will, to a certain extent, be obviated in the future, is the stranding of cars in winter when the roads are covered with snow, or when ice on the rails creates such a resistance that the vehicles are unable to proceed until an army of men have been engaged to clear the way. Only once has such a state of things happened in Paris. During January last there was a fall of snow in the afternoon which melted as soon as it touched the ground, and in the evening there was a sharp frost which covered the roads and rails with a layer of ice that entirely stopped all vehicular traffic, and for some hours there was the unusual sight of long lines of tramcars being unable to proceed. A still more serious matter was the dislocation of the electrical system whenever there was a fall of snow. This would never have happened if the tramway companies had been allowed to clear the track themselves, but as soon as the snow put in an appearance the municipal authorities distributed salt all over the principal thoroughfares, which melted the snow and produced a strong solution of saline mud. This mud, by filtering in around the surface contact plates, created short circuits, while in the slot system it filled up the conduits, and forming a conductor for the electricity, prevented the lines from working. On the companies making strong representations to the authorities they were given a certain time to clear the tracks before salt was put down on the roads, and the Thomson-Houston Company employed an electric brush similar to that used in the United States. This experiment proved successful, and it is probable that these precautions will prevent any further suspension of the electrical tramway service in winter.—The Engineer.

A HISTORICAL SKETCH OF SLAG CEMENT.*

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THE following paper gives an elementary statement of the nature and properties of slag cements.

A statement in general of the processes involved in the manufacture of cement from slag material or from limestone and clay material, will make clear the discussion which follows.

A Portland cement, commonly so called, is made from either pair of the following raw materials artificially mixed together in a finely divided form:

Compact limestone with from 18 to 20 per cent of clay.

Chalk and clay.

Marl and clay.

Clay-bearing limestone properly dosed with clay or shale, or limestone. This mixture is calcined at a high temperature to nearly the point of fusion. The resultant clinker is ground to a fine powder, and in this condition called Portland cement.

A "slag cement," commonly so called, is made from the cinder or slag which results when a mixture of limestone and iron ore is burned in the blast furnace. The iron ore contains the silica and alumina, which are found in the clay element of the mixture used in making Portland cement. This slag is suddenly cooled, dried and mixed with about one-fourth part of slaked lime, and then the mixture finely ground to form the cement.

Two plants in the United States make cement from slag material by a process similar to that of Portland cement manufacture, that is, the mixture of slag and limestone is calcined to a clinker. One of these, in Pittsburg, uses the granulated slag, mixed with compact limestone; this mixture is finely ground, then calcined in a kiln to a clinker, and ground again, just as in the case of Portland cement. [The other plant, in Chicago, uses a similar process.—Ed.]

For works requiring an early and final strength, Portland cement is usually specified by the engineer. The attempt to use under such specifications certain cements, called Portland cements, but made from a mixture of slag sand and slaked lime, has led to a dispute. On one side we find ranged those who claim that an essential feature of production of a Portland cement is a calcination or roasting of a certain artificial mixture of carbonated lime and clay to a clinker, and subsequent grinding to a powder. On the other side we find those who insist that the burning to a cinder of the limestone and other material of the blast furnace furnishes a material which, chemically, is nearly a proper mixture for a Portland cement, and that the subsequent correction by addition of a slaked lime paste does not, from the point of view of a definition, involve an error in the case of those who call this product Portland cement.

There are two ways of regarding the dispute. First, from the point of view of a descriptive term it is well to have a separate name for two products which are different in their mechanical and chemical properties. If we desire a sidewalk cement, we should not specify the material by any name which will involve a cement made by the second process above described for slag material, involving no calcination. Nor should we shut out a product like the Pittsburg product, or a similar product made in Chicago.

Second. From the point of view of historic origin it has been pointed out that the original patent for Portland cement involved a double calcination; first of the limestone, then of the mixture of this calcined limestone and clay. So strictly speaking our modern Portland cements have no right to succession to the term Portland.

The cements made by the first process have, however, the right of possession to this term Portland. It would then seem the part of wisdom to divide the cements of this country into three classes—natural, Portland and slag.

Natural will include those made by roasting and subsequent grinding of an argillaceous limestone (a natural mixture of limestone and clay).

Portland will include those made by calcining to a clinker and then grinding an artificial mixture of the proper proportion of limestone (or marl or chalk, or clay-bearing limestone) and clay (or slag sand). The slag cements will include those made by grinding a mixture of pulverized granulated slag and slaked

lime paste, which mixture has been made without applied heat.

In the paper below this understanding of the term "slag cement" is intended.

This matter is somewhat important as at least four brands of slag cement as described above are on the market as Portland cements. To ask for a definite classification is not to find fault with slag cements. They have a distinct and high value for many engineering works. Let engineers write the specifications and manufacturers put out their product on the same nomenclature.

The definition of Portland cement above referred to is in conformity with the specifications of the German association of cement manufacturers, the French *Ponts et Chaussées*, Swiss government, Austrian engineers and architects' association, Russian Minister of Roads and Railways, and recent specifications of the United States engineers.

MM. Brull and H. Henry, in a communication to the Congress for Unification of Tests of Materials before the Paris Exposition, July, 1900, have given information concerning the development of the manufacture of slag cement, from which communication the following facts are mainly derived:

In 1898 thirty-six million tons of slag were produced in connection with the manufacture of iron. Many futile attempts have been made to use that by-product. Successful use has been instanced in railway ballast, molded blocks for engineering structures, such as sea walls and embankments, and mineral wool.

In 1737 Belidor in his *Architecture Hydraulique* has noted that a mortar could be made of pieces of hard brick, splinters of rock and ground blast furnace slag mixed with fresh slaked lime. At the beginning of the century Vicat had noted that certain slags had the properties of pozzuolana. (Pozzuolana is a volcanic lava which, when mixed with hydraulic lime, forms an hydraulic cement. "Puzzolan" is an imported slag cement used extensively in St. Louis.)

The utilization of slag, however, was not attended with great importance until in 1861 Langen, a founder near Troisdorf on the Rhine, discovered that the slag could be granulated by sudden cooling. Instead of the solid mass of cooled slag, a slag sand could be produced. The effect of this granulation on the pozzuolanic properties of the slag was soon noted. In 1862 at Osnabrück the application of this granulated slag to the manufacture of cement was attempted and the subsequent use of this slag included chiefly the formation of bricks and molded stones by a mixture of this slag sand and slaked lime, a process which has extended itself to many countries.

About 1880 the process of making slag cement on a commercial scale by a cold mixture of granulated slag and slaked lime was inaugurated in the canton of Berne, Switzerland. About the same time certain manufacturers of Portland cements in Germany began to mix a ground slag sand with their product with the result of increasing its strength. It is said that such mixture up to 2 per cent is not harmful and is practised at the present day. The sophistications became so general in Germany and England that protests were made against the practice, adulterations of 30 per cent having been found. The manufacture of slag cement spread rapidly, and at one time there were nine mills in France and twelve in Germany. At the present time, according to MM. Brull and Henry, there are the following mills in operation:

Country.	No. Works.	Production (tonnes of 2,204.6 lbs.)
France	10	85,000
Belgium	5	
Luxemburg	2	
Switzerland	1	
Germany	12	180,000
Austria-Hungary	3	100,000
Spain	1	
Russia	1	
England	2	
United States	4	

These statistics do not include mills which roast the product in a kiln. Certain mills in Germany and two in the United States have lately transformed or built mills to manufacture this roasted product.

While these statistics are given in the paper of MM. Brull and Henry, it is to be noted that in a consular report to the State Department, dated 1895, the statement is made that the slag cement mills are gradually closing down, there being but one mill in Germany, one in Belgium and three in France. This report conflicts with the statement of the paper of MM. Brull and Henry, quoted, and with the account in that paper of the universal and successful use of large amounts of the product in France.

In the United States there are in the author's knowledge nine plants making cement from slag materials, two of these employing a roasting process.

In France (paper of MM. Brull and Henry) the use of slag cement is admitted for bridges and roads, railroads, mines, municipal service. It is allowed by the Administration of Roads and Bridges in hydraulic works; was used in dry dock at Boulogne; used in Metropolitan Railroad of Paris; is used in important bridges and tunnels.

A mixture of slag cement and granulated slag is made into bricks, molded stones, tile pipes. It is said that 60 parts of lime are used by volume with 250 to 300 parts of slag sand to form the bricks. The pipes withstand a pressure of 71 pounds per square inch and are used in sewers. Pipes are made of a stiff mortar of silicious sand and slag cement.

This cement is not recommended by the manufacturers in this country for such work as sidewalk work, where it is subjected to the influence of the atmosphere when spread out in thin sheets, but it is recommended for foundations, whether for streets, bridges, buildings, etc.

This paper does not pretend to give a detailed account of the process of manufacture. Briefly described the process is as follows:

1. Granulating the slag.
2. Drying the slag.
3. Mixing with desired per cent of slaked lime.
4. Grinding mixture to powder.

In some cases the slag is ground before being mixed with the slaked lime.

The stream of slag may be run into water, or a stream of water may be brought into contact with the slag as near the outlet as possible; or the slag may be run from the furnace to a trough where a stream of water is flowing. The result is sand, like broken pumice stone, or thin shell pieces of pinkish color, containing 30 per cent of water, or more.

Drying the slag sand is accomplished in a rotary cylinder with inclined axis heated by an interior or exterior flame, or by spreading the sand on sheet iron driers which are slowly passed through a heating chamber, or else in a vertical chamber with inclined runways of reversed grade, down which the slag runs and is dried.

The limestone is slaked in the mill and mixed with slag in a ball mill.

The materials are ground to an impalpable powder by the ordinary methods of cement manufacture.

The appearance of the slag cement is characterized by a delicate lilac color, in some cases almost white. When cement is made from slag by a process involving roasting, the cement is of a dark color like that of ordinary dark colored Portland.

It has not the coarse or gritty feeling which characterizes most Portland cement. It works fast, sets slowly, and passes ordinary tests for permanence of volume.

A part of the cement exposed to the air has to be well covered to prevent the surface from cracking. After drying out it will exhibit discolorations, yellowish or brown, whereas the part hardened under water will not exhibit such discolorations. The characteristic color of the fracture of a water-hardened briquette is green, but when the briquette dries out the fracture becomes white. The writer has noticed this green color, with a subsequent change to white, in the case of a well-known American Portland cement, and also the discolorations in the pat, indicating slag adulteration, or else a not sufficiently oxidizing flame in the kiln. The green color is due to the presence in slag cement of sulphide of iron. This sulphide becomes oxidized on exposure to the air and changes color. Slag cements contain usually from 0.5 to 1.5 per cent of sulphides.

It is this tendency to oxidation on exposure to the air which is destructive to mortar made of slag cements containing an excess of sulphides and makes it necessary to use the product in underground situations or the interior of thick walls. A parallel test of briquettes hardened in air and water should be made to check up the presence of sulphides. This disintegration does not occur in case of all slag cements; it is not a necessary defect.

METHOD OF DETERMINING AND EXPRESSING THE FASTNESS OF COLORS TO LIGHT.

WITH a view of determining absolutely and expressing with precision the degrees of resistance of colors

BELLANI'S ACTINOMETER.

to light, the author proposes to measure the insolation which they are capable of withstanding up to the time when their fading may be said definitely to commence, by means of the vaporization actinometer of Bellani, as modified by Desroix (see figure).

This consists of a bulb of dark blue glass, about 0.045 m. in diameter, attached to a graduated colorless glass tube, upon which is blown a second bulb of the same size as the first. The colored bulb is filled to the extent of two-thirds of its capacity with ethyl alcohol (90 degrees) and is inclosed in a clear glass bulb, a vacuum being produced in the intervening space. The air is exhausted from the interior of the apparatus, which is thus completely filled with the alcohol and its vapor.

The samples of colors, the fastness of which is to be ascertained, are exposed to light under the same conditions, side by side with this apparatus. The quantity of alcohol which is vaporized during the exposure is noted daily, the apparatus being inverted, after the reading has been taken, in order to replace the alcohol in the colored bulb and so reset the apparatus for use. This is continued until the colors commence to fade. The amount of alcohol which distills over during this time is expressed in terms of units of thermo-actinic, as measured by the apparatus, which it is proposed to name *photos*, a photo being the quantity of radiant heat required to maintain during one hour's time a difference of 17 deg. C. between the two thermometers in Arago's actinometric apparatus, this difference being found, by calculations based upon observations, to be the total effect of the sun's radiation outside the terrestrial atmosphere.

Each degree C. of difference between the temperatures shown by these two thermometers corresponds,

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