terioration of the thermocouple embedded in the magnesite when a high temperature was reached. These samples were burned in a specially designed platinum resistance furnace which was capable of maintaining a temperature of 1450°C . for a good many hours without volatilization of the platinum and consequent burning out. The control of the temperature was such that in no case did the thermocouple inside the crucible containing the magnesite vary more than four degrees in the hour during which the material was being held at constant temperature.

Samples of one gram each of the burnt magnesite, ground to pass a 100-mesh sieve, were placed in a series of weighed porcelain crucibles. Sufficient distilled water was then placed in each crucible to completely cover the sample. As soon as the samples were covered the crucibles were placed in a vacuum desiccator containing concentrated sulphuric acid, and the water was allowed to evaporate. Samples which were covered with water one day and placed in a vacuum desiccator over sulphuric acid appeared dry the following day. The rack containing the set of crucibles was then placed in a drying-oven at from 102° – 105°C . and allowed to remain over night. After cooling, the crucibles were weighed, and the gain in weight taken as the one-day hydration. After the one-day hydration water was again added, and the samples allowed to stand in a closed desiccator containing some water for two days, after which they were again dried *in vacuo* over sulphuric acid for one day, and again in a steam drying-oven over night. This second gain in weight was taken as the hydration after a total of three days. A similar method of hydrating and drying—first *in vacuo*, followed by steam drying-oven—was used for the hydrations up to and including the twenty-eight day test. Through an oversight the samples in this last case were left in the drying-oven two days before weighing. The fact that the samples dried in the drying-oven lost appreciably after prolonged drying led to a change in the method of drying after the twenty-eight day test. Beginning with the two-month test the samples, after allowing to stand covered with water at room temperature, were placed in a vacuum desiccator over sulphuric acid and allowed to remain until the weight had become practically constant. This usually required from seven to nine days. The percentage gain in weight of the various samples, after the different periods of hydration, is given in Table I.

The table shows clearly that at 500°C . the magnesite was not completely dissociated in one hour. Experiments made in this laboratory upon calcite showed very slight dissociation at 600°C . after an hour's heating. Since magnesium oxide alone probably exists as such in the sample burned at 600°C ., and since such magnesium oxide, as stated in the earlier part of this paper, would require 40.51 per cent. of the weight of the burnt magnesite for complete hydration, this amount has been taken as the basis for computing the curves given in Table II, which shows graphically the progress of the hydration.

A study of the curves, considered in connection with the fact that samples after hydration lose some of their water when dried in a steam-oven, seems to indicate the following conclusions:

1. That magnesite is not completely dissociated at 500°C . in one hour under the conditions used in the experiments.
2. That dissociation of the magnesium carbonate is complete at 600° , while that of calcium carbonate is not.
3. That the hydration of magnesium oxide burned at 600° , 700° or 800°C . is practically complete in three days.
4. That between 800° and 900°C . the calcium carbonate is dissociated, and that combination takes place between basic and acidic oxides, resulting in the formation of silicates or aluminates. The silicates or aluminates so formed combined with more water than would be required for the complete hydration of the basic oxides alone.
5. That a change in the constitution of the magnesium oxide sets in between 1000° and 1100°C . resulting in a marked decrease in the rate of hydration, and that this change becomes more marked with rise of temperature of burning, until at 1450°C ., or nearly the temperature required for burning Portland cement, the magnesium oxide after eighteen months' immersion in water has combined with only 61.4 per cent. of the water required for complete hydration.

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FREE LIME IN PORTLAND CEMENT. A MILL STUDY.

By ARTHUR G. SMITH.
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The purpose of this paper is to present actual results obtained by testing for free lime both the night and day runs of portland cement as manu-

factured at the mill according to the microscopic method of detecting free lime, as published by Alfred H. White.¹

A preliminary statement as to how samples are taken and observed is necessary here to properly interpret the results following. From four tube mills grinding finished cement a sample was taken each hour in the twenty-four, upon which tests for fineness, setting time and soundness were made. This gave a very accurate set of results showing the nature of the product leaving the mills for each hour. The pats so made from these separate samples, were, after 24 hours, kept in boiling water seven hours and a careful record made as to their condition. It will be noted that the results are reported as the number of perfect pats, number of fair pats and number of bad pats. By perfect pats are meant those which were strong, neither checked nor warped, and free from cracks; fair pats, those slightly checked or warped; bad pats, those badly checked, cracked or disintegrated. In addition to the hourly samples taken, a general average sample was taken on each shift. To get this sample as nearly an average of the output of all four mills as possible it was decided to take it from the screw conveyor carrying the cement to the stockhouse. The method devised is as follows: In the bottom of the screw conveyor housing a hole about 1/8 inch in diameter was bored and so placed that it was directly under the flight of the conveyor. From this it will be seen that upon each revolution of the screw a small portion of the cement was forced through the opening and collected. It was upon this general average sample from each twelve-hour run that the microscopic tests were made. The results covering a two-week run are herewith tabulated:

1909. Date.	Prediction from microscopic test of average sample.	DAY RUN.			
		Perfect	Boiling test.		
			General average.	Per- fect.	Fair. Bad.
June 3	Perfect (Trace)	Perfect Total pats.	47	45	2
" 4	Perfect (Trace)	Perfect Total pats.	48	41	4 3
" 5	Perfect (Trace)	Perfect Total pats.	48	45	1 2
" 6	Perfect (Trace)	Perfect Total pats.	48	47	1
" 7	Perfect 1/8 bad	Perfect Total pats.	48	39	9
" 8	Perfect (Trace)	Perfect Total pats.	46	44	2
" 9	Perfect (Trace)	Perfect Total pats.	46	44	2

¹ THIS JOURNAL, 1, 5, January, 1909.

1909. Date.	Prediction from microscopic test of average sample.	DAY RUN (Cont.).			
		Perfect	Boiling test.		
			General average.	Per- fect.	Fair. Bad.
June 10	Perfect (Trace)	Perfect Total pats.	25	25	
" 11	Perfect About 1/6 bad	Perfect Total pats.	48	40	1 7
" 12	Perfect 1/4 bad	Perfect Total pats.	48	38	10
" 13	Perfect (Trace)	Perfect Total pats.	48	48	
" 14	Perfect (Trace)	Perfect Total pats.	48	48	
" 15	Perfect (Trace)	Perfect Total pats.	46	45	1
" 16	Perfect 1/4 bad	Perfect Total pats.	43	36	2 5
NIGHT RUN.					
June 3	Perfect About 1/4 bad	Perfect Total pats.	44	35	9
" 4	Perfect About 1/4 bad	Perfect Total pats.	48	40	6 2
" 5	Perfect About 1/4 bad	Perfect Total pats.	48	39	4 5
" 6	Perfect (Trace)	Perfect Total pats.	48	45	1 2
" 7	Perfect 1/3 bad	Perfect Total pats.	48	36	8 4
" 8	Perfect 1/4 bad	Perfect Total pats.	48	40	2 6
" 9	Perfect (Trace)	Perfect Total pats.	37	36	1
" 10	Perfect (Trace)	Perfect Total pats.	46	44	2
" 11	Perfect 1/3 bad	Perfect Total pats.	48	32	5 11
" 12	Perfect (Trace)	Perfect Total pats.	48	45	3
" 13	Perfect (Trace)	Perfect Total pats.	48	48	
" 4	Perfect (Trace)	Perfect Total pats.	41	41	
" 15	Perfect 1/4 bad	Perfect Total pats.	38	32	4 2
" 16	Perfect 1/8 bad	Perfect Total pats.	43	37	3 3

In making our prediction with the microscope we endeavored to estimate the number of the hourly pats which we thought would be bad, judging from the amount of free lime present in the average sample. It will be noted that in most cases the prediction with the microscope checked very accurately with the boiling tests.

In predicting results by the microscopic method, we practically assumed that no other agencies besides free lime were causing unsoundness in the cement. We think we were justified in this, because the routine operation at this plant is very favorable for elimination of the other factors which might cause unsoundness except free lime, it being the standard practice to grind the raw materials, consisting of limestone and clay, to a fineness of

not less than 97 per cent. through a 100-mesh screen and the finished cement to an average fineness of 98 per cent. through a 100-mesh screen and 83 per cent. through a 200-mesh screen. Further, the raw materials contain less than the average proportion of ingredients which might cause unsoundness.

It will be noted that on each shift there were some few hourly pats which did not perfectly pass the boiling test. We attribute this to two causes: first, an occasional non-uniform mix of the raw materials, and second, to the formation of "rings" in the kiln. It is the nature of the class of raw materials used to cause "ringing" in the kilns, and when these so-termed "rings" have to be barred out, some underburned clinker is very likely to go through the kiln. This underburned clinker has no chance to age as the clinker passes direct from the kilns through a cooler and is ground to finished cement in from six to eight hours after leaving the kilns.

CONCLUSION.

It is the writer's belief that the microscopic test for free lime will be a great aid to the manufacturer. If the results obtained can be made quantitative, and an accurate method for sampling devised, good results must be obtained.

COPPER-CLAD STEEL—A NEW METALLURGICAL PRODUCT.

By WIRT TASSIN.

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For many years past attempts have been made to cover steel with a copper coat which could be of any desired thickness, and to so firmly weld the two metals that the combined product could be submitted to any of the usual methods for working metals without destroying the integrity of this weld.

The many methods tried in the past have been more or less successful failures, either from a metallurgical or a commercial standpoint, and it is only recently that a process has been developed for the successful welding of copper to steel in such a manner that it will stand the many methods used for working metals, and be at the same time a commercial metallurgical product. The weld between the copper and the steel is perfect within the limitations of a metallurgical process. The copper can be separated from the steel only by melting it off. The weld will resist sudden tem-

perature changes such as heating the combined metals red hot and then quenching them in ice-water. It will resist both stress and shock. In the accompanying illustration (Fig. 2) a section of a round is shown that has had its copper cut through to the steel, the section placed in a vise and repeatedly struck with a hammer.

The process by which this result is obtained may be described as follows: Steel of any desired composition and shape, which, for the purpose of this description will be regarded as being a mild basic open-hearth steel, rolled into rounds and cut into 26" billets, to make wire rods, is sand-blasted and pickled to remove scale. The billet, which has previously been drilled and tapped at each end, is hung by means of a rod and bushing screwed into one end, in a pre-heater and is brought to a red heat. When the desired temperature has been reached, the billet is then drawn into a tube (also previously heated) by means of a rod which is screwed into the top of the bushing. This rod slides up and down in the center hole of a three-jawed chuck, which holds the tube and centers the billet in it. A steel flange is then screwed on the bottom of the billet, thus forming with the tube a mold in which the billet is the core.

The mold and billet are now carried to a pot of specially prepared copper which is in a super-molten condition. The billet with its attached flange is now lowered out of the tube and into this copper, and kept there for a length of time sufficient to wet the surface of the steel and to form an alloy film. The billet is then drawn from the copper up into the tube, and the billet and its mold is carried to a second pot containing commercially pure copper, in which the final coat of copper is applied. The mold with its billet as a core is lowered into this pot and the molten copper rushes in through two openings in the top of the tube until the mold is filled. The mold is then withdrawn from the second crucible, and when the copper has frozen, the chuck, rod and flange are unscrewed. The tube and its contents are next placed in a ram and the copper-clad steel billet is pushed out of its mold. The billet is now given a washing heat and is then rolled to the desired size.

The rolling is, in general, similar to that of steel or copper, and it is interesting to note that in spite of the great differences between the physical properties of copper and steel, the two metals when so welded have, under proper conditions, practically the same rate of flow. The proportional areas