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FIRE BRICK AS MANUFACTURED AT CERRO DE PASCO, PERU AND SOME EXPERIMENTS WITH SILICA BRICK

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FIRE BRICK AS MANUFACTURED AT CERRO DE PASCO, PERU

and

SOME EXPERIMENTS WITH SILICA BRICK.

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New York.

THESIS

The Cerro de Pasco Mining Company is a New York corporation owning or controlling nearly all of the mining claims located at Cerro de Pasco, Peru, South America.

The mineral mined at this point is a fairly high grade copper and silver ore being very rich in places and differing greatly in its physical properties.

The high grade ore is of sufficient richness to warrant shipping it to the United States or England for treatment but the great bulk of the ore is not rich enough to ship so far at a profit. It became necessary, therefore, to treat this ore at the mines, shipping only the metals themselves and thus effecting a great saving in transportation charges. For this purpose a smelter was erected about six miles from Cerro at a favorable point on the Cerro de Pasco R.R. It was to supply this smelter with fire-brick at as low a cost as possible that the fire brick plant was constructed at Cerro.

The Cerro de Pasco Mining Company also owns coal mines at three points in this district, the nearest being located at Vinchuscancha, seven miles distant; the next at Goyllarisquisga, twenty-two miles distant and the other at Quishuarcancha, twenty-five miles distant.

At each of these mines fire clay forms either the hanging or foot walls and at Goyllarisquisga and Quishuarcancha both walls. This is a particularly fortunate circumstance as it enables the clay to be mined with the coal and at a comparatively small additional cost.

The fire brick plant at Cerro is between these mines and the smelter and although it would probably have been an advantage as far as transportation charges are concerned to locate the plant at one of the coal mines where the raw material and fuel is obtained, the fact that it is difficult to secure enough labor at the coal mines to keep them operating at their full capacity and that the topography of the country is not suitable for such a plant probably led to the selection of Cerro. Besides, at the time the fire brick plant was constructed the railroad was not completed to the coal mines and it would accordingly have been necessary to delay the construction of the plant until the railroad was finished, so that the heavy machinery could be transported had the plant been located at any one of these mines. This was not to be considered as it was very essential that brick be furnished as soon as possible for the construction of the smelter.

The fire brick plant erected at Cerro consisted of one large building divided into three parts. One part contained the boiler and coal bin, the central and larger part contained the engine and machinery while the third part was used as a drying room. (See plate I.)

The boiler was of the locomotive portable type and rated at about seventy-five horse power. This furnished steam to the engine and to the coils in the drying room.

The engine was a simple non-condensing slide valve horizontal engine with throttling governor, rated at about thirty-five horse power.

The brick-making machinery proper consisted of a disintegrator, wet pan, hand moulds and three hand presses. This equipment is hardly sufficient, as without a dry pan it was almost impossible to grind the clay as fine as is necessary for the best results without greatly decreasing the capacity of the plant. Plate I gives an idea of the arrangement of this machinery in the main part of the building.

In addition to the above, a supply of shovels, picks, sledges, wheelbarrows, &c. were required. The drying room was about one hundred feet in length and forty feet in width with four racks running its entire length except for a transverse isle in the centre of the building. These racks consisted of four by four posts from the floor to the ceiling, spaced about two feet apart with cleats one inch by three inches by two feet in length nailed on each post about eight inches apart from the floor up to about five feet.

The floor of the drying room consisted of one inch boards laid on stringers with two inch planks on top of the boards. Every two feet a space of about four inches was left between the two inch planks in which a two inch steam pipe was laid. Across each end was a four inch pipe with four by four by two inch tees every two feet to which the two inch pipes running lengthwise were connected. At the lowest point in the farthest corner a steam trap was connected to take care of the condensation in this floor coil. (See Plate I.) During the day the floor coil was furnished with steam from the exhaust of the engine and the four inch gate valve near the steam trap left open. At night this gate valve was closed and live steam from the boiler at about fifteen pounds pressure was turned on.

The two kilns were of the down draught type with a sixty foot stack between. They were twenty-six feet in inside diameter and seven feet six inches in height to the spring line of the roof. The walls were twenty-six inches thick, lined on the inside with English fire brick. These kilns had six fire-boxes and two doors. The main flue extended entirely across each kiln under the floor and a transverse flue extended at right angles to the main flue in a line with the doors dividing the kilns into four segments under the floors. The floors were supported by fire brick arches over the flues and rested on lateral flues six inches in width connecting with the main flues. (See Plate II.)

In the manufacture of fire brick it is necessary to use some kind of binder to hold the fire clay together in the moulds especially where the grinding is not fine as was the case at Cerro. For this purpose a blue clay found about a mile from Cerro was used. This clay being off the line of the railroad, it was necessary to cart it to the plant, one dump cart with a boy driver being used for this purpose all the time the plant was running.

To determine whether or not this binder clay was chemically suitable as well as to determine which of the coal mines furnished the best fire clay, analyses of these clays were made.

A good fire clay should be high in silica and alumina and low in fluxing materials such as iron oxide, lime and magnesia. The same applies to the binder, though in a less degree as not so much of it is used in making the bricks.

In analyzing these clays the writer proceeded as follows: The sample was first dried and pulverized on the bucking board at the assay office. One gram of the clay was then weighed out and three grams of sodium carbonate $Na_2 O_3$ were added for flux. This mixture was placed in a platinum crucible and heated at a high temperature in a muffle for thirty minutes, or until fusion was complete. The crucible was then cooled, placed in a number two beaker and covered with hot water. This solution was then acidulated with a few drops of H. Cl and allowed to digest for ten or twelve hours. usually over night. In the morning the crucible was taken out, washed well and the solution poured into a casserole and evaporated to dryness. This renders the alumina $Al_2 O_3$ soluble. A few drops of $H_2 S O_4$ should be added to the solution while evaporating to clean the Si Oi. Cool the crucible, add three c c of H. Cl and then enough hot $H_2 O$ to just cover bottom of dish. This was allowed to digest for several hours. Fifty c c of hot $H_2 O$ were then added and the solution boiled for a few minutes. $Si O_2$ the silica is insoluble and the other salts are now in solution. The solution was next filtered through ashless filter paper, the filter paper placed in a platinum crucible, dryed and incinerated in the muffle. The residue in the crucible is $Si O_2$ and its percentage of the original clay is readily determined by weighing. A few drops of $H NO_3$ were added to the filtrate to oxidize the iron. The solution was then neutralized by adding $N H_4 O H$ and a few drops in excess were added to make it slightly alkaline. This solution was then boiled under a watch glass for ten or fifteen minutes. This precipitated the iron and alumina which was filtered out while hot and washed with hot $H_2 O$. Sufficient H Cl was then added to the precipitate to dissolve it and $H_2 O$ was added to make up one hundred c c of the solution. One half this solution fifty c c was then taken and to this was added fifty c c of hot $H_2 O$ and 5 c c of H. Cl. Freshly prepared stannous chloride was then added drop by drop until the solution became colorless. It was then cooled quickly and twenty cc of a saturated solution of mercuric chloride was added.

This solution was then titrated with a standard solution of bichromate of potassium the condition of oxidation being tested by means of spots on a spot plate. (These spots consisted of a weak solution of potassium ferri cyanide K_3 Fe Cy_6.) When the spots became colorless the titration was stopped and the Iron calculated.

To the second hald of the solution which contained iron and alumina a drop or two of $H\ NO_3$ was added and then it was made slightly alkaline with $N\ H_4\ O\ H$. This solution was boiled for fifteen minutes, filtered, washed with hot $H_2\ O$, dried and incinerated. The residue contained $Fe_2\ O_3$ and $Al_2\ O_3$. Having determined the Fe by titration, the $Fe_2\ O_3$ was calculated and this deducted from the weight of the residue gives the percentage of $Al_2\ O_3$.

The filtrate remaining after the Fe and Al has been removed was usually about one hundred fifty c c which was alkaline. This was brought to a boil. In another beaker a solution of amonium oxalate was then brought to a boil and twenty c c of the boiling oxalate were added to the boiling filtrate. This was stirred well and allowed to stand for ten minutes on a hot plate. It was then filtered through ashless filter paper, dried and incinerated. This residue was Ca O and the percentage in the original sample was determined by weighing.

The fire clays of the Cerro de Pasco district contained scarcely a trace of magnesia and we did not as a rule attempt to determine its percentage in the sample.

The following tables give the analyses of average Cerro binder and fire clays and English fire clays.

Clay	% $Si\ O_2$	% $Al_2\ O_3$	% $Fe_2\ O_3$	% Ca O
Vinchuscancha	44.2	29.3	2.5	5.2

Goyllarisquisga	56.4	16.5	3.7	5.8
"	58.2	20.2	3.8	6.
Cerro Binder	57.4	24.6	5.4	2.7
New Castle-on-Tyne	51.1	31.3	4.63	1.4
" "	48.6	30.2	4.0	1.7
" "	51.1	30.4	4.9	1.8

The chemical analysis of the fire clays from Vinchuscancha and Goyllarisquisga showed that the Goyllarisquisga clay was the better and this accordingly was the clay used at the plant except occasionally when a carload was shipped in from Vinchuscancha to fill in when we were short of the Goyllarisquisga clay.

The clay received in carload lots was unloaded outside the plant near the disintegrator and allowed to season as much as possible before using. By exposing the fire clay to the weather it is softened and becomes much easier to handle in the disintegrator.

Before running through the disintegrator the clay was sorted by hand and all lumps containing pyrite or stained badly by iron were thrown out. The larger lumps were broken up by sledges until they were about the size of an egg and then put through the disintegrator which reduced them to about pea size.

Having passed through the disintegrator the fire clay was then mixed with the binder in the proportion of four cu. ft. of fire clay to one and one-half cu. ft. of binder in the wet pan where at the same time it was ground finer and moistened. At the end of about fifteen minutes the prepared clay was turned out of the wet pan.

This wet clay was then carried by boys to the tables where it was violently thrown into wooden moulds by the moulders. The moulds were of several shapes and sizes depending on the dimensions of the brick required. They have a shrinkage allowance of three-quarters of an inch to the foot which is about the amount the brick will shrink in drying and burning. From the moulds the brick were carried to the drying room and racked. At night these fresh brick were covered with canvas so that they would not dry too rapidly and be too hard to press.

The next morning the brick moulded the day before were pressed and returned to the drying room where they remained for at least two days before being set in the kilns. As only one kiln was burned at a time and as the burning took nearly a week, most of these bricks remained in the drying room six or eight days.

While one kiln was being burned the other was cooling and being emptied. As soon as one kiln was empty and while the other was still burning or cooling the setters began setting the dry unburned brick in the empty kiln after first repairing any damages to the floor or furnaces.

The bricks were set five over six beginning at the outer side of the kiln and working toward the centre. Between each tier of brick a space of from $2\frac{1}{2}$" to 1" was left for the down draught of the furnaces. This space was decreased toward the centre where the draught was greatest and at the same time the height of the tiers of brick was increased. At the centre the brick were set six over six and this was the highest point of the brick in the kiln. The kilns were filled from one door only on the side toward the drying room.

After the kiln was completely filled both doors were closed by walling them up with brick and mud and the kiln was ready for firing.

In setting the brick in the kiln an opening about five feet above the floor and four inches by four inches was left without obstruction from one door to the other. This was called the peep-hole and was used to determine the temperature of the mass of brick from the centre to the outside tiers. Segar cones were set in this peep-hole to measure the temperature at various points.

These segar cones are made of porcelain and have known melting points according to their numbers. Thus the number 11 cone melts at 2000° F, the number 12 at 2250° F.

Having filled the kiln and closed all openings, a slow fire is started in each of the fire boxes the damper in the main flue being left wide open as at first there is very little draught through the damp bricks. This fire drives out the last drop of moisture in the bricks in about two days. This process is called water smoking. From the second day on the fire is gradually increased until at the end of the third day all of the furnaces are going at their greatest capacity. Four men and two boys are required on each shift of twelve hours to keep up these fires at this stage. As soon as the bricks become hot or about the fifth day the damper is closed down half way as by this time the draught is very great in the stack due to the intense heat. About the fifth day a look into the peep-hole was taken to see the condition of the bricks. Before opening the peep-hole the fires were allowed to die down somewhat so that there might be no smoke in the kiln to obstruct the view through the kiln. If the segar cones in the peep hole showed no signs of melting the fire was renewed and increased if possible until the number 12 cone fused in the outer tiers of brick. This usually occurred about the sixth day.

Owing to the way the bricks were set the centre does not become as hot while firing as the outer tiers but as soon as it is a bright red and the cone in the outer tiers has fused the kiln is finished. In cooling the kiln the heat in the outer tiers is driven to the centre which is really burned after the fires are out.

As soon as the kiln is hot enough as shown by the segar cone or inspection of the peep-hole, a liberal supply of coal is thrown into each furnace, the damper is closed to within about one inch of the bottom of the flue, the ash doors and furnace doors are closed and the kiln is left for twenty-four hours.

At the end of twenty-four hours the ash doors are opened. At the end of the next day the fire doors are opened and possibly one or two bricks removed from the tops of the kiln doors. This drives the heat to the centre and burns the centre bricks.

At the end of three days half the bricks in the doors are taken out and the next day the kiln doors are opened entirely and the kiln cooled as fast as possible. By the fifth day the bricks were being taken out and loaded on cars for the smelter.

The capacity of each kiln was from 35000 to 40000 brick, depending on the size. The standard square brick manufactured at Cerro were 9" x $4\frac{1}{2}$" x $2\frac{1}{2}$". These bricks weighed about 7250# per M. while the English bricks purchased before the brick plant was constructed weighed about 7100# per M.

The Cerro bricks were not of as high a grade as the English either chemically or physically. As stated above, owing to a lack of proper machinery they could not be ground fine without greatly reducing the output of the plant. This necessitated the use of more binder clay

than was used in the English brick which in turn decreased the refractory and increased the fluxing qualities.

A chemical analysis of the English brick showed that it contained $Si\ O_2$ 61.3% $Al_2\ O_3$ 35.5% Fe O 1.54% Ca O 1.4% with traces of magnesia.

The average Cerro bricks contained $Si\ O_2$ 54.4% $Al_2\ O_3$ 36.4% Fe O 4.39% Ca O 3.2%. The percentage of fluxing materials, viz. Fe O and Ca O it will be noted is much greater in the Cerro brick than in the English brick. For this reason while the Cerro brick was good enough for boiler settings, flues, coke ovens, &c. it would not do for the reverberatory furnaces which the company proposed building soon after the writer left Cerro.

In order to see if it were possible to secure a high grade brick with a minimum of fluxing material we undertook some experiments with silica bricks.

Near the coal mines at Coyllarisquisga the railroad cuts through some sandstone bluffs which seemed to contain very little if any iron. Samples of this sand were secured, analyzed and found to be suitable for silica bricks. The analysis of this sandstone was made in identically the same way as the analyses of fire and binder clays. The Goyllarisquisga sandstone contained 93.6% $Si\ O_2$, 1.56% $Al_2\ O_3$ and .7% Fe O.

The problem was to mix the sand obtained by putting the sandstone through the disintegrator with sufficient binder to make a brick which would not be too friable to be handled or burned and at the same time not to increase the fluxes to an extent which would impair the value of the brick.

Mr. Henry Vogel an experienced fire brick man had preceded the writer as superintendent of the Cerro brick plant and had made some experiments with this sand. Mr. Vogel succeeded in making a brick which met the requirements and seemed very satisfactory. When the writer took charge of the plant Mr. Vogel gave him his formula for these bricks and explained how he had made them.

Mr. Vogel stated that he mixed eight parts of dry sand or silica with two parts of finely ground dry binder clay and wet this mixture down with a solution of one part lime slacked in six pails of water so that it was just damp enough to be handled in the press.

We attempted to make these bricks according to this formula several times and though we used a special die and press were unsuccessful in getting a brick that was not very soft and crumbling. Bricks made in this manner contained $Si\,O$ 90.1% $Al_2\,O_3$ 6.4% $Fe\,O$ 1.8% $Ca\,O$ 1.9%, so that in addition to poor physical characteristics the chemical ingredients were not up to the standard. A good silica brick should contain not less than 92% silica.

After trying in vain to get satisfactory results by mixing with very little water as suggested by Mr. Vogel we determined to try mixing in the wet pan and proceeding the same as with ordinary fire bricks.

For our first experiment with this method we used 400# of ground sandstone 75# of binder clay and 10# of slacked lime. This was thoroughly mixed in the wet pan, the lime being added in the form of paste. The bricks were moulded, dired for six hours and then pressed. These bricks dried well after pressing and seemed hard and firm but when burned they turned out too soft to handle. The chemical

analysis too showed too much lime though the brick was higher in silica. Si O 91.5% $Al_2 O_3$ 6.6% Fe O 1.4% Ca O 3.9%. (Note this analysis shows over 100% due probably to the fact that H_2 O was absorbed by the Ca O before it was weighed).

The second experiment was much more satisfactory and we secured a brick which while not up to the English standard would be without doubt entirely satisfactory. For this brick we used 400# of silica and 75# of binder clay ground fine mixing them in the wet pan but not adding lime at all. This brick was moulded, pressed and dried as with the first brick mixed in the wet pan. It dried well and burned much better than any we had tried before. We considered this to be a fairly successful brick and the writer believes it to be better than those Mr. Vogel made first because mixing in the pan was much quicker and less expensive than Mr. Vogel's dampening process, and second, because the chemical analysis was better. This brick contained Si O 91.7% $Al_2 O_3$ 6.9% Fe O.5% Ca O –.

In these experiments the writer was very efficiently assisted by the foreman of the factory who was an exceptionally intelligent Cholo or native.

The entire factory force of laborers was composed of Cholos. While these natives had some very bad qualities, yet if handled with a little consideration they were not bad workmen. Nearly all of them are natural thieves and unless watched closely will steal any tool they use. At first the writer had some difficulty on this score but finally got the men to be fairly honest by the rather unjust method of deducting the value of any article or tool stolen proportionately from the wages of all hands. After losing a little of their wages once or twice the innocent ones soon brought sufficient pressure to bear on the guilty to keep them from stealing from the fire brick plant though all of them had no hesitation in stealing from other departments of the company.

The wages of the men varied from forty cents a day for the boys to four sols (1 sol equals 50 cents American) a day for the foreman.

The capacity of the Cerro plant when operating steadily was about 2500 bricks per day. The average cost of these bricks covering a period of six months was about 12 £ Sterling per M. Comparing this to the cost of English bricks delivered at Cerro for 40 £ Sterling, it is easy to see why the fire brick plant was constructed and what an exceptionally paying investment it really is.