sands with over 1½ per cent of clay as determined by the American Foundrymen's Association fineness test are rejected by some foundrymen. The steel sands, if graded according to the Albany standard, range from 3 to 3½. The allowable range of coarseness figures for steel sands should be between 1.05 and 2.2. Probably the best way to judge a good steel sand from the fineness test is to consider the amount of material on the screens up to and including the 70 mesh and the clay content of the sand as determined by the American Foundrymen's Association method.

Core Sand

The core sands which are now being produced in Wisconsin have a wide range of fineness. This range is entirely permissible because some of the finer sands are better adapted to making small cores for castings on which a very good finish is desired. Some of the coarser sands are better adapted for heavier work in which the venting property of the sand is more important than the finish. The amount of clay and material which passes the 270 mesh screen is an important factor to consider in a core sand because an excess of this material consumes an undue amount of core oil which is a small but important factor in foundry costs. Core sands are not ordinarily graded and sold under a grade number as are the molding sands but they should be because the coarseness of the core sand means as much to the foundryman as does the coarseness of the molding sand. In Wisconsin the principal core sand producing district is around Berlin in Green Lake County. The core sands shipped from this district are principally unconsolidated sands and range in coarseness from 0.806 to 1.15 and would be classed as grades 1½ to 3 in the Albany district. They are the most widely used of any of the sands of the state. As the deposits are large and very uniformly graded, loading can be done very rapidly and without the supervision of an expert grader. It is interesting to note that over 50 per cent of the core sands from this district have a coarseness figure which ranges from 1.02 to 1.09. This range is very small and may be accounted for by the similarity of origin of the different deposits (p. 38).

Blast Sand

Many of the foundries of the state use sand blast for cleaning their castings, and most of the sands employed for this purpose are classified mechanically either by water or by screens. A sand which is widely used for this purpose in the state is produced by the Eau Claire Sand and Gravel Company and is known to the trade as "Red Flint" because of its red color. This concern is equipped to furnish any grade of sharp sand desired by its customers. The mechanical analysis of the "Red Flint" and a much coarser variety are listed in Table IV (pp. 78–91). There is some question among foundrymen whether a sand which is made up principally of round or of angular grains is more desirable. The sand composed of angular grains cuts at a more rapid rate at first than the one composed of round grains. On the other hand the sand with angular grains breaks up more readily and produces a great deal more dust. The presence of clay or fine material in the blast sand is very objectionable because if the sand is allowed to get damp, this fine material clogs the nozzles. The mineralogical content of the sand is also very important. A sand composed almost entirely of the mineral quartz is undoubtedly the best. Quartz is one of the most abundant minerals in sands and has a hardness of seven in a scale of ten.

Permeability

General Statement

The term permeability as applied to foundry sands should in no way be confused with porosity. Permeability is a physical property of sand which permits the passage of gases through it, whereas porosity refers to the volume of the pore space present in the sand. In the foundry sands are spoken of as "tight or close" and "open". These terms refer to the permeability; the "tight or close" sands have a low permeability, the "open" sands have a high permeability figure as determined by the American Foundrymen's Association test.

The permeability of a sand depends on several factors, as (1) the coarseness of the sand particles and their shape, (2) the amount of bonding material and its nature, (3) the moisture in the sand or its temper, and (4) the density of packing.

Standard Permeability Test

The standard test recommended for testing the permeability of molding sands by the American Foundrymen's Association and by which the Wisconsin sands were tested consists of measuring the flow of air through a standard specimen of sand whose water content is known and which has been rammed or tamped to a certain density. The sands are tested at several water contents in order to determine the water content at which the maximum permeability is developed. Core and steel sands are tested dry because in this condition their permeability is nearer to that which is actually encountered in service. Devices have been suggested for testing the permeability of the face of the mold and baked cores, but these have not been standardized and at present are used only in a few foundries.

The American Foundrymen's Association permeability test is becoming more and more widely used for the control of sand mixtures and heaps in the foundry. In control work the foundry foreman knows the condition of the sand in his heap which is

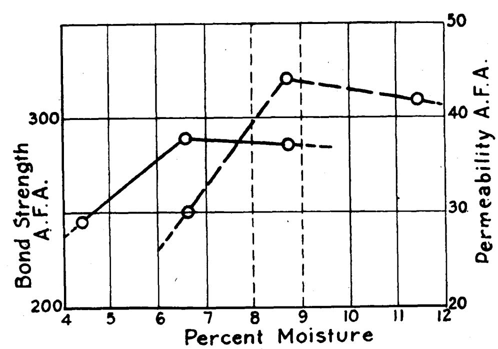

Figure 3.—Plot showing the best working range of a tested sand.

giving the smallest losses in castings. These conditions can be put on a quantitative basis with the tests and kept there by daily control tests. A number of foundries are now using American Foundrymen's Association tests as well as some other special ones for daily control purposes and have found that it is well worth while. For foundries which are running control work, the selection of new sand is an easy matter. As the sand is received, it is given the fineness, permeability, and bond strength tests at several different moisture contents. The results may be plotted, figure 3. This figure shows at a glance that the best working range for this sand is with moisture contents between 8 and 9 per cent. The limits of the working range could be broadened by the individual foundry, if it seemed best to work it on the wet side of the curve to obtain the greatest permeability.

Relation of Permeability to Grade

The relation of permeability to grade is only a general one and up to the present time molding sands have not been graded according to permeability. It is not entirely impossible to grade sands by their permeabilities, but the author believes that since the relation between grain size and permeability is so general, it is best to neglect it at this time. He suggests that producers of sand furnish at least the maximum permeability and if possible the range of permeability shown by the sand at different moisture contents. Columns 1, 23, 24, and 30, Table IV (pp. 78–91) give the laboratory number of the sands, the per cent moisture, the permeability, and base permeability of the sand for which it has been obtained.

Base Permeability

Procedure for test.—The test for base permeability has not been recommended as yet as a standard one by the American Foundrymen's Association. The molding sands collected during this investigation have been subjected to the following test. A sample of the sand to be tested has its clay substance separated after the manner usually followed in making a fineness test. The permeability of the clay-free sand is then determined dry (column 30, Table IV, pp. 78–91).

Value of the Data

It has been found by H. W. Dietert in the foundries of the United States Radiator Corporation that the permeability of the new sand gives no indication of the permeability of the sand after it is partially burned in the heap. He, therefore, feels that the base permeability is of utmost importance because by this data the permeability of sands may be compared under like conditions. Dietert[1] further says, "Some high clay sands are dense due to the amount of clay they contain. If natural permeability is the only consideration given, we would class these sands as closing up sands for heap sand, while in reality they may have an

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[1] Dietert, H. W., Commercial application of molding sand testing: Trans. Am. Foundrymen's Assoc. vol. XXXII, pt. 2, pp. 31–32, 1925.

open grain structure which would be shown in the base permeability reading. When the clay content of this sand is reduced by mixing in the heap its open grain structure would act as an opener."

Strength Tests

General Statement

The nature of the bond of molding sands is a much debated question at the present time. The bond of a molding sand is sometimes divided into two kinds, known as (1) mobile, and (2) static. The mobile bond is considered by some investigators to be composed of actual clay substance which is probably of a colloidal or a semi-colloidal nature. This kind of bond is of such a nature that it can be readily washed off the grains, whereas the static bond is not removed from the grains with ordinary washing. The clay content of the molding sands as determined by the American Foundrymen's Association fineness test is in general an indicator of the bond strength of the sand, figure 4.

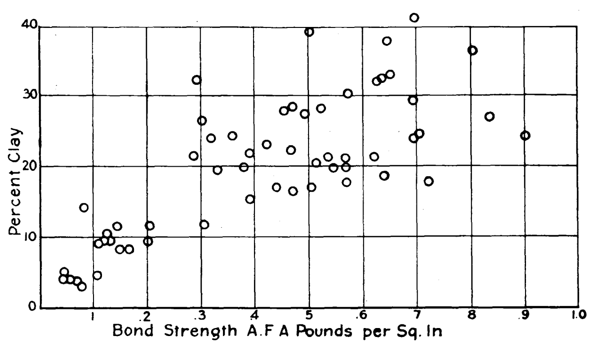

Figure 4.—Plot showing the relation between the percentage of clay and bond strength.

This figure shows that there is a general relation between the bond strength and the per cent of clay in the sand. The per cent of clay in the sand, however, does not give us any accurate measure of the bond strength. The author holds the opinion, as do many others, that some of the material determined as clay is very fine silt and adds very little if anything to the bonding strength of the sand.

Bar Strength Test (Doty Method)

The bonding strength of the Wisconsin sands was determined at several different moisture contents in order to find the maximum, columns 25 and 26, Table IV (pp. 78–91). This test is made by molding the sand of standard composition into a bar 16¾ inches long, 1 inch high, and 2 inches wide, which is pulled forward over an overhang at the rate of 6 inches per minute. The bar is allowed to break at the overhang and the weight of the breaks is a measure of the bonding strength of the sand. The breaks of an individual bar must not vary more than 10 per cent from the average and the average of each bar must not vary more than 5 per cent from the average. This method of expressing the results is sufficient for comparison of different results obtained from this test alone. It is the author's wish to compare the results of this test with the results of the compression and tensile tests which have been made on some of the sands. In order to do this it was necessary to convert the results which had been obtained in grams per break to pounds per square inch units. The author was very fortunate in getting T. C. Adams to develop a formula for this conversion. The formula is as follows:

$$P = 0.0000565 \times W^2$$

in which W equals the weight of the breaks in grams, and P the stresses in pounds per square inch.

Compression Strength Test

The compression test[1] measures one of the simplest stresses which can be determined and one to which the green sand mold is frequently subjected. The sample used for this test is the same size and shape as the one used for the permeability test. The machine on which these tests were made is one designed by T. C. Adams and built at the shops of the College of Mechanical Engineering at Cornell University. The results of this test are read directly from the machine in pounds force or in pounds per square inch units, column 27, Table IV (pp. 78–91).

Tensile Strength Test

The tensile strength test measures a simple stress and one to which a mold may be often subjected. The American Foundrymen's Association has tentatively adopted a tensile test as standard and has recommended the form of apparatus to be used. The general practice among foundries and sand-testing laboratories which are testing this property is to use a metal cylinder which is similar to the permeability cylinder in

[1] This test has now been adopted as standard by the American Foundrymen's Association.

dimensions and cut in half at the mid point of the two inch sand sample. The two parts of the cylinder are clamped together and the sand rammed in as is done for the permeability test. The bottom of the cylinder is attached to the base of the machine or laboratory table and a lid is attached to the top of the cylinder which in turn may be connected to a shot can by a thin wire over a series of pulleys or one large pulley. It seems that a long direct pull on the top half of the cylinder will give the most consistent results. The results for this test may be expressed in pounds force or pounds per square inch units as in the compression test. The results of the American Foundrymen's Association bond strength and compression tests, and the tensile tests are given in columns 25–28, Table IV (pp. 78–91).

Comparison of Different Bond Tests

The data taken from the American Foundrymen's Association bond test, the compression test, and the tensile test were calculated to pounds per square inch units in order to facilitate plotting on the same set of coordinates. It might be supposed that the characteristic curve for each test obtained by plotting the stresses in pounds per square inch units against moisture content would agree. This, however, is not true. In 50 per cent of the sands examined in this way the maximum bond strength (American Foundrymen's Association), compression, and tensile all fell at the same water content. In 20 per cent of the sands the peaks of the compression and tensile curves seem to agree. In 15 per cent of the sands there was a disagreement between all the peaks of the curves for the three tests. In the remaining 15 per cent of the sands there was an equal division between agreement of the curves for the bond (American Foundrymen's Association) and compressions tests, and for the curves of the bond (American Foundrymen's Association) and tensile tests. The conclusions which may be made from these facts are rather unsatisfactory because no one type of sand is in the majority and it seems to the author that the agreements noted are probably a coincidence rather than the fact that the sands are following any special law. The sands whose curves show agreement between compression and tension amount to about 70 per cent of the sands examined. The nature of the bonding material and the shape of the grains in these sands must be similar. This relation also shows that a better agreement may be expected from these tests than from any combination of them with the bond test (American Foundrymen's Association).

Dye Adsorption Test and Its Value

The dye adsorption test as recommended by the American Foundrymen's Association for the test of molding sands has been run on the samples collected for this investigation, and the writer is indebted to W. M. Saunders of Providence, Rhode Island, for the data. The test is designed to show in a quantitative way the clay substance in the sand. The dye used for the adsorption by the sand is an acid one (crystal violet) and is absorbed readily by basic colloids. If all the colloids present were basic colloids, the test at least would show this fact. Up to the present time no work has been done to show the exact nature of the colloids in molding sands; consequently the test is of little value as an indicator of the real bond in the sand. The test is supposed by some workers to be an indication of the surface area of the particles in the sand. Sands containing an appreciable amount of the fine material would adsorb a greater amount of dye and not indicate the bonding power of the sand because this fine material is usually considered inactive as a bonding medium. The test, however, does have some practical application. A core sand that has a high dye adsorption figure should be avoided because it probably would need a great deal more core oil than the ordinary sand. A foundry which desires to use the dye adsorption test as an indicator of the bonding strength of the sand will ordinarily meet with fair success. To apply the dye adsorption test to a series of sands such as those collected for this investigation with the aim of showing that the test has any direct relation to the bonding strength is almost impossible. The author has attempted this and found that the relation between clay substance or maximum bond strength and dye adsorption is only a general one. The dye adsorption figures are given in column 29, Table IV. (pp. 78–91).

Mineralogical Analysis

When it is possible to make a mineralogical analysis of the washed grains of the molding sand under a microscope, many interesting things can be determined. Quantitative mineral counts may give an indication of the refractoriness of the sand. A sand whose grains are composed principally of the mineral quartz would be the most refractory not considering the chemical composition and the amount of bonding material. As has been mentioned, a study of the shape of the grains is an important factor in molding sands as well as in blast sands.

Chemical Analysis

If a complete chemical analysis of a sand that is being used for foundry work is available, several things of interest may be obtained from it. If, for example, it is known from a mineral analysis that the grains are composed chiefly of the mineral quartz, then the other oxides present in the analysis must be found in the bond. If of the oxides present, alumina were the chief or only one, the sand would be quite refractory. If, however, the oxides of the alkalies such as potassium, sodium, calcium, or magnesium or even iron oxide are present in sufficient amounts to act as fluxing agents on the other materials, the sand will probably scab or burn on and give trouble in the cleaning room. The presence of lime in the molding sand is usually regarded with some disfavor, but it is a question how much of this material will really put a sand in the worthless class.

Life Test

There is as yet no accepted test for determining the life of a molding sand. It depends on several things, the principal one of which is the ability of the colloids present in the bond to rehydrate after they have been subjected to the heat of the molten metal in the mold.

Refractoriness

By refractoriness is usually meant the ability of any material to withstand heat without breaking down. In a molding sand it is usually considered as the temperature at which the sand fails by fusion. The property of incipient fusion may be measured by making a small brick of the sand to be tested and supporting this in a furnace on two sharp edges. The temperature at which the bar sags is the temperature of incipient fusion. This test is sometimes known as the sagging test. To test complete fusion a cone of the sand is heated and the temperature at which the cone bends over until the tip touches the base is the temperature of complete fusion. A molding sand which fails in either of the above mentioned tests below 1300° C., the usual temperature at which iron is poured, will give trouble in the foundry. If the sand fails below this point, it will surely scab on to the metal. A sand or clay to be used in steel molding should not fail below 1500° C., the usual temperature at which steel is poured. From some uncompleted research which the writer is carrying on, it seems that the amount of clay and the chemical composition of the clay are the principal factors controlling refractoriness.

CHAPTER II

GEOLOGICAL OCCURRENCE OF WISCONSIN MOLDING SANDS

Geological Formations

The formations which produce foundry materials in Wisconsin may be divided as follows: (1) bed rock, (2) glacial, and (3) recent.

The bed rock deposits may be further divided according to their geologic age. The youngest formation producing core or steel sands is the St. Peter sandstone of Ordovician age. The oldest sandstone formation is generally referred to as the Cambrian. This system has been subdivided in Wisconsin, but the general term will serve for this work.

As the glacial deposits are the most important producers of molding materials, a short glacial history of Wisconsin will be given in order to acquaint the reader with the geological occurrence of this type of formation.

During the last stages of continental glaciation in North America the ice sheet advanced into southeastern Wisconsin in two lobes which reached as far west as Kilbourn and south into northeastern Illinois. These lobes of ice are generally known as the Lake Michigan and Green Bay lobes because these two natural depressions guided the ice in its south and southwestward movements. These smaller lobes of the great ice sheet scoured the country over which they passed and the evidence of the invasion and the retreat of the ice is clearly visible today. While the glacier stood for some time over the southeastern portion of the state, extensive deposits of outwash material were laid down by the waters issuing from the front of the ice, and during the successive stages of the retreat of the glacier more material was dropped by the melting ice. In many places throughout the state large lakes were formed in front of the ice due to damming of the northeast drainage and also to the ponding of the water coming from the glacier behind material it had already deposited. Such rivers as the Wisconsin, Chippewa, and Buffalo helped to carry off some of the water flowing from the ice front; very extensive deposits of sand and gravel which are now far above the present stream levels are evidence of this fact. The outwash terraces, deposits of glacial lakes, and terraces above the present streams are all important producers of molding sands.

The general distribution of these formations is best shown by Alden on his map of the surficial geology of southeastern Wisconsin.[1] These glacial deposits may then be further divided according to origin and importance as follows: (1) deposits in glacial lakes, (2) terraces above present lines of drainage or along abandoned drainage lines, (3) deposits associated with terminal moraine deposits of the Lake Michigan and Green Bay lobes, (4) terraces of outwash, (5) wind-blown deposits, and (6) deposits of ground moraine.

The deposits of recent age are usually found along the present streams and lakes; the most notable are those along the shores of Lake Michigan.

Origin of Bond in Molding Sands

In discussing the origin of molding sands the principal thing which must be accounted for is the bonding material in the sand. There are two recognized processes by which the clay bond in the sand may originate. (1) It may be deposited as clay with the sand grains. It has been found that the clay content of the sands increases with the distance from shore. This sedimentary process is well illustrated in the deposits at Berlin in Green Lake County. Here the well defined beach ridges which are worked for core sand usually contain less than 5 per cent of clay whereas the flats which represent the bottom of an extinct glacial lake contain as much as 40 per cent clay at a quarter of a mile from the old beach line. The deposits of loess along the Mississippi River are very extensive and some are used as molding sands. The bond in this type of wind-blown deposit is the fine clay substance which was deposited simultaneously with the other materials of the loess. (2) The bond may also develop by the weathering of the original constituents of the sands since their deposition. This process seems to take place best on large flats and is aided to some extent by a covering of vegetation.

In this process the soluble materials are leached out and a residual clay is left as a coating on the quartz grains and as a filling in the interstices. This theory of the origin of the bond

[1] Alden, W. C., The Quaternary geology of southeastern Wisconsin: U. S. Geol. Survey Prof. Paper 106, Pl. III, 1918.

in molding sands was first advanced by D. H. Newland[1] and recently confirmed by C. M. Nevin[2] in connection with his work on the sands of the Albany, New York, district. The molding sands of Wisconsin which may have received their bond in this manner are those which are found on the large outwash flats in the southeastern part of the state. These deposits usually range in thickness from 16 to 20 inches and are underlain by sharp sand. The thickness of the deposit depends on the depth of weathering or the level of the water table for the particular region under discussion.

A combination of these two processes has been recognized as taking place in some of the sands associated with the terminal moraine areas. In these deposits the molding sand is usually found on the sides of the small ridges and knobs which are composed of sand. From a detailed study of these deposits it is found that the molding sand thins out near the top of the ridge or knob and sharp sand or gravel makes up the top. It is the writer's opinion that the bond in the sands of this type of deposit has developed by slope wash during deposition and possibly by some subsequent weathering. Good examples of this are found in the deposits at Kansasville, Racine County; Bassett, Kenosha County; and near Merrimac, Sauk County.

An excellent molding sand has been formed at Mondovi in Buffalo County by the weathering of the very sandy Eau Claire shale. This weathering accompanied by some slope wash has formed large terraces of this material.

Occurrences of Wisconsin Molding Sands

Introduction

The deposits of molding sand which are now being worked in the state as well as the new deposits which were located during the investigation are described by counties. The laboratory number of the sand, the owner and the operator of the deposit are also given. The tests for the sands mentioned in the following county descriptions are found in Table IV (pp. 78–91).

Brown County

At present there is little demand for molding sand in Brown County except at a small foundry of the Jos. F. Rothe Foundry

[1] Newland, D. H., Albany molding sand: New York State Museum Bull. 187, pp. 110–111, 1916.

[2] Nevin, C. M., Molding sands of the Albany district: New York State Museum Bull. 263, pp. 19–20, 1925.

Company in Green Bay. This concern obtains its sand from some small pits on a property about four miles east of the city in sec. 27, T. 24, R. 21 E. The molding sand pit has been very nearly worked out, but it is estimated that at least ten acres of sand still remain. The sand is not uniform and grades vertically into gravel, laterally into a clayey material, and down the slope into an excellent core sand, sample 821 (p. 78). The molding sand, number 820 (p. 78), is equivalent to a 2 of the Albany district and has a very good bond strength and permeability. The property is owned by James Mohn and operated by Joseph Bardouche.

Buffalo County

No molding sand pits are being worked at present in Buffalo County, but two excellent deposits of molding sand were found three-fourths of a mile north of the city of Mondovi. The first deposit is on land owned by W. L. Hauser in sec. 2, T. 24, R. 11 W. three-quarters of a mile north of Mondovi on S. T. H. 37. The second is on properties owned by William Hurtley and Jacob Thorsen in sec. 12, T. 24, R. 11 W. These prospects are not more than three-quarters of a mile from the Chicago, Milwaukee, St. Paul and Pacific Railroad station. The character of the surface indicates that they could be very profitably worked by large machinery. The material seems to occur in two distinct terraces along the old channel of the Buffalo or Beef River. The deposits are not of the typical outwash terrace type but have probably had their origin in the weathering and reworking of the Eau Claire shale which outcrops in this region. The sand samples, numbers 890 and 891 (p. 78), taken from the lower terraces on the Hauser property, vary in texture considerably. They have excellent bonding strength but rather low permeability. The sample, number 892 (p. 78) taken from the higher terrace on the Hurtley property, is very similar to the finer material of the lower terrace. These sands, however, may vary somewhat in texture and may give some trouble in loading to a certain grade. There is enough material present here to make a proposition which would at least stand further investigation and possibly the opening of a pit.

Columbia County

The Pacific Sand Company of Portage, Wisconsin operates a large quarry in the Cambrian sandstone from which they ship a crushed product represented by sample 867 (p. 78) and the quarry run by sample 866 (p. 78). These two samples show little difference in grain size and practically no difference in permeability. Both of these sands show a high percentage retained on the 100 mesh screen. It was hoped that they might prove of value as steel molding sands, but they were too fine in texture for this type of work. They are, however, widely used as core sands. The quarry is located on a spur of the Chicago, Milwaukee, St. Paul and Pacific Railroad in sec. 27, T. 12, R. 9 E.

Along the Chicago, Milwaukee, St. Paul and Pacific Railroad tracks about five miles south of the city of Portage in the SW. 1/4 sec. 27, T. 12, R. 9 E., the Pacific Sand Company operates one of the largest core sand pits in the state, samples 868 and 869 (p. 78). The deposit covers forty to sixty acres and the depth of working is controlled by the level of ground water which is usually twenty or thirty feet below the surface. The topography of the deposit is very undulating and the fact that it extends to such great depth leads the author to think that it is outwash associated with morainal deposits.

In the city of Kilbourn on the property of John Smith in sec. 2, T. 13, R. 6 E. there is a large sand and gravel pit of terminal moraine material which has been used from time to time for core work and as a blast sand. Sample 870 (p. 78) was taken from the bottom of the pit which varies greatly in texture vertically and horizontally. It might also be used as a steel sand. The owner has considered the possibility of classifying this sand by screening, but up to the present time this has not been done.

Any of the round flat topped hills in the vicinity of the village of Lodi could produce a very good steel or core sand from the Jordan sandstone, a division of the Cambrian. One sample, 899 (p. 78), was taken from the top of a hill a half mile west of Lodi station in sec. 28, T. 10, R. 8 E.

Dane County

A new deposit of molding sand was discovered on a terrace above the Wisconsin River about a mile and a quarter northeast of the center of the village of Mazomanie in sec. 10, T. 8, R. 6 E. This sand has a peculiar geologic history. It is found near the junction of Black Earth Creek and the Wisconsin River. The terraces along Black Earth Creek are too silty to form a good molding sand and those along the Wisconsin too sandy, but at the junction of the two streams a natural blending of the two materials forms an excellent sand, 883 (p. 78). The sand is located about one quarter of a mile from a branch line of the Chicago, Milwaukee, St. Paul and Pacific Railroad, and about a mile and a quarter from the main switch of the same railroad in the center of town. The property is owned by Paul Schroeder, R. F. D. 2, Mazomanie, Wisconsin.

On S. T. H. 13 in sec. 26, T. 7, R. 9 E. is a large sand and gravel bank owned and operated by William Keyes. With some care it would be possible to load a core sand for local use. Sample 813 (p. 78), taken from the lower part of the west face of the pit, showed that the material might be considered as a sharp sand of medium texture and good permeability.

The St. Peter sandstone outcrops in a small quarry in the little village of Rockdale in sec. 23, T. 6, R. 12 E. and for many years has been used as a core sand by the Creamery Package Company at Lake Mills and Fort Atkinson. This sand, which is represented by sample 901 (p. 78), could also be used for steel molding, but it will never become important because of its location. The nearest railroad is at London approximately six miles distant. The quarry is owned and operated by Ole Burns of Rockdale, Wisconsin.

Eau Claire County

The foundry materials which are being produced in this county and also unworked deposits of molding sands are found on the high terraces above the Chippewa River. The plant of the Eau Claire Sand and Gravel Company, which is located about three miles southwest of the city of Eau Claire on the tracks of the Chicago, Milwaukee, St. Paul and Pacific Railroad, excavates this terrace material. The plant is equipped with a water separator and a Hummer screen outfit which is capable of producing any texture of sand that the trade may desire. Sample 893 (p. 78) is sold to the trade as a core sand. It is a dry screen sand and is known as No. 40. The No. 30 "Red Flint" blast sand is used widely throughout the state as well as outside of the state. This sand, No. 894 (p. 78), is reddish in color and composed principally of grains of red quartzite. Sample 895 (p. 78) is a very coarse dry screened product which is sometimes used as a blast sand. The waste or slush from the water separation is not used. Testing of a sample of this material, No. 896 (p. 78), shows that it could probably be used as a core sand. It would be possible to obtain this sand for the foundry trade at a very low figure. The range of samples taken at the plant gives some idea of the possibility of the types of sand which it is possible to produce here. The sand represented by sample 893 (p. 78) has not been used as a steel sand, but it is of steel sand grade and should be tried for this work.

On the property of E. B. Robins a mile and a half south of Altoona station on U. S. 53 a very good molding sand of medium grade outcrops. The sample, No. 898 (p. 80), represents the sand which might be produced from this very extensive flat topped terrace.

Fond du Lac County

Just west of the city of Ripon in sec. 20, T. 16, R. 14 E. there are two fairly large quarries in the St. Peter sandstone. This formation in this region is very uniform in texture; a quarry face 25 to 30 feet in height shows little or no variation. As these quarries are not worked continuously, the faces are covered in places with iron stain which would not be found on the fresh face. These quarries were sampled as a possible source of steel sand. The tests on the samples, numbers 851 and 852 (p. 80), show that they are both of steel sand grade. One of the quarries is owned and operated by Miss Lillie Leuck of Ripon, the other, which is directly across the road from the Ripon Limestone Company's quarry, is not being operated at present. A haul of three-quarters of a mile is necessary to get this material to the tracks of the Chicago, Milwaukee, St. Paul and Pacific Railroad. The sand sells for $1.75 a yard or about $1.10 a ton (1924).

Green Lake County

It seems best to discuss the deposits of the Berlin district as a whole because of their similarity in origin rather than to separate the several deposits in Winnebago, Green Lake, and Waushara counties and discuss them individually under county headings.

Before describing the deposits of this district, it seems desirable to discuss briefly the history of glacial Lake Oshkosh[1] which occupied this area. The works cited indicate that this lake was held in on the north by the Green Bay lobe and on the south by hills. During the first stage the lake is supposed to have had a

[1] Upham, Warren, Glacial Lake Jean Nicolet and the portage between the Fox and Wisconsin rivers: Am. Geologist, vol. XXXII, pp. 105, 113–114, 330, 1903. Alden, W. C., op. cit., pp. 324–325. Martin, Lawrence, The physical geography of Wisconsin: Wisconsin Geol. and Nat. Hist. Survey Bull. 36, pp. 285–287, 1916. Thwaites recommends that glacial Lake "Jean Nicolet" be changed to glacial Lake Oshkosh in order to avoid confusion with glacial Lake Nicolet. Thwaites, F. T., Glacial geology of Portage, Waupaca, and Outagamie counties. (Unpublished.)

surface elevation of approximately 840 to 850 feet above sea level and drained south down the Rock River near Fond du Lac. The last stage of the lake is well recorded in the Berlin district, but clear evidence of the first stage at the elevation mentioned was not found. The author feels that there was a still higher stage which is not recorded in the literature, but which is well defined in this region at approximately 900 feet above sea level. More careful work would need to be done in this and adjoining areas in order to establish this hypothesis.[1]

A general relation seems to exist between the deposits in each stage of the lake. This relation simply stated is as follows. The well-defined beach ridges of the glacial lake are core sand producers. At the base of each ridge the molding sands occur and increase in clay content with distance from the beach ridge. The phenomenon is one which might be expected because it is normal for sediments to increase in clay content or fine material with distance from the shore. A very good example of this is seen in the pits of the Nathan Kintz and Company property in the N. ½ of sec. 13, T. 17, R. 13 E. Here the following relation exists: clay content of core sand at top of beach ridge, 0.74 per cent; clay content of molding sand in first foot below the surface 0.2 of a mile from the beach, 4.56 per cent; clay content of molding sand in second foot below surface and about 100 feet farther away from the beach ridge than the last sample, 30.66 per cent; and clay content of molding sand 0.25 of a mile from the ridge, 47.42 per cent. The texture of the sands in the above example varies from the beach ridge to the lake bottom; the sands on the beach are much coarser.

It has been mentioned in the discussion of texture of sands (p. 23) that over 50 per cent of the core sands from this district vary in coarseness only from 1.02 to 1.09. This variation is very small and can be accounted for only by the similarity of origin of all the core sand deposits. The core sands taken from pits which are supposedly at the lowest stage of the glacial lake (800 feet) are listed with their elevation above sea level, coarseness figure, and operator's name. Sample 853 (p. 88) runs a little high in coarseness, but inasmuch as this pit is twelve miles northwest of this general area, slightly different conditions of sedimentation may have prevailed. The beach ridge at Lohrville station where this sample, No. 853, was collected is very well developed.

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[1] Thwaites has also found evidence of this stage.

Sand number	County	Elevation	Coarseness figure	Operator	Page
861	Green Lake	800	1.04	Wisconsin Mineral Mining Company	82
854	Green Lake	820	1.04	Wisconsin Mineral Mining Company	82
855	Green Lake	800–820	1.064	Wisconsin Mineral Mining Company	82
853	Waushara	800	1.15	Wisconsin Mineral Mining Company	88

The core sand produced from the second or 850 foot stage of the lake as recorded in the literature is listed in the same manner

Sand number	County	Elevation	Coarseness figure	Operator	Page
857	Green Lake	840	1.157	Wisconsin Mineral Mining Company	82
829	Green Lake	840	1.072	Wheeler Mix	80
830	Green Lake	840–860	0.964	J. E. Mix Sand Company	80
863	Green Lake	840–860	1.095	Albert Gelhar	82

as above. The difference in coarseness for the sands of this stage may be due to the instability of the lake at this level.

The core sands from the highest stage of the lake (900 feet) are also listed.

Sand number	County	Elevation	Coarseness figure	Operator	Page
850	Green Lake	880–900	1.056	Ted Shier	82
902	Winnebago	900	1.112	Wisconsin Mineral Mining Company	90
856	Green Lake	880–900	0.806	H. G. Baehr and Sons	82
842	Winnebago	920	0.672	Hunt Brothers	90
835	Green Lake	900–920	0.890	Nathan Kintz	80

From the theory proposed for the origin of the sands of this district one might immediately think that further prospecting for molding sand might be made below the 800 foot elevation of the lake. The lake bottom of this stage is very swampy and in many places contains deposits of peat and marl. There are, however, molding sands below the intermediate or 850 foot stage of the lake. The elevations of the pits, coarseness figures, and operators' names are given below. These sands show a very good regularity of grain size.

Sand number	County	Elevation	Coarseness figure	Operator	Page
831	Green Lake	840–860	0.491	J. E. Mix Sand Company	80
833	Green Lake	840	0.506	C. A. Zamsow	80
841	Winnebago	840	0.565	Henry Traugett	88
843	Winnebago	840	0.380	Hunt Brothers	90
845	Winnebago	840	0.581	Hunt Brothers	90
846	Winnebago	840	0.593	Hunt Brothers	90
864	Green Lake	840–860	0.567	Albert Gelhar	82

The molding sands occurring below the highest stage of the lake (900 foot) are the most numerous and best developed of those associated with the different stages of the lake and may indicate a longer life of the lake at this stage. These samples are listed below.

Sand number	County	Elevation	Coarseness figure	Operator	Page
832	Green Lake	860–880	0.377	Nathan Kintz	80
834	Green Lake	860–880	0.853	Nathan Kintz	80
836	Green Lake	860	0.411	Nathan Kintz	80
837	Green Lake	880–900	0.679	F. B. Duberstein	80
838	Green Lake	880–900	0.551	F. B. Duberstein	80
839	Green Lake	900	0.658	Henry Traugett	80
840	Green Lake	900	0.547	Henry Traugett	80
844	Winnebago	860–880	0.596	Hunt Brothers	90
847	Green Lake	880–900	0.660	Ray Otto	82
848	Green Lake	880–900	0.577	Ray Otto	82
849	Green Lake	880–900	0.536	Ray Otto	82

The lists of core and molding sands taken from the different stages of glacial Lake Oshkosh show clearly that the sand deposited during the several stages of the lake had a similar origin. The photograph, figure 5 (p. 41), shows a section of the Samuel Wilcox and Company's pit, which is in a deposit formed at the highest stage of the lake. The section shows the sedimentary laminations of the deposit very well. This deposit has an elevation of 880–900 feet. The photograph, figure 6 (p. 41), shows the same feature in the pit of the Nathan Kintz Company. This pit is also in a deposit formed at the highest stage of the lake at

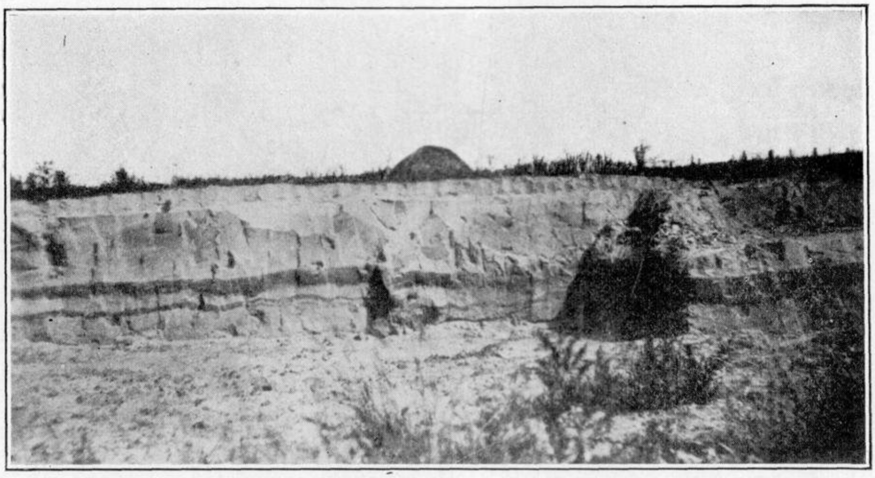

Figure 5.—Section of Samuel Wilcox and Company's pit. SE. ¼ of sec. 13, T. 17, R. 13 E. Berlin district.

an elevation of 860–880 feet. The map, figure 7 (p. 42), shows the distribution of the sands of the district and also the probable shore lines of the glacial lake at its different stages.

The Berlin district is one of the oldest molding sand producing districts in the state, but in recent years the trade has turned from molding sand to core sand. The reason for a shift in the product shipped from this district is not exactly clear. There has been a carelessness in the past in shipping sands which have not been exactly to grade. This fault cannot be blamed entirely

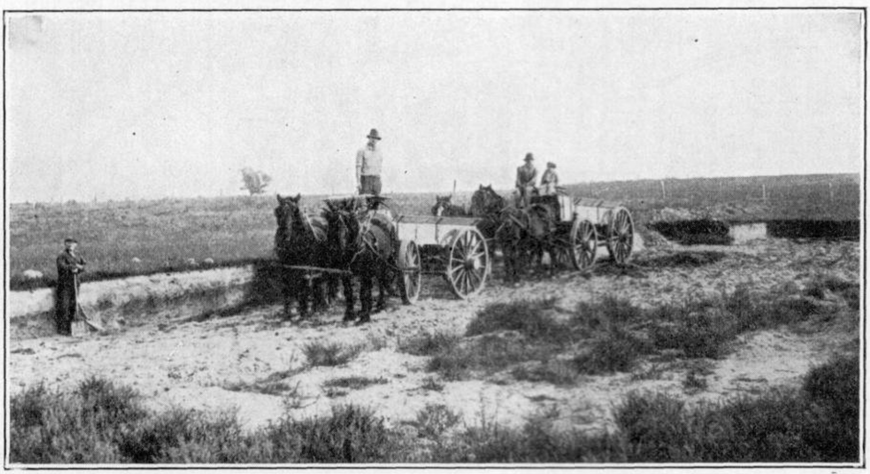

Figure 6.—Nathan Kintz and Company's molding sand pit. NE. ¼ of sec. 13, T. 17, R. 13 E. Berlin district.

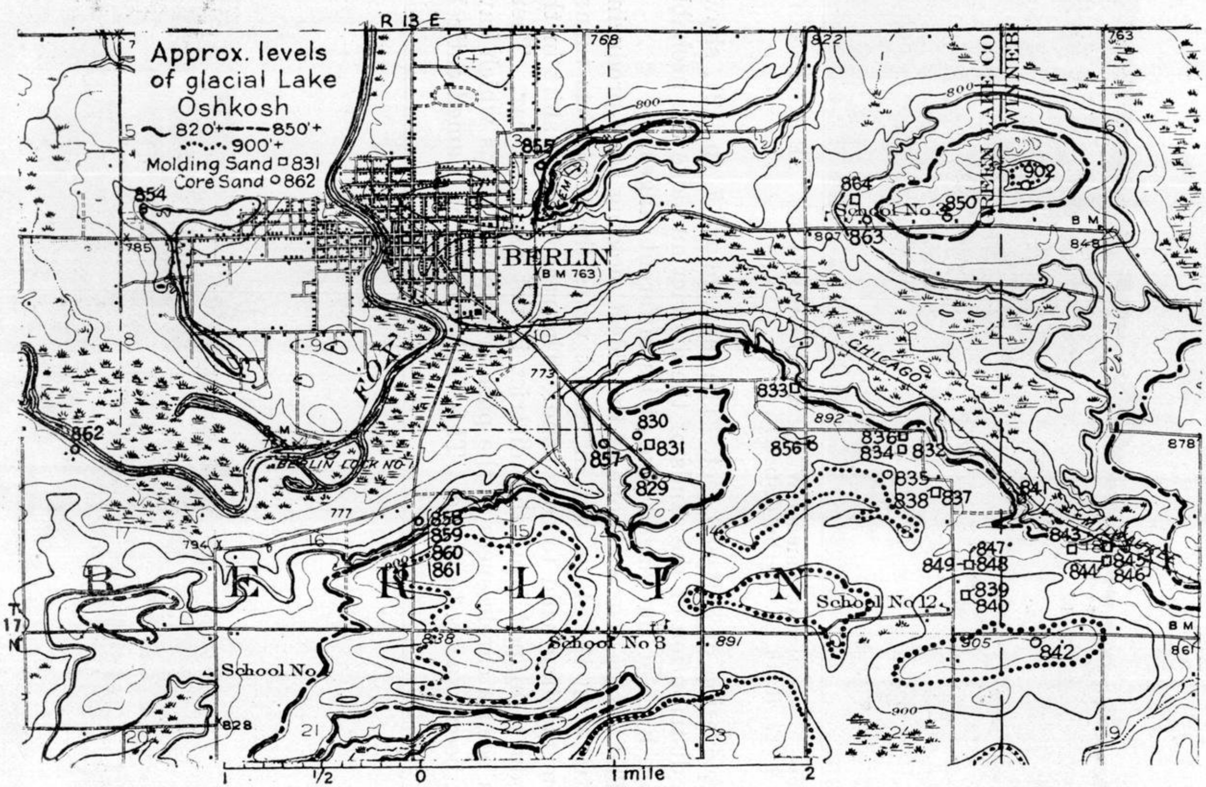

Figure 7.—Berlin molding sand district.

upon the producer because in many cases the foundryman has had no means of checking his shipments except by the feel of the sand which is not entirely reliable. The producers should, however, take great care in duplicating shipments to the same foundry. If this simple rule is followed, there is no reason why the Berlin district cannot be made one of the best molding sand producing districts of the state and hold a good name among the foundries of the state.

The Wisconsin Mineral Mining Company holds two sand properties which do not fit into the genetic classification given for the sands of this district. The first is a deposit of coarse core or steel sand which occurs in a recent terrace above the Fox River in the NW. 1/4 of sec. 17, T. 17, R. 13 E. and is represented by sample 862 (p. 82). It would be possible to load this sand by a conveyor on a small barge in the river and transfer it for shipment to the railroad in Berlin—a haul of about three miles along the river. The second deposit which may prove to be of great worth to the foundry trade in the future is a quarry in the Cambrian sandstone. This quarry is located in the SW. 1/4 of the NW. 1/4 of sec. 15, T. 17, R. 13 E. and is one mile south of a switch on the Chicago, Milwaukee, St. Paul and Pacific Railroad. Three samples were taken from the quarry: sample 858 (p. 82) was taken from a six foot section exposed below the base of the pillars of the storage bins; sample 859 (p. 82) was taken from a three foot section above the first sample; and sample 860 (p. 82) from a twelve foot section recently blasted off above the last sample. As all of these samples are of steel sand grade, it seems that it would be possible to produce a sand which would serve for steel molding. These sands could also be used for making cores.

Steel sand, sample 865 (p. 82) is produced from the St. Peter sandstone by Charles Kuehn at Utley Station. The quarry is located in sec. 36, T. 15, R. 13 E.

Sample 903 (p. 84) represents molding sand from the vicinity of Green Lake, Wisconsin. The sample was submitted by the Wisconsin Mineral Mining Company.

Iowa County

In the vicinity of Arena in sec. 16, T. 8, R. 5 E. on a terrace above the Wisconsin River there are large deposits of what may possibly be core sand. The terrace sand or the dune sands, which are common in this area, might both be used for core work. The sample, No. 884 (p. 84), was taken from the flat topped terrace and from the results of the tests could be used for steel work as well as core work. The deposits are only a quarter of a mile north of the switch on the Chicago, Milwaukee, St. Paul and Pacific Railroad at Arena station.

Kenosha County

A deposit of molding sand very similar to the one south of Burlington in Racine County occurs about a quarter of a mile north of Wheatland station along the Chicago, Milwaukee, St. Paul and Pacific Railroad tracks in sec. 25, T. 2, R. 19 E. Sample 806 (p. 84), which represents the sand taken from this pit and from others in this locality, has been sold for many years under the trade name of "Silvertown Sand." This deposit is part of a large outwash terrace through which the Rock River has cut its way. The sand is very coarse in texture and might be termed a molding gravel. It is an excellent material for making heavy castings. The sand layer is about 18 inches thick and is overlain by a six or eight inch sod and underlain by a sharp sand or gravel. The pit now being worked is on the Richter farm and is operated by the Garden City Sand Company of Chicago. The material is excavated by a trench digger similar to the one shown in figure 8. This method of working a pit is very good for large scale production and also allows the producer to mix sharp sand with the molding sand by adjusting the depth of the digger.

One molding sand pit and one unused deposit were sampled on the property of Ben Elverman near Bassett, Wisconsin. These deposits are on the Chicago & Northwestern Railroad in sec. 13,

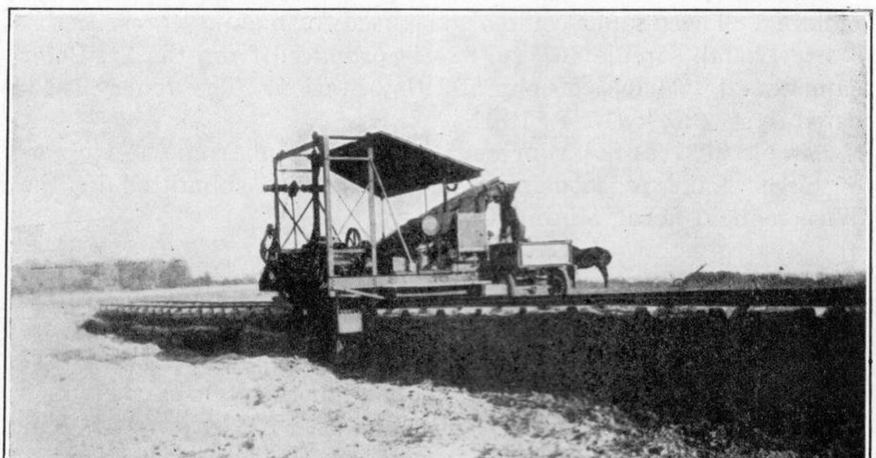

Figure 8.—Trench digger excavating molding sand on an outwash terrace.

T. 1, R. 19 E. The pit which is now being worked has had an origin similar to that at Kansasville in Racine County (p. 47) except that the sand is much finer in texture. The surface geology as mapped by Alden[1] shows 807 to be in the terminal moraine material of the Lake Michigan glacial lobe. The pit which is now being worked confirms this view; the molding sand grades vertically into sharp sand and gravel very rapidly and laterally it changes in texture very quickly. Great care has to be exercised in loading to keep the sand to grade. Most of the sand, sample 807 (p. 84), is fairly fine in texture and is shipped to foundries for making light iron castings.

The topography of the unused deposit directly across the track from the last pit described resembles those at Wheatland and Burlington. The deposit is very flat and, according to the owner who has recently test-pitted it, seems to be very regular in texture. The sample, No. 808 (p. 84), shows that this sand is quite coarse and that it could be used for making heavy castings. It has an excellent bond strength and permeability.

La Crosse County

In the past there have been two producers of molding sand near the city of La Crosse. These were Fred. Ebner and the La Crosse Sand Company. The former is the only producer at present. The silica sand, No. 889 (p. 84), is taken from a quarry in the Dresbach sandstone, a division of the Cambrian. The sample, No. 889 (p. 84), shows that the sand is very uniform but a little too fine grained for steel molding. It would make an excellent core sand.

On this same property molding sand has been produced from very extensive deposits of loess similar to those which are very widespread in the Mississippi Valley. This material, which is represented by sample 888 (p. 84), is exceedingly fine grained, due to its wind-blown origin, and has a good bonding strength but a very low permeability.

Milwaukee County

In the past many small deposits of molding sand have been worked south and west of the city of Milwaukee. As these deposits are entirely worked out, this section was looked into very carefully with a hope of finding new ones. A new deposit was located along the bluffs of Lake Michigan in sec. 13, T. 5, R. 22 E.

[1] Op. cit., Pl. III.

one mile southeast of the center of the city of South Milwaukee. The sand was deposited in glacial Lake Chicago and shows fine laminae. The deposit exhibits the following section:

Light gray clayey sand	2 feet
Clay laminae	2 inches
Light gray clayey sand	2 feet

The deposit extends a quarter of a mile along the lake shore and a similar distance west from the lake.

This sand, which is owned by Caveny & Company, 1026 Milwaukee Avenue, South Milwaukee, is located not far from two factory switches of the Chicago & Northwestern Railroad.

The sample, No. 801 (p. 84), is very fine in texture and has a good bonding strength but a low permeability. It is not used at present for foundry purposes, but could be used for very light castings, possibly for brass or aluminum.

Monroe County

In the city of Sparta one quarter of a mile north of the tracks of the Chicago, Milwaukee, St. Paul and Pacific Railroad and near the west edge of sec. 24, T. 17, R. 4 W. is the Teasdale sand pit which is a possible source of core sand. The material lies in a recent terrace above the La Crosse River. A section of the pit shows the following:

Fine brown sand	3 feet
Coarse sand	3 feet
Brown mottled sand	14 inches
White sand with some glauconite	4–6 feet

The sample, No. 887 (p. 84), was taken from the bottom half of the section. This sand is used for building purposes at present, but could be used for cores if necessary.

Outagamie County

East and west of the village of Hortonville, especially in sec. 34, T. 22, R. 15 E., a very good sharp sand, sample 826 (p. 84), occurs which could be used for steel or core work. The sand occurs in knobs or ridges which resemble dunes; the formation is very extensive in this general area. The grains are composed chiefly of quartz and the sand contains practically no impurities. The sand is very fortunately located along the tracks of the Chicago & Northwestern Railroad and could be easily shipped.

Racine County

About three and one-half miles north of the city of Racine molding sand occurs in connection with a well-defined beach ridge of glacial Lake Chicago. The deposit is on the bluff above Lake Michigan in sec. 17, T. 4, R. 22 E. The pits here are worked for core sand as well as molding sand. The molding sand occurs under a very thin sod cover in the first foot and a half of the deposit. The core sand occurs next below and is taken after the molding sand is removed. The deposit is not very accessible, for it is about one mile east of the tracks of the Chicago & Northwestern Railroad. It can be trucked, however, over a very good road to local foundries in Racine. It is estimated that at least 48,000 tons of sand is still available. This estimate includes core sand as well as molding sand. The pits are owned and operated by H. Gloede, Jr., 2022 North Wisconsin Street, Racine. The core and molding sands, represented respectively by samples 803 and 802 (p. 84), would be classified as equivalent in texture to 1½ and 2 Albany sands. The molding sand shows very good bond strength and permeability for a sand of this grade.

On S. T. H. 120 at Kansasville in sec. 28, T. 3, R. 20 E. about a quarter of a mile north of the Chicago, Milwaukee, St. Paul and Pacific Railroad, a new molding sand pit has recently been opened by the Walsh Sand and Gravel Company of Burlington, Wisconsin. The sand occurs on the edges of a small knoll of ground moraine as mapped by Alden.[1] The deposit has not been completely proven, but it would appear to cover about fifteen to twenty acres. The sample, No. 804 (p. 84), shows that the sand has an excellent feel and the fineness test shows that it compares favorably with a No. 2 Albany sand in fineness. It has a very good bond strength and good permeability as shown by the tests.

About one and one-quarter miles south of the city of Burlington along the tracks of the Chicago, Milwaukee, St. Paul and Pacific Railroad in sec. 4, T. 2, R. 19 E. a heavy grade of molding sand occurs in fairly large quantity. This deposit is a terrace of outwash material similar to many other deposits in this section. The sand, which is represented by sample 805 (p. 84), varies in clay content laterally and is shipped as a cupola clay as well as a heavy molding sand. The molding sand is covered by six to eight inches of sod. The sand is of variable thickness with a maximum of two and one-half feet. An estimate places 40,000 tons of this type of sand available in this immediate vicinity.

[1] Op. cit., Pl. III.

The property is owned and operated by the Walsh Sand and Gravel Company of Burlington, Wisconsin.

Rock County

There are two large producers of molding sand in Rock County, the Northwestern Molding Sand Company whose pits are east of the city of Beloit along the Chicago, Milwaukee, St. Paul and Pacific Railroad tracks in sec. 36, T. 1, R. 13 E., and the Janesville Wisconsin Molding Sand Company, Inc., whose pits are along the Chicago & Northwestern Railroad about five miles northwest of the city of Janesville in secs. 21 and 22, T. 3, R. 12 E.

The deposits at Beloit are mapped by Alden as occurring in terraces of outwash similar to those at Wheatland. A general section of the pits follows:

Overburden	1½–2 feet
Molding sand	4–5 feet
Clay	floor

The overburden is removed by a large two-horse scraper.

The author feels that this is not a true outwash deposit, but that it is instead a terrace of an abandoned channel of the Rock River. The depth of the molding sand allows these pits to be worked by steam shovel, as is shown in the photograph, figure 9.

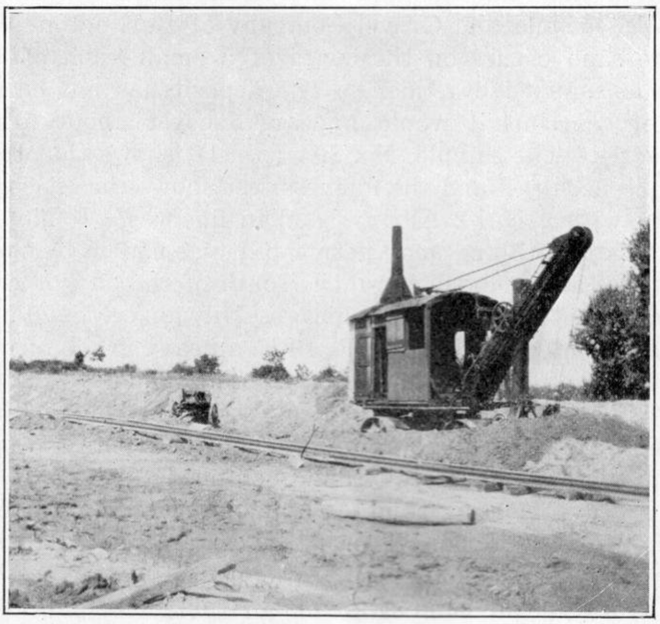

Figure 9.—Steam shovel digging molding sand at the pits of the Northwestern Molding Sand Company. Beloit, Wisconsin.

The sand varies somewhat in texture, for it ranges from a No. 1½ Albany in sample 809 (p. 86) to a No. 2 Albany in sample 810 (p. 86), but varies little in bond strength and permeability.

The pits at Janesville are also mapped as outwash deposits, but they do not resemble the typical outwash. The section in the pit is as follows:

Overburden	½ foot
Molding sand	2–2½ feet
Clay	floor

The samples taken from the different sections of the pit vary in all properties. Sample 814 (p. 86), taken from the west pit, is quite fine in texture and resembles a No. 1 Albany sand. It has a good bond strength and low permeability, which is probably due to the large amount of clay in the sample. The sample, No. 815 (p. 86) taken from the east pit, resembles a No. 2 Albany and has a good bond strength and permeability.

At South Beloit, Illinois, the Guetschow Brothers Sand Company, R. F. D. 1, Box 2, Beloit, operates core sand pits which supply the local trade. The sand, which is represented by sample 811 (p. 90), is taken from pits in small knobs which may be fossil dunes on a high terrace above the Rock River. The sand is dug by hand and hauled by truck to foundries in Beloit, a mile and a quarter distant.

Sauk County

The two principal localities producing foundry sands in Sauk County are: (1) the Ableman district, which is operated by the L. J. Pierson Mineral Company, and (2) the Merrimac district, which is operated by the Walsh Sand and Gravel Company of Burlington, Wisconsin.

The pits in the Ableman district are in the extinct glacial Lake Baraboo. The deposits consist of laminated sands, clays, and silts varying in depth from ten to fifteen feet. A pit has recently been opened in sec. 32, T. 12, R. 6 E. along the tracks of the Chicago & Northwestern Railroad between North Freedom and Baraboo. This pit is worked to a depth of eight feet and shows the following section:

Sod overburden	1 foot
Laminated sand and clay (good molding sand)	5 feet
Laminated sands (good core sand)	3 feet
Clay	floor

Sample 871 (p. 86) was taken from the eight foot face of the pit mixed with a quarter of a shovel of the clay base. This is similar to the sand as it is shipped at present. Sample 872 (p. 86) is a mixture of the sand and clay from the upper five feet of the deposit. The tests indicate this to be a very good molding sand with good bonding strength, good permeability, and a fair working range. Sample 873 (p. 86) was taken from the bottom three feet of the pit and would make a fair core sand. This pit is operated by an electric conveyor which lifts the sand from the floor of the pit to the cars on the siding.

Samples were taken from another pit operated by the L. J. Pierson Mineral Company along the Chicago & Northwestern Railroad tracks one-eighth of a mile north of Ableman station. This deposit has had an origin similar to the last except that the sand here is exceedingly fine and might be considered as a silt. The sample, No. 875 (p. 86), taken from the lower eight feet of this pit, shows a strong lime reaction, and the tests conducted on it in the laboratory indicate that it has a fair bonding strength but an exceedingly low permeability. The extreme fineness of the material may account for these characteristics. Sand 876 (p. 86) is shipped from the upper four feet of the pit as a cupola clay or sometimes as a bonding mixture.

During the war when there was a great demand for steel molding sand near at hand, a quarry was opened in the Cambrian sandstone by the North Freedom Silica Company along the mine switch in sec. 15, T. 11, R. 5 E. two and one-half miles south of North Freedom. The sample, No. 874 (p. 86), shows a very uniform grain structure by the sieve analysis and a fair permeability.

In the Merrimac district the Walsh Sand and Gravel Company has recently opened two large pits which have proved very profitable. Both pits are in the terminal moraine deposits of this area and resemble kames and small outwash terraces in their structure. The first pit is located in sec. 2, T. 10, R. 7 E. and is about a three hundred yard haul from a siding along the Chicago & Northwestern tracks. There are about eight to ten acres of this material with an average thickness of two feet. The sand, No. 877 (p. 86), shows a medium texture, good bonding strength, and fair permeability. Along the edge of this pit a high clay sand represented by sample 897 (p. 88) is produced. It is being used for cupola clay as well as a heavy molding sand.

On property owned by William Taylor about a mile and a quarter northeast of Merrimac station in sec. 35, T. 11, R. 7 E. the Walsh Sand and Gravel Company is producing an excellent sand which corresponds to a 1 Albany in texture and shows good bonding strength and permeability. The deposit was sampled in three places: near the top of the hill, No. 878 (p. 86); six feet down the slope, No. 879 (p. 86); and at the base of the hill, No. 880 (p. 86). The three samples show very little variation in any of the properties tested.

On S. T. H. 23 one and a quarter miles north of Spring Green some possible deposits of core sand occur on the property of R. L. Reymann in sec. 6, T. 8, R. 4 E. These sands have had a peculiar origin which is well brought out by their fineness test. The sands have been blown up from the extensive flats along the Wisconsin River in this area. The first sample, No. 885 (p. 86). was taken from the roadside in front of the Reymann farmhouse. This sample has a coarseness figure of 0.952, whereas the second sample, No. 886 (p. 88) which was taken at an elevation of forty feet below the first, shows a coarseness figure of 1.17. From the coarseness figures it is seen that the finer material has been carried farther up the bluff by the wind. These sands are non-calcareous and are composed almost entirely of quartz grains. They are very extensive along the bluffs in this region. As the two samples indicate, almost any grade of core sand desired could be produced.

Sheboygan County

Sheboygan County is covered almost entirely by red glacial drift which is not a favorable formation for the production of molding sand. Along the shore of Lake Michigan about two miles southeast of the city of Sheboygan in sec. 26, T. 15, R. 23 E. beach sand is being dug and hauled to the Kohler Company at Kohler, Wisconsin. The sand, which is represented by sample 819 (p. 88), is used for cores and a coarser grade is used for blast sand. The sand grains consist principally of white crystal quartz, quartz stained yellow, and some dark minerals. This material occurs at the water's edge and is replenished during storms. It is excavated with a horse scraper.

Walworth County

A new deposit of molding sand was discovered on the farm of C. C. Randolph along the tracks of the Milwaukee Electric Lines in sec. 16, T. 4, R. 18 E. just east of the village of East Troy. This material has had a geologic history similar to that at Wheatland (p. 44). There are at least 20,000 tons of sand available here, and it appears to be an excellent material for making heavy castings. The sample, No. 900 (p. 88), was taken in a roadside cut opposite the farm buildings.

Washington County

About three and a half miles northwest of the village of Barton and in sec. 27, T. 12, R. 19 E. S. T. H. 55 and the Chicago & Northwestern Railroad cut through a ridge of outwash which may be used as a brass or aluminum molding sand. The sample, No. 818 (p. 88), shows that this sand is very fine in texture, has a fair bond strength, and low permeability. The grains are principally fine quartz sand with some lime, as is shown by the acid test in the field. The ridge in which the deposit occurs is about fifteen feet high and seems to be fairly continuous across country. This material could be readily shipped if there is any demand for it.

Waukesha County

There are two excellent deposits of heavy molding sand in Waukesha County, one near Dousman which is now being used, and one new deposit near Oconomowoc. The pits which are now being worked are three quarters of a mile southeast of Dousman and a quarter of a mile south of the Chicago & Northwestern Railroad tracks in sec. 2, T. 6, R. 17 E. The unworked material is two miles southeast of the city of Oconomowoc along The Milwaukee Electric Railway & Light tracks in sec. 17, T. 7, R. 17 E. Both of these deposits are composed of outwash material and are very similar in all their properties to the sand at Wheatland and East Troy. Twenty to twenty-five thousand tons of the Dousman sand similar to sample 816 (p. 88) are still available. About two hundred carloads of this sand are shipped to the Allis Chalmers Company of Milwaukee yearly. The sand is used for very heavy floor work. The sample, No. 817 (p. 88), taken near Oconomowoc, represents a sand which could also be used for this type of work.

The method of operating the pits at Dousman is very characteristic of the manner in which most of the farm molding sand pits are worked on a small scale. The sod overburden is removed by hand shovel and thrown into the portion of the pit from which the molding sand has already been removed. The sand is shoveled by hand into dump wagons. The photograph, figure 10 (p. 53), shows a section of the pit at Dousman. The sand has been removed in the foreground and the bottom of the pit covered with the overburden.

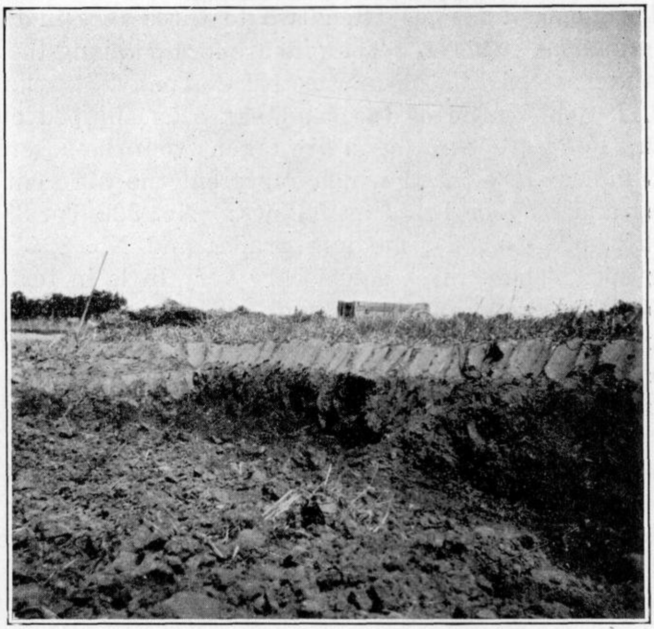

Figure 10.—Section in molding sand pit at Dousman. Shows method of working.

Waupaca County

Sample 827 (p. 88) is from a kame in sec. 6, T. 22, R. 15 E. which is owned by the Green Bay & Western Railroad Company. Sample 828 (p. 88) is from a stream terrace in sec. 26, T. 23, R. 11 E., 1½ miles south of Scandinavia.

Waushara County

The deposit of core sand at Lohrville station, sample 853 (p. 88), which is operated by the Wisconsin Mineral Mining Company was described under the Berlin District in Green Lake County because of its similarity of origin with these deposits (pp. 38–39).

Winnebago County

One mile west of the city limits of Neenah in sec. 29, T. 20, R. 18 E. there are several pits of molding and core sands which have been worked for many years. Most of the sand taken from these pits is used by the Neenah Foundry Company and foundries in the immediate vicinity. The sand occurs in an area of slightly undulating ground moraine which has been modified by lake action. This deposit ranges from two to three feet in thickness and covers about 30 acres. The pits are located along the electric line of the Eastern Wisconsin Electric Company's tracks (abandoned 1928), but none of the sand has been shipped over this railroad. Four grades of sand are taken from the several small pits. Samples were taken which represent the different grades produced and may be listed as follows: No. 822 (p. 88), light grade; No. 823 (p. 88), medium grade; and No. 824 (p. 88), heavy grade. These three sands vary very little in texture and would be considered as 0 to 1 Albany. The tests show also only a slight variation in bond strength or permeability among the different grades. Sample 823 represents one which is hauled for a medium strength sand, but it has the greatest strength of the three samples taken. Core sand similar to sample 825 (p. 88) underlies nearly all of the molding sand. The pit was not opened enough to determine any variation in texture of the core sand, but it would probably show some variation. The pits are owned and operated by Ben Shultz, R. F. D. 9, Neenah, Wisconsin.

The pits of the Hunt Brothers (samples 842–846, p. 90) near the western line of the county, one pit operated by Henry Traugett (sample 841, p. 88) and one operated by the Wisconsin Mineral Mining Company (sample 902, p. 90) have been described with the Berlin district deposits in Green Lake County because of the similarity of their origin (pp. 39–40).

Illinois

Sample 812 (p. 90) is used by the Fairbanks Morse Company at Beloit. It was collected at their bins to compare with Wisconsin sands. Sample 881 (p. 90) known as No. 5 Blackhawk and 882 (p. 90) known as Hardware were also collected for comparison. All three sands are produced at Rockton, Illinois.

Sample 811 (p. 90) from South Beloit, Illinois is discussed under Rock County (p. 49).

SUMMARY

The sands used for foundry purposes in Wisconsin are found principally in glacial deposits although some of the materials are taken from the consolidated bed rock formations which outcrop in many places throughout the state. The finer textured molding sands as well as those used for cores are found associated with the material which was deposited in glacial lakes. The largest deposit of sand which has had this origin is found in the

Berlin district in Green Lake, Winnebago, and Waushara counties. Other fine textured sands are produced from deposits associated with terminal moraine materials in Dane, Sauk, and Columbia counties. The coarser molding sands, which sometimes are termed molding gravels, seem to be concentrated in the large outwash terrace deposits of the southeastern counties of the state and are worked principally in Waukesha and Racine counties.

The sandstones which are possible sources of steel molding sands outcrop in a belt which starts in Fond du Lac County, swings southwest through Green Lake, Columbia, and Sauk counties, and then northwest through La Crosse and Buffalo counties. These sandstone formations are not all of the same age, but the product which it would be possible to produce from them is quite similar. The sand from the St. Peter formation is in general slightly too fine for steel molding, but makes an excellent material for cores. The sandstones of Cambrian age, which were sampled over the state, are pure quartz sands and generally have a texture which is very desirable for steel molding.

If the original purpose of this investigation is to be accomplished, some suggestions in regard to the future of the molding sand industry in the state must be made. Future prospecting should follow along these somewhat general lines with Alden's[1] map as a guide. Outwash terraces, or sand plains as they are sometimes called, should be thoroughly investigated as a source of coarse molding sand, and the glacial lake deposits of the Berlin district should be more thoroughly gone over as sources of fine molding sand and core sands. The outcrops of Cambrian sandstone, where they have been sampled for this investigation, have been shown to be of steel sand grade. These formations should be carefully investigated by steel foundries or producers of steel molding sand as possible local sources of this type of material.

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[1] Op. cit., Pl. III.

List of Producers

The molding sand producers of the state are listed alphabetically below:

Producer	Location	Sample number
Baehr, H., and Sons	Berlin	856
Bardouche, Joseph	Green Bay	820 821
Burns, Ole	Rockdale	901
Caveny and Company	South Milwaukee	801
Duberstein, F.	Berlin	837 838
Eau Claire Sand and Gravel Company	Eau Claire	893 894 895 896
Ebner, Fred	La Crosse	888 889
Elverman, Ben	Bassett	807
Garden City Sand Company	Wheatland	806
Gelhar, Albert	Berlin	863 864
Gloede, H., Jr.	Racine	802 803
Guetschow Bros.	South Beloit	811
Hunt Bros.	Berlin	842 843 844 845 846
Janesville Wisconsin Molding Sand Company	Janesville	814 815
Keyes, William	Madison	813
Kintz, Nathan, Sand Company	Berlin	832 834 835 836
Kuehn, Charles	Utley Station	865
Lange, Otto	Sheboygan	819
Lueck, Lillie	Ripon	851 852
Mix, J. E., Sand Company	Berlin	830 831
Mix, Wheeler	Berlin	829
Northwestern Molding Sand Company	Beloit	809 810

Producer	Location	Sample number
Pacific Sand Company	Portage	866 867 868 869
Pierson, L. J., Mineral Company	Kirkwood	871 872 873
	North Freedom	874
	Ableman	875 876
Schier, Ted.	Berlin	850
Shultz, Ben.	Neenah	822 823 824 825
Smith, John A.	Kilbourn	870
Traugett, Henry	Berlin	839 840 841
Wachsmuth, Christ.	Dousman	816
Walsh Sand and Gravel Company	Burlington	805
	Kansasville	804
	Merrimac	877 878 879 880 897
White and Traugett, Ray Otto, Manager	Berlin	847 848 849
Wisconsin Mineral Mining Company	Berlin	854 855 857 858 859 860 861 862 902 903
	Lohrville	853
Zamsow, C. A.	Berlin	833

CHAPTER III

A STUDY OF THE REFRACTORINESS OF MOLDING SANDS

Object of the Investigation

It is a well known fact that molding sands vary in refractoriness. This phenomenon has never been well understood. It is the purpose of this part of the report to review some recent work which seems to indicate the causes for the variation in refractoriness of different green molding sands. It is hoped also to devise some test by which the variation in this property in different sands may be detected.

Economic Importance of the Work

Sands are used which are not refractory enough for the type of work in which they are employed. These sands cause troubles in casting which are known to the foundryman as scabbing, sand-stick (an English term), burning on, and washing in the mold. Scabbing or burning on shows that the sand on the face of the mold has fused and on cooling has adhered to the iron or steel on the face of the casting and remained there after the casting has been knocked out. This scabbing causes difficulties in the cleaning room and thereby increases the cost of the casting.

Certain sands wash in the mold. This action may take place when sands of low refractoriness are used. In this case the molten iron or steel fuses with the clay of the molding sand on the face of the mold while the metal is running through. This action has a tendency to pull the mold to pieces or cause it to "wash". This difficulty is much more serious than the first because the casting may be filled in places with the sand material. When the casting is shaken out and cleaned, holes develop.

Previous Work of the Same or Similar Nature

There seems to be a scarcity of literature on the subject of the refractoriness of sand-clay mixtures or molding sands. The United States Bureau of Mines Laboratory at Columbus, Ohio, has undertaken a study of the refractoriness of a selected group of sands furnished them by the American Foundrymen's Association. This investigation has not been completed as yet, but a preliminary statement of progress by G. A. Bole[1] gives some interesting information. The sands, as well as the bonding clay, were tested at different temperatures in varying atmospheres. It was found from an inquiry to the foundry trade that the conditions under which a sand is used are usually reducing, but the exact amount of reduction was not determined. The effect of reducing and oxidizing conditions on the softening points of the clays and sands was found to be quite marked, and also dependent upon the different fluxes present. It was found that bloating took place in high iron sands and clays under reducing conditions. It was also found that the effect of oxidizing versus reducing conditions could not be measured by cones in the sands which were high in silica. In the case of high iron sands, the difference was as much as four Seger cones, and moderate reduction seemed to lower the softening point more than did extreme reduction.

A very extensive work by A. L. Curtis,[2] Chatteris, England, gives a method by which the refractoriness of sands, clays, or any finely divided material may be obtained. During the development of this method a micro-telescope was designed and built by which the test specimens could be studied or photographed while they were being heated. The specimens were arranged in small fire clay troughs which were mounted on a moving platform in order to move them without handling into the field of the telescope and under the flame of the oxy-coal gas blowpipe. Seger cones were used to determine the heat of the blowpipe, and after a certain heat was established, it was kept constant by pressure gauges in the gas lines supplying the blowpipe.

The investigation was made on naturally-bonded English and Belgian steel sands and on certified steel sand mixtures obtained from English and American foundries.

The results do not seem very conclusive from a general standpoint as no definite conclusions were made in regard to the exact mixture which would give certain refractoriness on service. The data concerning the local English steel sands should be of great interest to the English steel foundries.

METHOD OF MAKING TESTS

In this work there are two properties of clays or sand-clay mixtures which depend directly on the refractoriness. The prop-

[1] Personal communication.
[2] Curtis, A. L., Steel moulding sands and their behavior under high temperatures: Carnegie Scholarship Memoir, 1925.

erties are softening temperature and fusion temperature. The first property has been studied by two methods, by noting the amount of bending in cones made of molding sand and artificial sand-clay mixtures which were set upright in a gas muffle furnace, and also by noting the relative amount of bending during firing in the same type furnace of bars supported on fire clay knife edges. The property of fusion has been tested by noting the temperature at which the cone turned over or its tip touched the base.

The temperatures of the furnaces were recorded by means of a Platinum-Platinum Rhodium thermocouple. Records were kept of every run of the furnaces in order to have the rise in temperature of the furnace for each run kept as near constant as possible. It was found by plotting the furnace characteristics, time against temperature for different runs, that only slight variations in these curves were noted above a temperature of 1000° C., which was in the working range of the experiments. The tests were conducted at temperatures between 1000° C. and 1510° C. which was about the highest temperature that could be obtained with the furnace used.

It was impossible to study the exact atmospheric conditions in the furnace because of the lack of equipment and the type of furnace used. The furnace, however, was run at what from the color of the gas flames seemed to be oxidizing conditions. The author realizes the importance of the study of the composition of the furnace gas, as has been brought out by the work recently done by the United States Bureau of Mines Laboratory at Columbus, Ohio.

Experiments With Artificial Sand-Clay Mixtures

Sand

A sand as nearly pure in silica as possible was selected because this would give a standard reaction of the fluxes present in the clay with the silica grains. The sand selected is a product produced by the Pennsylvania Glass Sand Company principally for the glass sand industry. It was thought that this would insure its purity. The formation from which this material is obtained is known geologically as the Oriskany. It occurs very extensively in the Appalachian Mountains and is quarried and crushed in the states of Pennsylvania, Maryland, and Virginia.

As a matter of record, a complete sieve analysis of the silica sand is given. This analysis was made by shaking the sand through a standard nest of sieves for thirty minutes in a Ro-Tap machine.

	Weight retained Per cent
On 6	----------
On 12	----------
On 20	0.40
On 40	13.58
On 70	69.84
On 100	15.88
On 140	0.90
On 200	0.08
On 270	----------
Pan	----------
Total	100.68

This sand would make an excellent steel sand and shows a coarseness figure of 1.523 (pp. 16–18).

A microscopic study of the separates of the screen analysis to detect any mineral other than quartz in the sand and also the shape of the grains gave the following general results. The grains are primarily colorless to white crystalline quartz. In the material retained on the 200 mesh screen an estimate of about 5 per cent of foreign material was found, which consisted of dark brown to black rock and mineral fragments. This portion is so small, considering the amount retained on this screen; that it could hardly be expected to alter the complete chemical analysis of the material. From the mineralogic analysis of the grains it is judged that the sand contains between 98 and 100 per cent of SiO_2.

The grains are dominantly sub-angular to angular; only a few of those retained on the 40 and 70 mesh screen show rounding. An interesting relation exists between the nature of the grains and the screen sizes. On the 20 and 40 mesh screens many compound grains made up of quartz crystals were noted whereas on the finer screens these were absent. The crushing has reduced the material on the finer screens to individual grains.

Clay

The clay used in the sand-clay mixtures for this work was a glacial clay collected near the village of Forest Home, about one-quarter of a mile east of the limits of the city of Ithaca, New York. The origin of the material is very evident from its mode of occurrence. It is a boulder clay of glacial origin and contains many pebbles of shale, sandstone, and in some cases fragments of limestone.

In its raw condition it could hardly be used for making sand-clay mixtures because of the impurities, such as pebbles and organic matter, which are present. The raw clay was first dried, then finely ground and washed. The washing was accomplished by flotation; the clay was allowed to settle in a large tank from which it was recovered, dried, and ground again before using.

Before moistening in the mixture this material is a light yellowish brown color. After slaking in water a sample of the clay was washed through a 200 mesh screen and left but 1.25 per cent residue. It can be concluded then with fairness that at least 98 per cent of the clay has acted as a bonding medium in the mixture.

This clay, as well as several others extracted from the molding sands, was fired in cones at different temperatures. The glacial clay at cone 4 (1210° C.) showed no signs of fusion or bending and burned a pinkish red color. At cone 9 (1310° C.) fusion had commenced and the cone was slightly bent. At cone 11 (1350° C.) the clay fused completely and the tip of the cone touched its base. It was light brown in color and had a vitreous luster on the outside. Inside it showed an exceptionally dense structure, was greenish in color, and resembled the igneous rock pitchstone except that it was not mottled.

The following chemical analysis of the clay was made in order to study the relation between its composition and fusion temperatures. This subject will be discussed more in detail later.

FOREST HOME CLAY

SiO_2	66.08	Analysis by G. W. Cavanaugh
Al_2O_3	17.50	
Fe_2O_3	8.00	
CaO	1.00	
MgO	1.58	
Loss on ignition	4.62	
Total	98.78	

If the undetermined material in the chemical analysis just given is considered as alkali or fluxing material, it will be noted that there is present 3.80 per cent which may be considered as a flux. This figure includes the Ca0, 1.00 per cent; Mg0, 1.58 per cent; and material not determined, 1.22 per cent. This clay fused completely at cone 11 (1350° C.) as has been noted and is therefore classed as a grade B clay according to its refractoriness.

Sand-Clay Mixtures

The sand and clay just discussed have been mixed in the following proportions:

Clay Per cent	Sand Per cent	Clay Per cent	Sand Per cent
10	90	35	65
20	80	40	60
25	75	50	50
30	70		

Two hundred grams of each mixture was made up, placed in an iron mortar, and mulled dry with an iron pestle for 5 minutes, tempered to a good feel with water, and then mulled for 10 minutes. With the exception of the mixture which contained 10 per cent clay, this process gave products which resembled a natural molding sand to the feel of the thumb. The mulled sand as it was taken from the mortar was rammed into a small box mold (fig. 11), which gives a bar 3 by 1½ by ¼ inches. The mixture

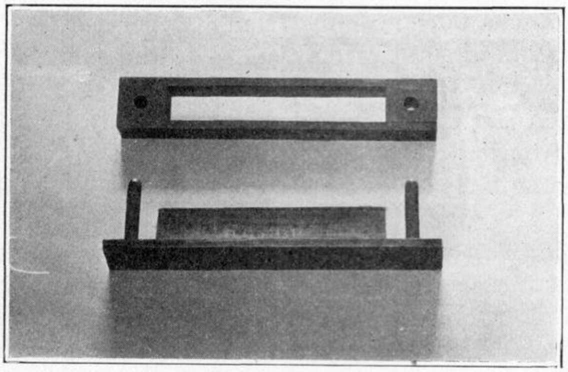

Figure 11.—Box used in bar test.

was then tempered almost to a mud in order to mold the cones for testing. The bars and cones were both allowed to air dry completely before firing.

The fineness data of these mixtures were calculated from that obtained from the tests on the sand and clay alone and are listed below. For this calculation the clay material retained on the 200 mesh screen is distributed equally on the 5 screens with larger mesh openings than the 200 mesh, and the clay which washed through the 200 mesh screen is divided equally between the 270 mesh screen and the Pan. These amounts can both be considered as active bond because there was no material retained on these screens in the sand.

	Screen size	Clay 10 per cent	Clay 20 per cent	Clay 25 per cent	Clay 30 per cent	Clay 35 per cent	Clay 40 per cent	Clay 50 per cent
	6							
	12	-------	--------	--------	--------	--------	--------	--------
	20	0.36	0.32	0.30	0.28	0.26	0.24	0.20
	40	12.25	10.93	10.29	9.62	8.96	8.31	6.99
	70	62.84	55.88	54.52	49.02	45.44	42.06	35.11
	100	14.34	12.78	12.00	11.22	10.45	9.70	8.14
	140	0.81	0.80	0.78	0.75	0.73	0.70	0.65
	200	0.11	0.14	0.16	0.18	0.19	0.21	0.24
Active bond	270	4.9	9.8	12.25	14.70	17.15	19.60	24.50
	Pan	4.9	9.8	12.25	14.70	17.15	19.60	24.50
	Total	100.51	100.45	102.55	100.47	100.33	100.42	100.33

The calculated analyses given above show clearly the distribution of grains in the mixture and if the amounts retained on the 270 mesh and the Pan are considered as clay, it will be noticed that these amounts vary only from 0.2 per cent to 1 per cent from the actual amount of clay added to the sand in making the mixture.

These mixtures were studied microscopically to determine the actual distribution of the clay after the mixture had been made. The following facts were noted in regard to the different mixtures:

10 per cent clay—90 per cent sand.—There was no regular distribution of the clay in or among the sand grains. None of the grains showed complete coating with clay and only a few showed patches of clay adhering to them. This character seems to be accounted for by the small amount of clay present which in turn accounts for the very poor binding qualities of this mixture.

20 per cent clay—80 per cent sand.—It would be quite natural to expect that a small amount of plastic clay similar to the one used in this mixture would tend to bind the small particles of the quartz sand together and that additional amounts would affect the larger ones. This sequence of events seems to have taken place in these samples, and the first stage is recorded in this mixture. The fine grains adhere to one another and the majority of the larger grains are completely coated with clay.

25 per cent clay—75 per cent sand.—The same thing has taken place in this mixture except that there seems to be a thicker coat of clay which can readily be decreased in thickness by rubbing the grains on paper.

30 per cent clay—70 per cent sand.—This mixture shows a very thick coat of clay and fine sand on the larger grains, and some of the grains show compounding.

35 per cent clay—65 per cent sand.—In this mixture the clay is in excess of the fine sand in the material found coating the grains and many of the grains show compounding.

40 per cent clay—60 per cent sand.—The clay coating of the grains seems to be very strong and the compounding of the grains seems to be much greater, at least there are more grains held together in one compound grain.

50 per cent clay—50 per cent sand.—The grains that show coating are well coated, but relatively there are only a few grains in comparison with the number of fine clay particles around them.

This microscopic analysis of the mixture was made on the dry material and gives a very clear idea of the progressive action of the addition of clay to sand in binding it together. It was hoped to get as even a distribution as possible of the clay about the grains in the mixtures in order to have equal reactions between the clay and the sand in all parts of the cones and bars when the firing tests were made. The microscopic analysis shows that this has been accomplished without a doubt.

Cones

The results of the firing test on the cones of the different mixtures is very well shown in the photograph, figure 12 (p. 66). The cones are arranged from left to right in order of clay content: 10 per cent, 20 per cent, 25 per cent, 30 per cent, 35 per cent, 40 per cent, 50 per cent, and the last small cone on the right is composed of the clay used in the mixture. The cones of the mixtures and clay were first fired at cone 4 (1210° C.). At this temperature none of them showed any signs of fusion or bending and all were of a pinkish red color. This firing is represented by the bottom row in the photograph, figure 12.

The next firing, represented by the second row from the bottom in the photograph, was made at cone 9 (1310° C.). No fusion or bending was noted at this burn, but all the sand-clay mixture cones and the clay burned to a dark chocolate color. The temperature of the next burn was cone 11 (1350° C.), only 40° C. higher than the last, but at this temperature the clay and the 50 per cent clay mixture failed completely. The 40 per cent mixture showed almost complete failure whereas the 35 per cent mixture showed only slight bending. The rest of the cones showed practically no bending, but all showed that the bond had fused appreciably. Only the cones which showed no bending were fired at the next temperature, cone 14 (1410° C.). At this temperature the mixtures with 35 per cent and 30 per cent of clay failed completely by fusion.

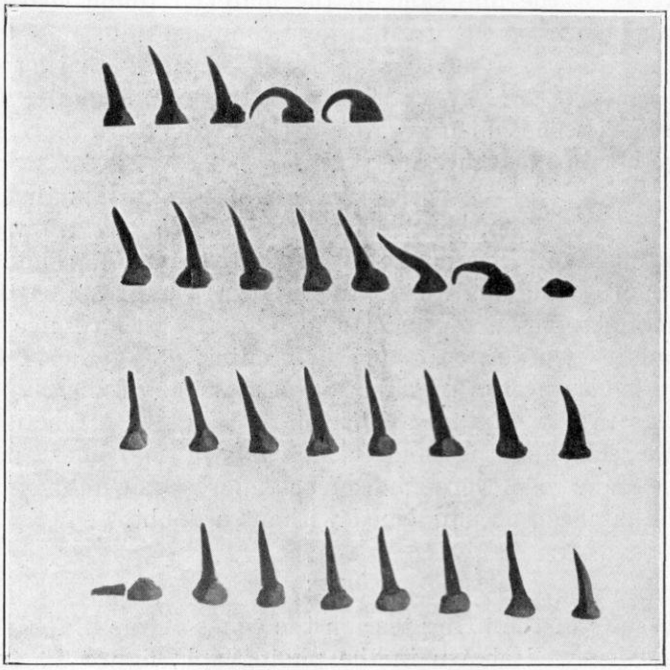

Figure 12.—Sand-clay mixture cones. The bottom row was fired at cone 4 (1210°C.), the second row at cone 9 (1310°C.), the third at cone 11 (1350°C.), and the fourth at cone 14 (1410°C.).

Some very definite conclusions can be drawn from this experiment. None of the sand failed until the bonding clay failed. At the temperature of complete fusion of the clay, sand-clay mixtures above 35 per cent clay showed little fusion to complete fusion at 50 per cent clay. With increase in temperature, the mixtures of lower clay contents showed fusion. By starting with these results a general law may be derived: sand-clay mixtures (molding sands) show failure in cones by complete bending at the temperature of fusion of the clay if the mixture has 50 per cent of clay; the failing temperature increases as clay content decreases (fig. 13, p. 67).

The curve shown in figure 13 shows the relation just stated in a graphic way for a specific case where the clay and the sand-clay mixture containing 50 per cent of clay fused at 1350° C. It will be noticed that the curve becomes a straight line for mixtures of higher clay contents, an indication that they are all

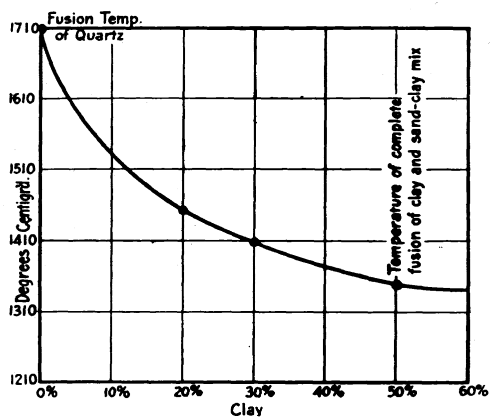

Figure 13.—Curve showing the relation between the fusion temperature of sand-clay mixture cones and the percentage of clay in the mixtures.

controlled by the fusion point of the clay. The points on the curve were actually located by firing tests until the limit of the furnace was reached, 1510° C. Above this the fusion point of quartz is placed as a mixture with no clay and the curve is continued to this point. This portion of the curve indicates what probably happens in these regions.

It has been suggested that this work can be carried further with mixtures made of clays of different compositions, and thus of different fusion points. This experimentation would, of course, add to our knowledge of the subject, but it seems very evident from the work done with the molding sands (pp. 75–76) that curves similar in characteristics to figure 13 would be obtained with possibly slight variations. Clays with lower fusing points would fall below the curve in figure 13 and probably be somewhat steeper, whereas the clays of higher fusion points would fall above and probably be somewhat flatter.

In concluding the work done on the cones made of the different sand-clay mixtures, it may be said that this method is an excellent way to study the softening point and fusion point of sand-clay mixtures from a qualitative standpoint, but it is impossible to get any quantitative data for comparative work from this method. Another difficulty noted with the method is that of observing the actual time at which complete fusion takes place. This difficulty might not be encountered with some types of furnaces where constant observation was possible.

Bars

Bars of the different sand-clay mixtures were made up as described before and allowed to air dry before firing. These bars were exceptionally strong for artificial mixtures.

The choice of the size of the bar, especially the two smaller dimensions, was more or less arbitrary. Square bars were tried but require a greater temperature to give an appreciable bending. Round bars are rather difficult to make because it is almost impossible to ram all parts equally in a tube and then push the specimen out without fracturing it. The length of the bar was chosen because it fitted in the furnace and also because it gave a fair distance, 2 inches between the supports used in firing.

The bars of the seven different mixtures were placed in the furnace on the fire clay knife edges which were set 2 inches apart. Figure 14 shows very well the results of firing at

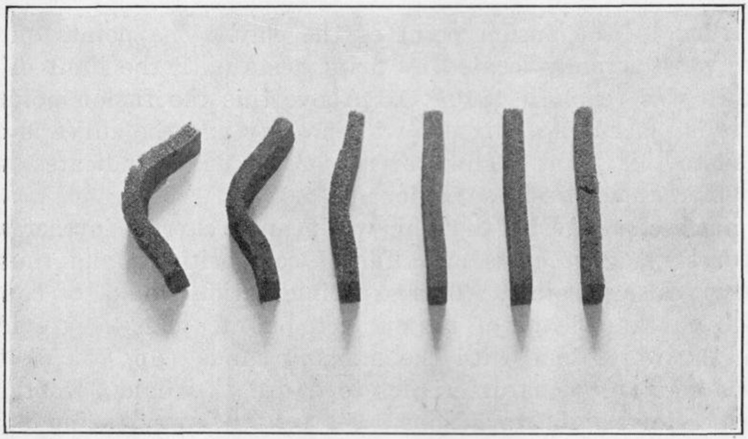

Figure 14.—Sand-clay mixture bars fired at 1350°C. They show the relative amount of bending in mixtures of different clay content.

cone 11 (1350° C.). The bar with the maximum clay content, 50 per cent, is at the left and showed the greatest bending. There also seems to be a regular decrease in bending with a decrease in clay content. If it had been possible in this work to carry the testing over a greater range of temperature, it would have been possible to show that the amount of bending is not exactly a straight line function, but a smooth curve. This fact is very evident from the data shown in figure 15.

The data used in drawing the curve shown in figure 15 were obtained in the following manner. Two sets of bars were fired at cone 9 (1310° C.) and the amount of bending calculated. The calculation was made as follows: the edge of each bar was

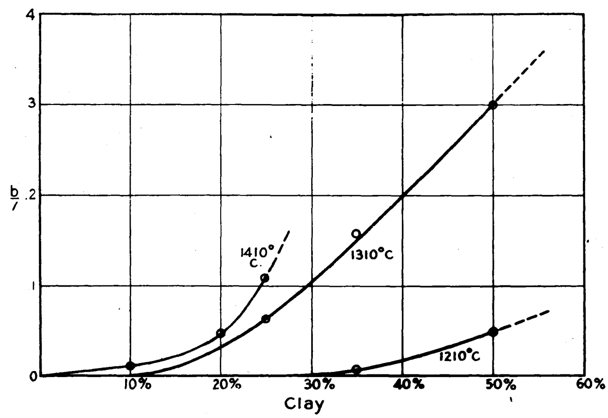

Figure 15.—Curves showing the relation of bending (b)/(1) in sand-clay mixture bars to the percentage of clay.

traced on a paper and a straight horizontal line drawn between the two support points. The length of this line is 2 inches and has been designated as *l*. The length of the vertical line or maximum amount of bending has been designated as b. The value of $\frac{b}{l}$ is plotted against the percentage of clay in the bar for each temperature of firing.

The results of the tests follow:

Cone 4 (1210°C)		Cone 9 (1310°C)		Cone 14 (1410°C)	
Clay Per cent	$\frac{b}{l}$ Inches	Clay Per cent	$\frac{b}{l}$ Inches	Clay Per cent	$\frac{b}{l}$ Inches
50	0.05	50	0.3	25	0.11
35	0.005	40	0.2	20	0.045
----------	----------	35	0.158	10	0.01
----------	----------	25	0.063	----------	----------

In figure 15 the curves for the higher temperatures are steeper than that of the lower temperature. At the lower temperature only softening of the clay bond would show by bending in the bars.

This method of testing the relative softening point of sand-clay mixtures gives quantitative results that are easily compared. Besides testing the softening point of the different mixtures by noting the amount of bending, complete fusion may be noted when the bar loses its original shape and sags to the bottom of the furnace muffle.

Comparison of Cone and Bar Tests

As previously stated, the amount of bending shown by a cone and the temperature of complete fusion are both factors to which it is very difficult to assign quantitative figures. Another difficulty encountered in the testing of cones is making all the cones the same both as to height and size of base. This factor is an important one because it has been noticed that long slender cones show complete bending at a lower temperature than a short stout cone of the same material. With the methods used for making the cones for this work, it was very difficult to make duplicate cones of the same material and equally, if not harder, to make duplicates of different materials.

On the other hand, if a standard mold box is used to make the bars and these are used as test specimens, the difficulty of varying sizes and shapes of the pieces may be overlooked. Probably the greatest advantage that the bar bending test has over the cone method of testing is that the results of the test may be expressed in a quantitative way.

Standard Test

The most important and costly part of the equipment which is needed to test softening or fusion points of sand is a furnace. There are many types on the market. The type that is heated by electricity is more expensive than the one heated by gas. A furnace for testing green molding sand or sand-clay mixtures to be used in an iron foundry must be capable of reaching at least 1600° C. This maximum gives a fair testing range above the ordinary temperature at which iron and steel are poured.

The furnace used must be so arranged that it is possible to record the temperature by means of some device such as an optical pyrometer, a calibrated thermocouple connected to a millevolt meter, or a recording volt meter, or Seger cones. This part of the equipment is indispensable.

The mold box shown in figure 11 (p. 63) can be made in any shape out of stock steel. The test pieces used in this investigation, 3 by ½ by ¼ inches, were found to be very convenient. It is therefore suggested that this size be used as a standard.

The supports for the bars in the furnace are readily molded from a standard fire clay and burned. These may be used indefinitely.

Procedure of Test.—Bars of the several molding sands or sand-clay mixtures which are to be tested are made up in the mold box from sand tempered to a good feel and allowed to air dry for at least 24 hours. The bars are then placed in the furnace and heated to the desired temperature. The bars are removed from the furnace and the ratio $\frac{b}{l}$ calculated for each bar; by comparison of these figures the amount of softening of each sand may be noted.

It is suggested that some standard temperature be set for burning sands that are used for casting the different metals, such as 1000° C. for brass and aluminum, 1350° C. for iron, and 1600° C. for steel.

No standard figures for the ratio $\frac{b}{l}$ can be given here for any of the standard sands because they were not available when this work was done. It would be a relatively easy problem, however, to set a figure with certain limits which could be used by all as a guide in purchasing new sands or evaluating new deposits.

Molding Sands or Natural Sand-Clay Mixtures

Selection of Samples

As a result of the experiments described above, some excellent ideas were obtained in regard to the action of sand-clay mixtures on heating. For further tests it was thought best to select a series of samples which contained nearly the same clay content but came from different locations and had different modes of origin. Samples with which the author was familiar were picked and the thirty-two are listed in Table V (pp. 92–93) with their formation and their clay content as determined by the American Foundrymen's Association fineness test.

Samples were selected with the following clay contents: 10 per cent, 15 per cent, 20 per cent, 25 per cent, 30 per cent, and a few with more. An allowance of 1 per cent was made for most of the samples selected and those in any group are not from the same locality but may have had a similar origin.

Sand Grains

Some have thought that the size of the grain may have an influence on the refractoriness of the sand. This statement in general has been found not to be true. The coarseness figure as determined by the author is given for each sand in column 4, Table V (pp. 92–93). As will be shown later, in any group of a given clay content the coarseness has played little or no part in the resistance of the sand to heat.

As there is sufficient difference in the coarseness of the sands in the different groups (column 4, Table V, pp. 92–93), any effects due to this, if there are such, will show in the firing tests of the sands.

Two other factors that may influence the refractoriness of naturally bonded sands may be obtained from a microscopic study of the separates of the screen analysis: (1) the mineralogy of the grains, and (2) the amount of staining of the grains.

In studying the mineralogy of the grains little attention was paid to any of the minerals except quartz; all others were considered as impurities. In most cases mineral counts were made in order to determine the actual percentage of impurities in each sand. From these figures estimates have been made of the purity of the sand grains on a quartz basis. In certain of the sands it was found that the grains were entirely or partially coated with iron stains. Estimates have also been made of this staining because it may be an important factor in starting the fusion of the quartz and because in this case a flux is in very intimate contact with the quartz grains.

In columns 5 and 6, Table V (pp. 92–93) the percentage purity of the grains on a quartz basis and the percentage of stained grains are given for most of the sands tested.

The data given in columns 5 and 6 (Table V, pp. 92–93) has been studied to ascertain if there is any definite relation between the two factors and the fusion temperatures of the sands (column 8, Table V, pp. 92–93). No definite relation was noticed, but several facts were disclosed which lead the author to think that these factors have some bearing on the refractoriness of the sands. Sands which contain some lime cement show in general low fusion temperatures. Sands that contain a large percentage of impurities, as well as those which are badly stained, also seem to have a low fusion temperature, even though they contain the same general type of clay. Examples of this are seen in sands 1525 and 1517. The bonding clay extracted from these sands showed similar refractory properties, but the tests of the natural sand-clay mixtures (molding sands) showed varying properties of refractoriness. Sand 1525 was the most refractory; it showed complete fusion at 1510° C. Its grains were 94 per cent pure and showed 55 per cent staining, whereas sand 1517, which almost completely fused at 1410° C., was 55 per cent pure and showed about 25 per cent of its grains stained. It would appear from this that the purity of the sand grains had some effect on the refractoriness of the mixture.

Extracted Clays

After noting the action on firing of several of the molding sands with the same clay content, as determined by the American Foundrymen's Association fineness test, it was decided to test the refractoriness of the clays in these sands after they had been separated from the sand grains.

The separation was accomplished in the following manner: 4 50-gram samples of the molding sand were placed in quart jars which were nearly filled with tap water, corked, and then agitated for 30 minutes. No floculating agent was used because it was desired to have the clay as pure as possible for the testing. After the agitation the samples were allowed to stand 10 minutes, and then the clayey water was siphoned off and collected. The jars were filled again, the material was stirred by the jet of water used in filling and then allowed to stand for 10 minutes. At 5 minute intervals the same procedure was repeated until it was impossible to suspend any of the clay in the water. The clayey water was allowed to stand in the collecting tank until the supernatant liquid became clear. The water was then siphoned off. The clay was collected from the bottom of the tank and dried before testing.

The clays extracted from the eleven molding sands selected for this test were made up into cones and fired at successive temperatures until they all reached their temperature of complete fusion. It was found that many of the clays fused completely at approximately the same temperature and thus could be grouped according to their refractoriness.

In columns 9 and 10, Table V (pp. 92–93) the grade of the clay according to its refractoriness and the temperature of complete fusion of clays of that grade are given.

From each one of the grades given in the table one clay was selected for chemical analysis in order to see what effect its composition had on the fusion temperature of the clay.

	Grade A No. 833 Per cent	Grade B No. 1520 Per cent	Grade C No. 1517 Per cent	Grade D No. 878 Per cent	
SiO_2	69.10	54.80	55.33	57.73	
Al_2O_3	15.35	22.60	21.50	12.67	
Fe_2O_3	6.85	8.57	8.00	6.85	Analyses by G. W. Cavanaugh
CaO	1.60	0.75	0.90	0.75	
MgO	0.20	0.30	1.72	1.00	
Alkalies as K_2O	-------	-------	-------	6.33	
Loss on ignition	5.80	10.14	8.20	13.70	
Total	98.90	97.17	95.65	99.06	
Total flux	2.98	3.88	6.97	9.03	
$SiO_2+Al_2O_3$	84.45	77.40	76.83	70.40	

Some very interesting relations in regard to the refractoriness of the clays may be drawn from these chemical analyses. It is noted that the total fluxes determined from the sum of Ca0, Mg0, alkalies and undetermined material increases as the clays decrease in refractoriness, and that the sum of $Si0_2$ and Al_20_3 determinations increases with the refractory properties of the clays. There does not seem to be any relation between the amount of iron and refractoriness.

The calculated mineral composition of these clays is given below.

	Grade A No. 833 Per cent	Grade B No. 1520 Per cent	Grade C No. 1517 Per cent	Grade D No. 878 Per cent
Chlorite	4.99	2.88	7.22	4.77
Orthoclase	----------	----------	----------	43.10
Muscovite	5.57	16.09	22.10	----------
Paragonite	5.43	11.47	21.50	----------
Kaolinite	25.58	28.55	7.90	9.86
Quartz	50.50	27.95	29.22	23.80
Limonite	8.02	10.00	9.47	8.10
Water	----------	3.79	2.81	10.55
Total	100.09	100.73	100.22	100.18

Some may object to the list of minerals used in the above calculation, but certain minerals have to be assumed. As these minerals are common in altered rocks and clays, they were used. In the calculation of the minerals from the clay analyses, the Ca0 and Mg0 were taken together as Mg0 and assigned to the mineral chlorite ($4H_20.\ 5Mg0.\ Al_20_3.\ 3Si0_2$). The total alkalies, which were obtained by the difference between the total determined percentage and 100 per cent, were divided according to their molecular weights into Na_20 and K_20. All the K_20 was assigned to the mineral muscovite ($2H_20$. K_20. $3Al_20_3$. $6Si0_2$) and the Na_20 to the mineral paragonite ($2H_20$. Na_20. $3Al_20_3$. $6Si0_2$). The Al_20_3 remaining after the above assignments was calculated as kaolinite ($2H_20$. Al_20_3. $2Si0_2$). All the $Si0_2$ left was calculated as the mineral quartz ($Si0_2$). The total Fe_20_3 was assigned to the mineral limonite ($2Fe_20_3$. $3H_20$) and the remaining H_20 was calculated as water. The clay from sand No. 833 did not show any excess of water and that from No. 878 showed too great an excess. The last case may indicate that there were present in the clays some hydrated minerals which were not calculated. In the clay from sand No. 878 the alkalies were all calculated as K_20 in the mineral orthoclase (K_20. Al_20_3. $6Si0_2$). The reason for this was that the analysis showed a lack of Al_20_3 for either muscovite or paragonite.

From the melting points of the minerals calculated above, the fusing points of the different clays were figured. Curiously enough the two more refractory clays gave the highest calculated melting points and the two less refractory ones showed nearly the same calculated melting points. In determining such figures it must be kept constantly in mind that one is dealing with a complex system of melted solids which have been partially studied by the physical chemists. The exact reactions between masses of the minerals present is unknown and can only be speculated upon. Thus, it will be seen that any figure for the melting point obtained in this way is at its best only relative.

Molding Sands

In the preceding discussion it has been noted that the bonding clays of molding sands have different refractory properties. It is now possible to show in a qualitative way the relation between these facts and the fusion temperatures of molding sands.

Cones of the thirty-two different molding sands were then fired at different temperatures. If the failure of these sand cones is considered with respect to the clay content of the different groups (columns 8 and 9, Table V, pp. 92–93), the following is noted. The cones fired at 1210° C. may be neglected because there were no failures at this temperature; those fired at 1310° C. may also be neglected because the only failure at this temperature was 812, a high lime sand. At 1410° C. 16 per cent of the sands in the 10 per cent clay group failed, 50 per cent in the 15 per cent group, 42.8 per cent in the 20 per cent group, 57.2 per cent in the 25 per cent group, and 75 per cent in the 30 per cent group. Approximately the same relation has been worked out for the sands fired at 1510° C., except that there was a greater percentage of failures.

at this temperature. Consequently it may be said, in general, that molding sands fail according to their clay content.

Now let us consider a particular group; for example, the sands containing 15 per cent clay. Of the sands in this group 50 per cent failed at 1410° C. and the other 50 per cent were still standing at 1510° C. There does not seem to be any order to the failure; for example, samples 1508 and 810 stood at 1510° C. whereas numbers 1517 and 872 failed on either side at 1410° C. The only explanation that can be made is that the clays bonding the sand grains have different refractory properties. If Table V (pp. 92–93) is referred to again, it will be seen that two sands, 1508 and 810, which stood at 1510° C., have bonding clays that have been classed as A and B grades according to their refractoriness whereas the two sands, 1517 and 872, which failed at 1410° C., have clays that are classed in the C grade. Other similar examples may be noted. These facts seem to show that sands of the same clay content may fail at different temperatures according to the refractoriness of their bonding clays.

Summary and Conclusions

The author wishes at this time to set down in concise form a few of the facts which have been obtained from the studies of artificial and natural sand-clay mixtures treated at different temperatures in what was supposed to be an oxidizing atmosphere. This work by no means exhausts the problem, but it is felt that the high points have been touched and that the conclusions given are worthy of the thought of any one who may make further investigation along this line.

The importance of this work to the foundry industry is rather difficult to estimate, but in it lies one of the problems of the casting industry.

Too much stress cannot be put on the condition of the atmosphere in which tests similar to the ones used in this paper are conducted. It was impossible to control the atmosphere in these tests, but other investigators have found that this is an important factor affecting the refractoriness of sands.

There are two distinct properties of refractoriness which may be tested in this type of work: (1) incipient fusion, and (2) complete fusion. These properties may be tested in two ways: (1) by the bending of cones, a qualitative test, and (2) by the bending of bars. The latter method can be made quantitative by measuring the bending from the horizontal and stating this as a relation, bending divided by the length between supports. It was found that this method was the better of the two used.

The study of artificial sand-clay mixtures gave some very interesting information. Sands with over 30 per cent of bonding clay showed failures in cones at the temperature of complete fusion of the bonding clay. The experiments thus indicated that the percentage and the grade of the bonding clay controls the temperature of complete fusion. It is, of course, realized that few sands which are now used contain more than 30 per cent clay, but it was thought best to work in this higher range in order to determine the exact action of the bonding clay on firing.

The study of the refractoriness of naturally bonded sands or molding sands presented a problem which was not easily solved. It was first thought that molding sands fused in order of their clay content. This hypothesis was found to be true in general, but there were so many exceptions to the rule that some other cause was sought. The extracted bond clays of several sands showed widely different refractory properties. The chemical analyses of these clays indicated that the total fluxes and amount of $Si0_2$ and Al_20_3 present followed the refractoriness closely. The melting points of the calculated minerals in the clays indicated the order of magnitude of the melting points of the clays, but no definite conclusions were based on this for good physical chemical reasons.

Thus, it may be said that the difference in the refractoriness of molding sands is due (1) to the amount of clay present, (2) to the grade of refractoriness of the clay bond, (3) to some extent to the purity of the sand grains, considering the mineral quartz as a standard, (4) to a much less extent to the staining of the grains, and (5) to the size of the grains. Little if any basis can be given for this last conclusion except that the sands studied varied greatly in fineness, and sands with different fineness and other similar properties showed like actions on firing.

It might be well to suggest other modes of attacking this problem further. The study of artificial sand-clay mixtures made of the same grain with clays of different refractory properties, and also mixtures of different sized grains with the same clay should give interesting results. The study of the chemical nature of the bond in relation to the refractoriness of sands is a most interesting problem and one which has only been touched on in this paper because of the expense of making chemical analyses. Above all, some standard should be set for the relation $\frac{b}{1}$ in some of the well known and widely used molding sands.

TABLE IV—THE MOLDING SANDS OF WISCONSIN

1 Analysis number	2 County	3 Location	4 Operator	5 Type of sand	6 Type of formation	7 Screen size—meshes per square inch On 12	8 On 20	9 On 40	10 On 70	11 On 100	12 On 140	13 On 200
820	Brown	Sec. 27, T. 24, R. 21 E.	Joseph Bardouche Green Bay	Molding	Fluvial glacial terrace	0.32	0.42	4.86	27.62	31.70	4.96	2.42
821	Brown	Sec. 27, T. 24, R. 21 E.	Joseph Bardouche, Green Bay	Core	Fluvial glacial terrace			2.32	28.96	43.72	10.36	4.24
890	Buffalo	Sec. 2, T. 24, R. 11 W.		Molding	River terrace		0.50	8.64	10.18	25.46	7.36	5.12
891	Buffalo	Sec. 2, T. 24, R. 11 W.		Molding	River terrace		0.20	2.64	10.54	3.54	2.94	2.30
892	Buffalo	Sec. 12, T. 24, R. 11 W.		Molding	River terrace			1.54	9.44	3.88	3.14	2.34
866	Columbia	Sec. 27, T. 12, R. 9 E.	Pacific Sand Co., Portage	Core	Cambrian sandstone		0.08	3.82	0.88	85.22	5.70	1.72
867	Columbia	Sec. 27, T. 12, R. 9 E.	Pacific Sand Co., Portage	Core	Cambrian sandst.		0.14	5.76	0.80	78.68	8.44	2.50
868	Columbia	Sec. 27, T. 12, R. 9 E.	Pacific Sand Co., Portage	Core	Outwash			0.17	12.32	81.52	4.00	0.76
869	Columbia	Sec. 27, T. 12, R. 9 E.	Pacific Sand Co., Portage	Core	Outwash			0.36	17.08	61.84	13.10	4.60
870	Columbia	Sec. 2, T. 13, R. 6 E.	John A. Smith, Kilbourn	Steel and core	Terminal moraine	0.98	1.48	30.04	46.78	17.96	1.28	0.18
899	Columbia	Sec. 28, T. 10, R. 8 E.		Steel and core	Jordan sandstone			2.34	50.47	31.44	9.84	1.84
813	Dane	Sec. 26, T. 7, R. 9 E.	William Keyes, Madison	Core	Delta			1.00	22.74	34.98	15.88	8.26
883	Dane	Sec. 10, T. 8, R. 6 E.		Molding	Terrace		0.40	2.18	10.80	34.26	7.32	2.74
901	Dane	Sec. 23, T. 6, R. 12 E.	Ole Burns, Rockdale	Steel and core	St. Peter sandstone	0.34	0.32	3.14	41.60	38.54	11.00	1.90
893	Eau Claire	Sec. 19, T. 27, R. 9 W.	EauClaire Sand & Gravel Company, Eau Claire	Steel and core	Terrace		3.28	54.54	0.38	41.18	0.24	0.06
894	EauClaire	Sec. 19, T. 27, R. 9 W.	EauClaire Sand & Gravel Company, Eau Claire	Blast	Terrace	7.52	45.12	46.28	0.48			
895	EauClaire	Sec. 19, T. 27, R. 9 W.	EauClaire Sand & Gravel Company, Eau Claire	Blast	Terrace	85.30	14.04	0.10				
896	EauClaire	Sec. 19, T. 27 R. 9 W.	EauClaire Sand & Gravel Company, Eau Claire	Steel and core		0.40	1.68	18.10	66.04	9.68	1.54	0.38

1 Analysis number	14 On 270	15 Thru 270	16 Clay	17 Total	18 Coarseness figure	19 Group	20 Albany number	21 Grain fineness	22 Grain class	23 Moisture Per Cent	24 Permeability	25 A F.A. bond Grams per break	26 A.F.A. bond Pounds per square inch	27 Compression Pounds per square inch	28 Tensile Pounds per square inch	29 Dye Adsorption figure	30 Base permeability	31 Page
820	2.04	3.10	22.56	100.00	0.943	3	2	72	4	5.6 9.0 9.9	185 198 82	283 289 255	0.454 0.472 0.368	3.32 2.93 2.71		1960		34
821	2.80	2.02	5.66	100.08	0.999		2	75	4	3.6 5.4 7.4	112 119 102	92 97 94	0.048 0.053 0.054	0.45 0.41 0.35		320	.67	34
890	6.00	19.68	16.60	99.54	0.789	2	1½	141	2	3.4 4.0 6.0 8.1	21.8 22.7 46.0 42.0	 278 258 256	 0.436 0.376 0.371	6.95 10.28 6.78 6.65	0.60 0.74 0.45 0.38	1920	11.4	34
891	6.70	38.54	32.04	99.44	0.412	1	0	197	2	5.5 6.4 8.6	7.5 21.0 16.2	 331 309	 0.620 0.540	11.95 12.41 10.50	1.14 1.14 0.84	2400		34
892	5.28	36.04	38.06	99.72	0.353	1	0	343	1	4.4 6.9 8.4 11.2 12.3	4.0 6.3 8.5 17.8 32.0	 333 317	 0.625 0.567	10.20 13.05 11.50	0.80 1.37 1.10	3200		34
866	1.04	0.32	1.30	100.08	0.99		2	72	4	Dry	105					32		35
867	1.62	0.62	1.26	99.82	1.00		2	72	4	Dry	108					40		34
868	0.36	0.22	0.62	99.97	1.02		2	72	4	Dry	108					40		35
869	1.68	0.46	0.96	100.08	0.97		2	75	4	Dry	65					56		35
870	0.14	0.10	0.72	99.66	1.765		4	40	6	Dry	173					8		35
899	0.64	0.34	2.28	99.46	1.167		3	59	5	3.2	151					108		35
813	7.26	6.54	2.36	99.02	0.853		2	99	4	3.5 5.7 7.7	72 87 67	94 96 95	0.049 0.052 0.051	0.38 0.41 0.41		172	40	36
883	2.92	10.90	28.30	99.82	0.675	2	1½	107	3	6.3 8.1 10.2	22.7 42.0 46.0	274 284 308	0.424 0.456 0.535	 8.51 10.10	 0.60	1766		35
901	0.80	0.70	1.50	99.82	1.175		3	62	5	Dry	93					144		36
893			0.40	100.08	1.943		4	41	6	Dry	287					24		36
894			0.60	100.00	4.049		6	14	10							8		36
895		0.04	0.50	99.98	7.890		6	6	11									36
896	0.28	0.28	0.96	99.34	1.624		3	41	6	Dry	178							36

TABLE IV—THE MOLDING SANDS OF WISCONSIN—**(Continued)**

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
						Screen size—meshes per square inch																								
Anaylsis number	County	Location	Operator	Type of sand	Type of formation	On 12	On 20	On 40	On 70	On 100	On 140	On 200	On 270	Thru 270	Clay	Total	Coarseness figure	Group	Albany number	Grain fineness	Grain class	Moisture Per Cent	Permeability	A.F.A. bond Grams per break	A.F.A. bond Pounds per square inch	Compression Pounds per square inch	Tensile Pounds per square inch	Dye Adsorption figure	Base permeability	Page
898	EauClaire	Sec. 22, T. 27, R. 9 W.		Molding	Terrace			0.84	20.48	20.96	13.16	11.70	9.04	11.80	12.02	100.00	0.736	2	1½	121	3	4.5 6.3 8.3	13.8 **21.0** 19.0	192 170	0.208 0.163	4.52 5.79 4.01	0.31 0.26 0.22	992		37
851	Fond du Lac	Sec. 20, T. 16, R. 14 E.	Miss Lillie Leuck, Ripon	Steel	St. Peter sandst.		0.66	10.02	41.52	37.08	6.26	1.38	0.70	0.46	0.54	98.62	1.287		3	56	5	Dry	93					280		37
852	Fond du Lac	Sec. 20, T. 16 R. 14 E.	Miss Lillie Leuck, Ripon	Steel	St. Peter sandst.	0.20	0.14	4.10	34.28	45.22	11.90	2.20	0.94	0.38	0.72	100.08	1.147		3	65	5	Dry	67					400		37
829	Green Lake	Sec. 14, T. 17, R. 13 E.	Wheeler, Mix, Berlin	Steel and core	Glacial Lake Oshkosh			1.54	35.40	40.76	12.74	4.30	2.82	1.36	0.86	99.78	1.072		3	72	4	Dry	52					120		39
830	Green Lake	Sec. 14, T. 17, R. 13 E.	J. E. Mix Sand Co., Berlin	Core	Glacial Lake Oshkosh			0.74	23.80	41.82	19.12	8.08	4.46	1.40	0.58	100.00	0.964		2	83	4	Dry	52					100		39
831	Green Lake	Sec. 14, T. 17, R. 13 E.	J. E. Mix Sand Co., Berlin	Molding	Glacial Lake Oshkosh		0.14	1.82	3.02	27.70	6.24	3.64	4.78	15.68	36.88	99.90	0.491	2	1	141	2	4.7 6.0 8.3 10.5 11.8	32 46 90 **93** 93	241 298 331 337 378	0.328 0.502 0.619 0.643 0.805			3472	65	40
832	Green Lake	Sec. 13, T. 17, R. 13 E.	Nathan Kintz Sand Company, Berlin	Molding	Glacial Lake Oshkosh		0.10	0.54	2.22	13.56	7.02	5.18	12.10	28.60	30.66	99.98	0.377	1	0	194	2	6.5 8.1 8.7		309 320 316	0.540 0.579 0.565			2852		40
833	Green Lake	Sec. 11, T. 17, R. 13 E.	C. A. Zamsow, Berlin	Molding	Glacial Lake Oshkosh			0.34	1.08	18.44	11.88	14.94	24.60	19.10	9.46	99.84	0.506	2	[a]1	169	2	2.8 4.3 5.6 8.3 9.0	19.0 19.5 20.0 **21.0** 12.6	190 176	0.204 0.176			804	13	40
834	Green Lake	Sec. 13, T. 17, R. 13 E.	Nathan Kintz Sand Company, Berlin	Molding	Glacial Lake Oshkosh			1.32	12.22	44.86	16.36	9.16	6.04	5.02	4.56	99.54	0.853	3	[b]2	98	4	3.5 5.5 8.0	48 **61** 54	110 117 110	0.068 0.077 0.068			320	28	40
835	Green Lake	Sec 13, T. 17, R. 13 E.	Nathan Kintz Sand Company, Berlin	Core	Glacial Lake Oshkosh			0.58	8.20	53.92	21.48	9.40	4.60	0.70	0.74	99.62	0.89		2	88	4	Dry	61					360		39
836	Green Lake	Sec. 13, T. 17, R. 13 E.	Nathan Kintz Sand Company, Berlin	Molding	Glacial Lake Oshkosh	0.40	0.34	2.26	8.04	7.76	4.26	2.60	5.30	21.58	47.42	99.96	0.411	1	[c]0	176	2	6.3 8.0 9.6 10.1 12.6	30 80 **90** 73 63	275 287 336 364 350	0.428 0.465 0.639 0.750 0.692			3036		40
837	Green Lake	Sec. 13, T. 17, R. 13 E.	F. Duberstein, Berlin	Molding	Glacial Lake Oshkosh			0.36	7.38	30.72	17.54	13.66	10.90	10.38	8.42	99.36	0.679	2	[d]1½	126	3	2.8 4.5 5.5 8.3	16.7 21.8 **23.4** 16.7	161 145 141	0.147 0.119 0.113			472	12.2	40
838	Green Lake	Sec. 13, T. 17, R. 13 E.	F. Duberstein, Berlin	Molding	Glacial Lake Oshkosh			0.58	8.50	17.16	11.64	9.90	11.26	20.28	20.50	99.82	0.551	2	[e]1	157	2	3.9 6.2 8.2	10.0 **15.2** 9.0	269 302 268	0.409 0.515 0.406			1704	16.2	40
839	Green Lake	Sec. 13, T. 17, R. 13 E.	Henry Traugett, Berlin	Molding	Glacial Lake Oshkosh			0.26	6.66	28.48	19.28	11.92	12.08	12.80	8.16	99.64	0.658	2	[f]1½	133	3	3.1 4.0 6.0 7.7 8.9	16.2 21.8 22.6 **23.5** 22.7	168 147 144	0.160 0.122 0.117			440	15.7	40
840	Green Lake	Sec. 13, T. 17, R. 13 E.	Henry Traugett, Berlin	Molding	Glacial Lake Oshkosh			0.44	8.96	19.48	13.44	7.94	9.16	18.44	21.96	99.82	0.547	2	[g]1	149	2	6.3 8.2 9.6 12.2 13.3	18.4 23.4 **30.0** 2.6 2.2	217 225 190	0.267 0.286 0.204			1676	10.3	40

[a] Producer's grade, 3L
[b] Producer's grade, 1L
[c] Producer's grade, 3H
[d] Producer's grade, 1L
[e] Producer's grade, 3H
[f] Producer's grade, 1
[g] Producer's grade, 2

TABLE IV—THE MOLDING SANDS OF WISCONSIN—(Continued)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
						Screen size—meshes per square inch																								
Analysis number	County	Location	Operator	Type of sand	Type of formation	On 12	On 20	On 40	On 70	On 100	On 140	On 200	On 270	Thru 270	Clay	Total	Coarseness figure	Group	Albany number	Grain fineness	Grain class	Moisture Per Cent	Permeability	A.F.A. bond Grams per break	A.F.A. bond Pounds per square inch	Compression Pounds per square inch	Tensile Pounds per square inch	Dye Adsorption figure	Base permeability	Page
847	Green Lake	Sec. 13, T. 17, R. 13 E.	White & Traugett Company, Berlin	Molding	Glacial Lake Oshkosh			0.16	0.92	34.64	21.60	13.24	14.54	9.24	4.64	98.98	0.660	2	1½	130	3	3.0 3.7 5.8 8.0	**33.0** **44.0** **49.0** **28.0**	150 176 123 119	0.127 0.175 0.086 0.080			504		40
848	Green Lake	Sec. 13, T. 17, R. 13 E.	White & Traugett Company, Berlin	Molding	Glacial Lake Oshkosh		1.24	0.54	1.80	27.56	12.58	8.18	7.66	16.82	24.24	100.62	0.577	2	[h]1	144	2	3.8 5.9 7.9 9.7	8.8 20.0 **40.0** 27.0	 237 198	 0.317 0.222			1504	12.2	40
849	Green Lake	Sec. 13, T. 17, R. 13 E.	White & Traugett Company, Berlin	Molding	Glacial Lake Oshkosh		0.06	0.50	2.00	28.04	13.42	8.48	8.58	16.64	23.22	100.94	0.536	2	[i]1	145	2	4.1 6.2 8.3 9.8	12.6 33.0 **42.0** 22.7	 274 239	 0.425 0.323			1536	12.2	40
850	Green Lake	Sec. 1, T. 17, R. 13 E.	Ted Schier, Berlin	Steel and core	Glacial Lake Oshkosh			0.72	29.98	50.34	11.24	3.20	2.28	1.20	1.34	100.30	1.056		3	72	4	Dry	67					300		39
854	Green Lake	Sec. 5, T. 17, R. 13 E.	Wisconsin Mineral Mining Company, Berlin	Core	Glacial Lake Oshkosh			1.98	32.94	39.40	13.44	6.00	3.48	1.60	1.10	99.94	1.040		2	75	4	Dry	54					300		39
855	Green Lake	Sec. 3, T. 17, R. 13 E.	Wisconsin Mineral Mining Company, Berlin	Core	Glacial Lake Oshkosh			1.04	39.70	37.46	11.38	3.00	1.80	0.68	4.86	99.92	1.064		3	66	5	2.5 3.5 5.6 8.0	**105** **112** **103** **73**	 87 95 94	 0.043 0.051 0.050			144	17.8	39
856	Green Lake	Sec. 13, T. 17, R. 13 E.	H. Baehr & Sons, Berlin	Core	Glacial Lake Oshkosh			0.50	10.00	43.54	17.44	9.00	8.20	6.28	4.94	99.90	0.806		1½	105	3	2.8 3.9 5.5	**42** **50** **44**	 137 77	 0.101 0.034			544	36	39
857	Green Lake	Sec. 15, T. 17, R. 13 E.	Wisconsin Mineral Mining Company, Berlin	Steel and core	Galcial Lake Oshkosh			3.48	35.18	49.20	7.78	3.24	0.90	0.16	0.76	100.70	1.157		3	64	5	Dry	30					144		39
858	Green Lake	Sec. 15, T. 17, R. 13 E.	Wisconsin Mineral Mining Company, Berlin	Steel and core	Cambrian sandstone		0.70	15.90	34.24	41.96	5.24	0.80	0.20	0.08	0.88	100.00	1.383		3	54	5	Dry	146					160		43
859	Green Lake	Sec. 15, T. 17, R. 13 E.	Wisconsin Mineral Mining Company, Berlin	Steel	Cambrian sandstone		1.14	19.60	48.30	25.60	3.40	0.44	0.14	0.08	1.24	99.94	1.509		3	46	6	Dry	185					400		43
860	Green Lake	Sec. 15, T. 17, R. 13 E.	Wisconsin Mineral Mining Company, Berlin	Steel and core	Cambrian sandstone		1.68	30.98	15.14	48.14	2.28	0.24	0.10	0.08	1.16	99.80	1.572		3	50	5	Dry	212					360		43
861	Green Lake	Sec. 15, T. 17, R. 13 E.	Wisconsin Mineral Mining Company, Berlin	Core	Glacial Lake Oshkosh			0.58	27.96	54.08	12.04	3.28	1.52	0.34	0.36	100.16	1.040		2	70	4	Dry	75					8		39
862	Green Lake	Sec. 17, T. 17, R. 13 E.	Wisconsin Mineral Mining Company, Berlin	Steel and core	Terrace		0.30	16.84	62.90	15.88	2.64	0.62	0.30	0.20	0.66	100.34	1.518		3	45	6	Dry	122					40		43
863	Green Lake	Sec. 1, T. 17, R. 13 E.	Albert Gelhar, Berlin	Steel and core	Glacial Lake Oshkosh			1.00	39.08	40.50	11.20	3.44	2.44	1.10	1.46	100.22	1.095		3	69	5	Dry	70					72		39
864	Green Lake	Sec. 1, T. 17, R. 13 E.	Albert Gelhar, Berlin	Molding	Glacial Lake Oshkosh	0.50	0.16	0.80	1.50	37.68	5.50	2.44	3.90	14.36	33.02	99.82	0.567	2	1	130	3	4.5 6.7 8.7 9.4 11.3	**50.0** **61.0** **67.0** **96.0** **54.0**	 339 330	 0.650 0.615			2620	25.8	40
865	Green Lake	Sec. 36, T. 15, R. 13 E.	Charles Kuehn, Utley Station	Steel	St. Peter sandstone		0.20	3.28	35.24	51.48	7.40	1.10	0.54	0.34	0.58	100.16	1.173		3	62	5	Dry	90					8		43

[h] Producer's grade, 2

[i] Producer's grade, 3

TABLE IV—THE MOLDING SANDS OF WISCONSIN—(Continued)

1	2	3	4	5	6	7	8	9	10	11	12	13
						Screen size—meshes per square inch						
Analysis number	County	Location	Operator	Type of sand	Type of formation	On 12	On 20	On 40	On 70	On 100	On 140	On 200
903	Green Lake		Wisconsin Mineral Mining Company, Berlin	Molding					2.88	7.04	9.18	10.70
884	Iowa	Sec. 16, T. 8, R. 5 E.		Steel and core	Terrace			0.60	41.44	47.44	7.32	1.42
806	Kenosha	Sec. 25, T. 2, R. 19 E.	Garden City Sand Company, Wheatland	Molding	Outwash terrace	2.44	5.92	10.28	31.48	8.84	2.38	1.00
807	Kenosha	Sec. 13, T. 1, R. 19 E.	Ben Elverman, Bassett	Molding	Terminal moraine	0.34	0.50	2.12	10.08	7.88	4.00	2.92
808	Kenosha	Sec. 13, T. 1, R. 19 E.		Molding	Outwash terrace	2.30	3.56	7.90	29.36	14.42	4.14	2.00
888	La Crosse	Sec. 4, T. 15, R. 7 W.	Fred Ebner, La Crosse	Molding	Loess		0.18	1.94	10.74	4.58	2.94	2.18
889	La Crosse	Sec. 4, T. 15, R. 7 W.	Fred Ebner, La Crosse	Core	Dresbach sandstone		0.74	8.24	2.70	77.20	6.72	2.34
801	Milwaukee	Sec. 13, T. 5, R. 22 E.	Caveny and Co., S. Milwaukee	Molding	Glacial Lake Chicago			0.10	0.30	2.24	3.90	5.10
887	Monroe	Sec. 24, T. 17, R. 4 W.	Teasdale Sand Pit	Core	Terrace of La Crosse River		0.18	2.06	10.32	66.98	13.76	3.66
826	Outagamie	Sec. 34, T. 22, R. 15 E.		Steel and core	Dunes			0.14	38.66	40.64	14.04	3.44
802	Racine	Sec. 17, T. 4, R. 22 E.	H. Gloede, Jr., Racine	Molding	Glacial Lake Chicago			0.80	13.58	48.20	18.10	4.74
803	Racine	Sec. 17, T. 4, R. 22 E.	H. Gloede, Jr., Racine	Core	Glacial Lake Chicago			0.12	2.42	25.26	33.26	20.26
804	Racine	Sec. 28, T. 3, R. 20 E.	Walsh Sand and Gravel Company, Kansasville	Molding	Ground moraine		0.14	0.98	30.18	37.04	7.64	2.44
805	Racine	Sec. 4, T. 2, R. 19 E.	Walsh Sand and Gravel Company, Burlington	Molding	Outwash terrace	0.42	1.10	6.58	40.36	15.26	4.78	1.80

1	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Analysis number	On 270	Thru 270	Clay	Total	Coarseness figure	Group	Albany number	Grain fineness	Grain class	Moisture Per Cent	Permeability	A.F.A. bond Grams per break	A.F.A. bond Pounds per square inch	Compression Pounds per square inch	Tensile Pounds per square inch	Dye Adsorption figure	Base permeability	Page
903	17.54	33.04	18.60	98.98	0.377	1	0	189	2									43
884	0.40	0.16	1.00	99.78	1.147		3	61	5	Dry	85					48		43
806	1.16	5.38	30.82	99.70	1.154	4	3	62	5	5.1 6.1 7.9 10.9 12.6	219 **243** 219 185 167	 294 336 382 **445**	 0.489 0.638 0.825 1.165	 3.66		3636	58	44
807	6.04	24.56	41.40	99.84	0.454	2	1	161	2	7.6 11.2 12.6	85 **93** 85	279 324 **352**	0.444 0.594 0.700	4.36 3.44		4220	8.8	45
808	2.06	5.84	27.42	99.00	1.192	4	3	73	4	1.6 4.8 6.2 7.2 10.2 12.5	193 **212** 173 156 82 47	 301 305 **384** 374	 0.513 0.525 0.835 0.791	 3.82		3336	29	45
888	5.20	33.10	39.02	99.88	0.387	1	0	207	1	6.9 9.0 11.2 14.3	10.3 16.7 **27.0** 16.7	290 299 **337** 321	0.475 0.505 0.641 0.584	10.50 10.81 9.41 9.55	1.07 0.94 0.57 0.62	3200		45
889	0.82	0.22	0.66	99.64	1.10		3	70	4	Dry	88					40		45
801	18.94	59.80	10.08	100.46	0.298	1	00	254	1	4.0 6.1 7.8 9.3	10.7 11.4 **12.6** 12.2	146 **157** 149	0.121 0.127 0.126			440	13	46
887	1.20	0.38	1.10	99.64	0.999		2	75	4	Dry	65					88		46
826	1.14	0.94	1.04	100.04	1.068		3	69	5	Dry	61					160		46
802	2.74	3.74	8.30	100.20	0.867	3	2	88	4	2.9 3.3 4.5 6.5 8.4	90 93 **105** 87 72	161 **162** 141 110 105	0.146 0.148 0.112 0.068 0.062			636		47
803	13.18	2.76	2.40	99.66	0.651		1½	118	3	3.7 5.9 7.7 10.0	**133** 87 79 62	86 92 94 **101**	0.042 0.048 0.050 0.058			164	52	47
804	1.32	2.38	16.96	99.08	0.907	3	2	72	4	3.2 5.4 7.3 9.3	105 **126** 126 70	 **327** 286 252	 0.605 0.462 0.359			2504	80	47
805	1.50	3.90	24.38	99.08	1.039	3	2	66	5	6.4 8.2 10.0 12.6	134 **162** 138 33	334 342 **400** 339	0.631 0.660 0.905 0.654			3036	82	47

TABLE IV—THE MOLDING SANDS OF WISCONSIN—(Continued)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
						Screen size—meshes per square inch																								
Analysis number	County	Location	Operator	Type of sand	Type of formation	On 12	On 20	On 40	On 70	On 100	On 140	On 200	On 270	Thru 270	Clay	Total	Coarseness figure	Group	Albany number	Grain fineness	Grain class	Moisture Per Cent	Permeability	A.F.A. bond Grams per break	A.F.A. bond Pounds per square inch	Compression Pounds per square inch	Tensile Pounds per square inch	Dye Adsorption figure	Base permeability	Page
809	Rock	Sec. 36, T. 1, R. 13 E.	Northwestern Molding Sand Company, Beloit	Molding	Ab'ndon'd terrace of Rock River			1.52	19.46	25.08	5.54	2.40	3.28	17.74	24.94	99.96	0.672	2	1½	126	3	5.1 8.9 10.3 11.6	80 **88** 61 30	316 337 **353**	0.564 0.642 0.704	2.93 2.84 2.70		2688	7.9	49
810	Rock	Sec. 36, T. 1, R. 13 E.	Northwestern Molding Sand Company, Beloit	Molding	Ab'ndon'd terrace of Rock River			2.38	18.74	43.56	6.52	3.00	2.84	8.14	14.46	99.64	0.854	3	2	93	4	2.3 4.8 6.3 8.5	56 **93** 62 55	**318** 290 252	0.572 0.475 0.358	2.33 3.15 2.61 2.20		2076	30	49
814	Rock	Secs. 21 and 22, T.3, R.12E.	Janesville Wisconsin Molding Sand Company, Janesville	Molding	Ab'ndon'd terrace of Rock River			1.76	12.04	28.14	3.90	1.42	2.04	21.34	29.52	100.16	0.591	2	1	140	2	6.4 8.0 10.2 11.3	24.2 40.0 **73.0** 65.0	280 327 332 **351**	0.444 0.605 0.622 0.695	4.07 3.6 3.28 3.21		3372	6.5 (Not a full sample)	49
815	Rock	Secs. 21 & 22, T.3, R. 12E.	Janesville Wisconsin Molding Sand Co., Janesville	Molding	Ab'ndon'd terrace of Rock River			2.64	28.20	36.86	5.56	1.26	1.00	7.14	17.38	100.04	0.903	3	2	85	4	2.4 3.7 5.8 8.1	88 **112** 10.2 7.0	290 **315** 250	0.475 0.561 0.353	3.28 3.06 2.65		2000	30	49
871	Sauk	Sec 32, T. 12, R. 6 E.	L. J. Pierson Mineral Company, Kirkwood	Molding	Glacial Lake Baraboo			0.60	1.00	29.02	24.14	13.72	8.30	12.72	9.90	99.40	0.622	2	1	132	3	3.7 5.9 8.0 9.4	27.8 38.0 **46.0** 21.8	**152** 129	0.131 0.094			1456	22.7	49
872	Sauk	Sec. 32, T. 12, R. 6 E.	L. J. Pierson Mineral Company Kirkwood	Molding	Glacial Lake Baraboo			0.54	1.06	24.24	21.74	13.74	7.22	15.69	15.18	99.68	0.559	2	1	131	3	3.8 6.1 8.1 9.7	18.4 38.0 **46.0** 17.8	**265** 208 194	0.397 0.244 0.212			1752	30.0	50
873	Sauk	Sec. 32, T. 12, R. 6 E.	L. J. Pierson Mineral Company Kirkwood	Core	Glacial Lake Baraboo		0.18	1.80	0.62	37.34	28.18	14.12	7.68	5.10	4.74	99.76	0.748		1½	111	3	2.6 3.6 5.6	**44.0** 52.0 48.0	**108** 107	0.067 0.065	1.34		672	33.0	50
874	Sauk	Sec. 15, T. 11, R. 5 E.	N. Freedom Silica Co., N. Freedom	Steel	Cambrian sandst.	0.26	1.94	4.74	0.58	80.42	8.56	1.36	0.62	0.20	1.14	99.82	1.090		3	71	4	Dry	88					72		50
875	Sauk	Sec. 28, T. 12, R. 5 E.	L. J. Pierson Mineral Company Ableman	Molding	Glacial Lake Baraboo		0.36	0.42	16.82	11.90	1.72	7.44	6.14	35.60	19.04	99.44	0.546	2	1	182	2	3.6 5.4 7.7	6.0 **10.7** 9.0	**243** 197	0.334 0.220			2200	7.9	50
876	Sauk	Sec. 28, T. 12, R. 5 E.	L. J. Pierson Mineral Company Ableman	Molding	Glacial Lake Baraboo			0.40	0.04	5.48	3.40	3.06	5.42	40.96	41.56	100.32	0.222	1	00	238	1	7.0 8.9 10.5 12.1	7.9 8.8 11.8 **29.0**	297 **355** 308	0.499 0.713 0.536			5400	9.7	50
877	Sauk	Sec. 2, T. 10, R. 7 E.	Walsh Sand and Gravel Company, Merrimac	Molding	Terminal moraine	0.24	0.82	1.82	0.28	46.86	12.50	5.96	4.74	7.94	18.44	99.60	0.735	2	1½	108	3	4.3 6.2 8.1 9.6	47 75 **90** 49	334 **336** 280	0.630 0.639 0.444			2328	22.7	50
878	Sauk	Sec. 35, T. 11, R. 7 E.	Walsh Sand and Gravel Company, Merrimac	Molding	Terminal moraine				0.50	18.18	26.98	19.30	13.00	12.14	9.80	99.90	0.555	2	1	144	2	3.9 6.2 8.0 9.6	21.8 23.4 **29.0** 17.8	141 **148** 136	0.112 0.124 0.104			560	28.0	51
879	Sauk	Sec. 35, T. 11, R. 7 E.	Walsh Sand and Gravel Company, Merrimac	Molding	Terminal moraine			0.18	0.40	23.64	27.34	13.90	10.70	11.70	11.60	99.46	0.580	2	1	132	3	2.6 3.4 4.9	27 **32** 29	**233** 200	0.307 0.226	6.31 5.95 4.71	0.50 0.49 0.30	1120	21.0	51
880	Sauk	Sec. 35, T. 11, R. 7 E.	Walsh Sand and Gravel Company, Merrimac	Molding	Terminal moraine			0.28	1.54	22.64	28.08	15.52	10.20	9.38	11.84	99.48	0.598	2	1	142	2	2.5 4.1 5.4 7.6	27 **31** 29 19.5	**161** 147 129	0.147 0.122 0.094	3.98	0.22	944	21.0	51
885	Sauk	Sec. 6, T. 8, R. 4 E		Core	Dune				0.94	86.52	8.72	1.84	0.74	0.20	1.04	100.00	0.952		2	75	4	Dry	115					224		51

TABLE IV—THE MOLDING SANDS OF WISCONSIN—(Continued)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
						Screen size—meshes per square inch																								
Analysis number	County	Location	Operator	Type of sand	Type of formation	On 12	On 20	On 40	On 70	On 100	On 140	On 200	On 270	Thru 270	Clay	Total	Coarseness figure	Group	Albany number	Grain fineness	Grain class	Moisture Per Cent	Permeability	A.F.A. bond Grams per break	A.F.A. bond Pounds per square inch	Compression Pounds per square inch	Tensile Pounds per square inch	Dye Adsorption figure	Base permeability	Page
886	Sauk	Sec. 6, T. 8, R. 4 E.		Core	Dune			8.56	25.60	55.30	5.56	2.00	1.24	0.52	1.26	100.04	1.17		3	64	5	Dry	173					176		51
897	Sauk	Sec. 2, T. 10, R. 7 E.	Walsh Sand and Gravel Company, Merrimac	Molding	Terminal moraine	0.70	0.80	1.34	19.44	12.80	8.94	4.34	6.14	12.08	32.84	99.42	0.675	2	1½	121	3	3.6 4.8 6.7 8.8 10.9	49.0 **108.0** 80.0 75.0 56.0	 243 315 **334**	 0.334 0.515 0.630	 12.41 10.81 8.91	 1.05 1.12 0.80	2176		50
819	Sheboygan	Sec. 26, T. 15, R. 23 E.	Otto Lange, Sheboygan	Core	Beach			0.36	2.32	89.96	6.60	0.30	0.06	0.04	0.70	99.71	0.989		2	72	4	Dry	88					40		51
900	Walworth	Sec. 16, T. 4, R. 18 E.		Molding	Outwash	1.10	0.60	6.04	43.28	13.28	4.34	2.14	2.44	5.54	21.56	100.32	1.089	4	3	72	4	2.7 3.8 4.6 6.0 8.4 10.1	99.0 **126.0** 105 93 85 49	 305 **330** 323	 0.526 0.615 0.590	 11.50 10.50 9.88	 1.20 1.10 1.00	2408		52
818	Washington	Sec. 27, T. 12, R. 19 E.		Molding	Outwash			0.06	0.48	0.50	1.30	6.14	29.08	48.74	14.60	100.90	0.280	1	00	252	1	1.6 3.6 5.5	10.0 **12.2** 10.3	 **125** 122	 0.088 0.084	0.35 0.80 0.67		240	7.5	52
816	Waukesha	Sec. 2, T. 6, R. 17 E.	Christ. Wachsmuth, Dousman	Molding	Outwash terrace	[j] 1.78	2.96	15.34	34.74	8.54	2.16	1.06	1.32	5.70	24.34	100.54	1.733	4	4	61	5	4.2 6.5 8.3	138 **193** 185	252 **350** 340	0.358 0.694 0.655	3.88 3.28 3.38		2320	52	52
817	Waukesha	Sec. 17, T. 7, R. 17 E.		Molding	Outwash	[k] 3.08	4.32	26.84	27.54	11.64	0.94	0.36	0.54	2.64	17.54	100.44	2.501	4	4	42	6	7.0 7.8 10.6	376 **417** 178	348 **356** 304	0.685 0.717 0.523	4.02 3.54 2.81		3104	134	52
827	Waupaca	Sec. 6, T. 22, R. 15 E.	Green Bay & Western Railroad Co.	Molding	Kame	0.36	0.34	1.34	4.22	35.84	18.14	8.56	7.32	6.98	16.18	99.28	0.716	2	1½	112	3	3.9 4.0 5.5 8.3	46 52 **70** 67	272 288 255	0.418 0.468 0.368	 2.52		1560	27	53
828	Waupaca	Sec. 26, T. 23, R. 11 E.		Molding	Stream terrace, Scandinavia	0.32	0.54	7.36	9.60	33.52	3.08	1.38	2.18	20.42	21.56	99.96	0.796	2	1½	129	3	4.6 6.2 8.7 9.1 9.3	19.5 36 44 **87** 67	300 **307** 285	0.500 0.534 0.459			2720	7.7	53
853	Waushara	Sec. 18, T. 18, R. 12 E.	Wisconsin Mineral Mining Company, Lohrville	Core	Glacial Lake Oshkosh		0.08	6.28	29.36	51.98	7.54	1.38	0.72	0.90	1.20	99.44	1.15		3	63	5	Dry	67					320		38 39 53
822	Winnebago	Sec. 29, T. 20, R. 18 E.	Ben Shultz, Neenah	Molding	Ground moraine			0.14	6.66	12.86	13.88	10.28	13.24	20.46	21.96	99.48	0.476	2	1	165	2	4.3 6.0 7.8 9.7	12.2 13.4 **14.3** 13.8	196 **263** 229	0.218 0.391 0.296	2.55 2.90 2.42		1604	11.0	54
823	Winnebago	Sec. 29, T. 20, R. 18 E.	Ben Shultz, Neenah	Molding	Ground moraine	0.34	0.28	0.94	2.58	11.94	9.82	7.54	14.22	24.14	28.26	100.06	0.441	1	0	204	1	6.3 7.1 7.7 9.7 11.1 11.6	13.8 14.3 16.2 24.2 **40.0** 15.7	253 276 295 **303** 287	0.362 0.431 0.493 0.519 0.465	3.41 3.56		2120	8.0	54
824	Winnebago	Sec. 29, T. 20, R. 18 E.	Ben Shultz, Neenah	Molding	Ground moraine		0.14	0.54	1.86	12.44	9.44	8.28	14.80	25.26	27.68	100.44	0.397	1	0	184	2	5.7 7.1 7.5	27.8 **34.0** 23.4	264 **297** 282	0.393 0.497 0.449	 3.79 3.73		2860	10.7	54
825	Winnebago	Sec. 29, T. 20, R. 18 E.	Ben Shultz, Neenah	Core	Ground moraine	0.12	0.08	0.24	10.12	57.44	16.08	6.30	4.48	3.64	1.76	100.26	0.88		2	91	4	Dry	58					200		54
841	Winnebago	Sec. 18, T. 17, R. 14 E.	Henry Traugett, Berlin	Molding	Glacial Lake Oshkosh			0.74	9.60	21.40	10.44	7.40	8.74	21.44	19.96	99.72	0.565	2	1	152	2	5.9 8.0 9.7	21.0 **36.0** 24.2	306 **316** 279	0.529 0.565 0.439			2720	12.2	40 54

[j] 2.6 per cent was retained on 6

[k] 5 per cent was retained on 6

TABLE IV—THE MOLDING SANDS OF WISCONSIN—(Continued)

1 Analysis number	2 County	3 Location	4 Operator	5 Type of sand	6 Type of formation	7 Screen size—meshes per square inch: On 12	8 On 20	9 On 40	10 On 70	11 On 100	12 On 140	13 On 200
842	Winnebago	Sec. 19, T. 17, R. 14 E.	Hunt Bros., Berlin	Molding & core	Glacial Lake Oshkosh			0.38	11.70	22.46	19.00	12.38
843	Winnebago	Sec. 18, T. 17, R. 14 E.	Hunt Bros., Berlin	Molding	Glacial Lake Oshkosh			0.36	1.56	13.50	8.74	6.90
844	Winnebago	Sec. 18, T. 17, R. 14 E.	Hunt Bros., Berlin	Molding	Glacial Lake Oshkosh			0.48	10.80	25.96	8.88	5.96
845	Winnebago	Sec. 18, T. 17, R. 14 E.	Hunt Bros., Berlin	Molding	Glacial Lake Oshkosh		0.08	0.56	8.60	11.98	9.72	9.94
846	Winnebago	Sec. 18, T. 17, R. 14 E.	Hunt Bros., Berlin	Molding	Glacial Lake Oshkosh	0.76	0.86	3.06	3.00	21.98	6.56	3.46
902	Winnebago	Sec. 6, T. 17, R. 14 E.	Wisconsin Mineral Mining Company, Berlin	Core	Glacial Lake Oshkosh			0.32	44.88	36.10	10.74	3.32
811	Illinois		Guetschow Bros. Sand Company, South Beloit	Core	Dune		0.40	7.10	54.90	25.48	5.96	1.34
812	Illinois	Rockton		Molding		0.10	0.22	0.74	5.22	13.56	6.04	3.82
881	Illinois	Rockton		Molding				0.46	0.54	38.86	12.04	4.44
882	Illinois	Rockton		Molding		0.24	0.46	0.60	0.44	9.30	4.54	4.00

1 Analysis number	14 On 270	15 Thru 270	16 Clay	17 Total	18 Coarseness figure	19 Group	20 Albany number	21 Grain fineness	22 Grain class	23 Moisture Per Cent	24 Permeability	25 A.F.A. bond Grams per break	26 A.F.A. bond Pounds per square inch	27 Compression Pounds per square inch	28 Tensile Pounds per square inch	29 Dye Adsorption figure	30 Base permeability	31 Page
842	12.28	11.94	9.68	99.82	0.672	2	1½	130	3	4.8 5.7 8.3	20.0 **28.0** 18.4	136 **140** 133	0.105 0.111 0.100			608	15.7	39 54
843	11.74	30.50	26.96	100.26	0.380	1	[l] 0	196	2	4.4 6.0 8.2	4.7 6.5 **10.0**	 **232** 222	 0.304 0.278			1560	6.7	40 54
844	7.46	20.44	19.52	99.50	0.596	2	[m] 1	146	2	4.3 6.1 8.2 9.5 11.5	12.6 18.4 25.8 **29.0** 10.7	262 **309** 272	0.388 0.540 0.418			2280	11.0	40 54
845	12.14	23.58	23.48	100.08	0.581	2	[n] 1	171	2	4.4 6.3 7.9 9.8 11.8	7.2 11.0 13.8 **14.7** 11.8	202 **230** 224	0.230 0.299 0.284			1536	11.4	40 54
846	5.98	25.96	28.40	100.02	0.593	2	[o] 1	165	2	4.4 6.6 8.7 9.5	16.2 30.0 **44.0** 42.0					2672	6.7	40 54
902	1.54	0.88	2.06	99.84	1.112		3	66	5									39 54
811	0.60	0.46	3.08	99.32	1.286		3	54	5	Dry 2.2 3.9 5.8	133 173 **178** 173	 **119** 87 85	 0.081 0.043 0.041	 0.35 0.28 0.26		544	108	49 54
812	7.34	43.22	19.84	100.10	0.341	1	0	209	1	4.6 6.5 8.6 10.0 11.5	5.3 5.6 **7.5** 5.8 4.7	**260** 222 207	0.382 0.279 0.242	3.0 2.16 2.13		2236	5.3	54
881	5.10	16.54	21.68	99.66	0.575	2	[p] 1	136	3	4.4 6.1 8.2 9.9	99.0 **142.0** 96.0 50.0	257 **316** 301	0.373 0.564 0.512	11.25	1.07	2400	12.2	54
882	6.58	48.96	24.76	99.88	0.353	1	0	237	1	4.4 6.4 8.2	4.7 **6.0** 5.6	 **252** 226	 0.359 0.288	 10.75	 0.80	 2760		54

[l] Producer's grade, 2
[m] Producer's grade, 3
[n] Producer's grade, 2 Blended
[o] Producer's grade, 3 Blended
[p] Producer's grade, 5 Blackhawk

TABLE V

MOLDING SANDS OR NATURAL SAND-CLAY MIXTURES

1	2	3	4	5	6	7	8	9	10	11
Sample number	Formation	Clay Per cent	Coarseness figure	Purity Per cent	Staining Per cent	Remarks	Fusion temperature of molding sand Degree Centigrade	Grade of clay	Fusion temperature of clay Degree Centigrade	Page
1524	Magothy Formation, Maryland Coastal Plain	9.06	0.875	93	26	------------	1510	------	----------	71-76
833	Glacial Lake Oshkosh, Berlin, Wisconsin	9.46	0.506	94	36	------------	----------	A	1410	71-76
1525	Aquia Formation, Maryland Coastal Plain	9.70	0.538	94	55	------------	1510	C	1310	71-76
878	Terminal moraine, Merrimac, Wisconsin	9.80	0.555	98	2	------------	----------	D	1250	71-76
871	Glacial Lake Baraboo, Kirkwood, Wisconsin	9.90	0.622	97	32	------------	----------	------	----------	71-76
801	Glacial Lake Chicago, S. Milwaukee, Wisconsin	10.08	0.298	87	57	Lime cement in coarse grains	1410	------	----------	71-76
1517	Aquia Formation, Maryland Coastal Plain	14.10	0.619	55	25	------------	1410+	C	1310	71-76
1508	Matawan Formation, Maryland Coastal Plain	14.30	0.707	--------	--------	------------	----------	A	1410	71-76
810	Abandoned terrace of Rock River, Beloit, Wisconsin	14.46	0.854	94	36	------------	----------	B	1350	71-76
872	Glacial Lake Baraboo, Kirkwood, Wisconsin	15.18	0.559	97	56	------------	1410	C	1310	71-76
1527	Sunderland Formation, Maryland Coastal Plain	15.56	0.745	99	47	------------	----------	------	----------	71-76
1509	Aquia Formation, Maryland Coastal Plain	15.76	1.116	--------	--------	------------	1410	------	----------	71-76
815	Abandoned terrace of Rock River, Janesville, Wisconsin	17.38	0.903	98	19	------------	----------	B	1350	71-76
875	Glacial Lake Baraboo, Ableman, Wisconsin	19.04	0.546	91	55	------------	1410	D	1250	71-76
1513	Lafayette Formation, Maryland Coastal Plain	19.10	0.576	--------	--------	------------	----------	------	----------	71-76
1534	Sunderland Formation, Maryland Coastal Plain	19.80	0.952	96	14	------------	----------	------	----------	71-76

TABLE V—Continued

1	2	3	4	5	6	7	8	9	10	11
Sample number	Formation	Clay Per cent	Coarseness figure	Purity Per cent	Staining Per cent	Remarks	Fusion temperature of molding sand Degree Centigrade	Grade of clay	Fusion temperature of clay Degree Centigrade	Page
812	Rockton, Illinois	19.84	0.341	89	49	Lime cement in coarse grains	1310	------	----------	71-76
838	Glacial Lake, Oshkosh, Berlin, Wisconsin	20.50	0.551	--------	--------	------------	1510	------	----------	71-76
1506	Aquia Formation, Maryland Coastal Plain	20.08	0.973	--------	--------	------------	1510	------	----------	71-76
828	Stream terrace, Scandinavia, Wisconsin	21.56	0.796	98	20	------------	1510	------	----------	71-76
848	Glacial Lake, Oshkosh, Berlin, Wisconsin	24.24	0.577	96	32	------------	----------	------	----------	71-76
816	Outwash terrace, Dousman, Wisconsin	24.34	1.733	82	2	------------	1510	------	----------	71-76
882	Rockton, Illinois	24.76	0.353	86	42	Lime cement in coarse grains and some small ones	1410	------	----------	71-76
1507	Matawan Formation, Maryland Coastal Plain	24.76	0.683	--------	--------	------------	1510	------	----------	71-76
809	Abandoned terrace of Rock River, Beloit, Wisconsin	24.94	0.672	--------	--------	------------	1510	------	----------	71-76
1520	Sunderland Formation, Maryland Coastal Plain	25.82	0.495	83	81	------------	----------	B	1350	71-76
808	Outwash, Bassett, Wisconsin	27.42	1.192	80	35	------------	1410	B	1350	71-76
814	Abandoned terrace of Rock River, Janesville, Wisconsin	29.52	0.591	97	16	------------	----------	------	----------	71-76
806	Outwash terrace, Wheatland, Wisconsin	30.82	1.154	67	8	------------	1510	------	----------	71-76
831	Glacial Lake, Oshkosh, Berlin, Wisconsin	36.88	0.491	96	23	------------	1410	------	----------	71-76
807	Terminal moraine, Bassett, Wisconsin	41.40	0.454	90	35	------------	1510	------	----------	71-76
836	Glacial Lake, Oshkosh, Berlin, Wisconsin	47.42	0.411	92	40	------------	1410	------	----------	71-76

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