II

Point Shirley Copper works

N. Whitney Conant 68

The following Review is respectfully submitted to the Faculty of the Massachusetts Institute of Technology, as a graduating thesis, by N. Whitney Conant, a candidate for a degree in the department of Mining and Geology.

Review of the Smelting Works of the Revere Copper Company.

The Works of the Revere Copper Company are situated at Point Shirley, about six miles from Boston, and immediately upon the sea coast. The location is one of the best, since it is removed from towns and farming lands and, therefore, no serious injury is occasioned by the fumes of Sulphurous acid, that inevitably attend the reduction of Sulphuret ores, and which must be allowed to escape possessing all their qualities deleterious to vegetable life since no cheap and feasible process has as yet been originated which will either utilize or render inert the poisonous vapors.

The advantages of convenient landing, for the unloading of the vessels bringing supplies are had, by the erection of a wharf near the works, in deep and sheltered water.

The Works are comprised in a space of about ten acres, in which there is ample room for the buildings for furnaces and kilns, sheds for storing coke, clay, bricks, and charcoal, blacksmith shop, oven for preparing the coke, &c. A railway traverses the wharf and works in all directions and furnishes an easy means of conveying the materials from place to place.

The arrangement of the Smelting Works proper, that is the building containing the furnaces, is shown by the drawing of the Plan of Main Building. The part enclosing the furnaces is a simple wooden frame structure, open its entire length on the side in front of the furnaces, but capable of being closed by doors. The object of this is to afford plenty light to the workmen and ready egress for conveying away the slag which is deposited in the yard on that side.

The building is two hundred and eighty two feet long by sixty feet broad, the roof twelve feet high at the side, and thirty in the centre. It contains twelve Cupola furnaces arranged in groups of two, as shown, having one stack or chimney for each pair. The wide space between the different pairs of furnaces is needed for the sand moulds in which the regulus is cast.

The engine house is of brick as indicated by the coloring. The engine is non-condensing of forty-horse power, and is used for driving the blast and the small stamp mill for mixing stepe and crushing ore.

Tracks of fifty inch guage are laid in front and behind the furnaces.

The ores reduced by the Company are obtained principally from California and the mines near West Farley, Vermont, and are for the most part, Sulphides containing considerable arsenic and some antimony.

Some carbonate and silicate ores are occasionally worked, but not in any great quantity.

The system of smelting employed is that known as the Continental method and consists of a roasting in the open air and fusion in cupola furnaces, with a final refining in a reverberatory furnace, a scheme of reduction which, under favorable circumstances, gives, usually, very satisfactory results.

Before proceeding to discuss the reduction of the ores, the construction of the furnaces, apparatus for creating the blast, preparation of the fuel and other necessary materials will be reviewed.

A description, with references to the plates, of the furnaces, is given, but the drawings are thought to be so complete, that an exact enumeration of the parts and their dimensions would be superfluous.

The various materials employed in construction are represented in the drawings by the different tints, as follows: Carmine indicates common bricks; Dark yellow, fire bricks; Gamboge, wood; Green, cast iron; Blue, wrought iron; Neutral tint, stone.

The furnaces in which the smelting is performed are of the kind known as low Cupola furnaces and consist of a shaft like structure of mason work, fifteen feet high, six feet broad, and five feet, six inches deep, communicating with a chimney or stack, placed near, by means of a flue at the top.

In the construction of the group of furnaces and stack 16000 common bricks and 5800 fire bricks are required. The common bricks are laid with ordinary lime mortar and the fire bricks, with a mixture consisting of one part fire clay to three of sand. The Company make most of the fire bricks used by them, obtaining the clay for the purpose from the Island of Martha's Vineyard. They are not burned but simply sundried. An imported English brick, known as the Black

Hancock fire brick, is used for repairing the lower part of the furnace where the action is greatest. The value of a fire brick for a smelting furnace, depends not so much on its power of withstanding an intense heat, as that of resisting the fluxing or dissolving action of the charge.

The iron work necessary, is shown fully by the drawings.

The drawing of the Plan of Furnaces and Stack, is a horizontal section at the surface of the ground, showing the thickness and position of the parts composed of fire and common bricks, of the cast iron Stepe box in front, of the iron pillars, and blast pipe. The bearing plates to which the wrought iron rods are bolted, binding or cramping the stack together, do not extend to the ground, as would be indicated by the plan, but only as far as shown in the Elevations. They are, however, drawn in connection with the plan in order to show the section of the plates and way of applying them.

The Sections of Furnace are on the lines AB, and CD, in the plan, and show the shape and material of the walls.

Sections of the foundations are also shown, which extend down the thickness of seven bricks, widening a brick and a half at the bottom

A section of one of the tuyères is also given. The tuyères are of cast iron, the outer six inches, and the rest, of fire clay, or simply an opening left in the bricks. It does not answer to have them wholly of iron, since the inner part is rapidly destroyed, of whatever material composed, and the fire clay will last as long as the furnace can be used, before requiring repair.

It is unnecessary that the fire bricks extend lower than the ground, since the space between the foundations and the top of the box, is rammed with a mixture of sand and clay, having a layer of stepe above so that heat sufficient to destroy common bricks is not felt at the bottom.

Neither is it required that the whole of the walls should be of fire bricks, but only the interior and lower parts, where the heat is greatest. Since the front is replaced every time, when starting the furnace, as great thickness is not demanded there as on the other sides.

The inner and outer walls of the two materials are not bound together by the interlocking or breaking joint of the bricks of the different kinds, as the fire bricks being larger, by an inch on each dimension, render it impracticable and the binding of the iron rods, ties, and bearing plates is sufficient to prevent cracking of the walls by the heat.

The interior of the furnace is made four inches wider at the front than at the back, in order to make the contents, when in operation, tend to move forward.

The top of the flue is closed with tiles of fire clay, as well as the bottom where it leads into the Stack.

The Stack being the same on the sides and back as in front, with the exception of the small door, only the front Elevation was drawn. The door is for removing the fine ore, dust, &c carried over by the draught, and so great is the amount, it is necessary to clean the stack once a week. The top or chimney extends ten feet after it stops narrowing, reaching above the roof.

It is essential that the stack should be bound together, also, on account of the heat from the furnaces.

Since the furnaces on either side the stack are similar, only the elevations of one are shown. The cast iron box seen in the Front, and Side Elevations of Furnace is lined with fire bricks and filled with Stepe, a mixture consisting of one part charcoal, one part clay, and three parts coke well pulverized, and is used as a basin into which the melted components of the charge flow and separate by the difference of their specific gravities; the slag going off in front, while the metal or regulus is drawn from the spout at the side.

The small Window seen in the Rear Elevation, is for charging the ore mixed with the fuel and flux into the furnace.

Stout wooden platforms of simple construction ten feet high, fourteen feet broad, and twenty four feet long, extend behind the furnaces, between them and the car track)

The ore &c being thrown upon this platform from the cars, are conveniently mixed and fed.

The Cupola furnace is the most economical of all apparatuses for smelting. The consumption of the fuel taking place in immediate contact with the ore, subjects it to the most intense action and the heated gases or flames having to pass, on their way upward, through the layers of mineral, the latter absorbs most of the heat so that they pass off at quite a low temperature, compared with those that escape from a reverberatory furnace.

Cylindrical furnaces of wrought iron, lined with fire bricks and of about the capacity of the cupola furnaces, have been tried by the Company. They were charged at the top the same as the others and the blast admitted on three sides; the product obtained by smelting in them was very good. The use of them, however, has been abandoned, owing to the trouble and expense of the thorough repairing which they required every two or three days.

The Draught.

Since great heat is required for the smelting, a strong draught has to be created in the furnaces which promotes combustion, acting as a large blowpipe. The draught or blast, as it is more generally called, is generated here in two ways; first, by two single acting air pumps, of sixty eight cubic feet capacity, making twelve double strokes per minute, forcing air into a receiver, of about three fourths their size, placed between them, from which the main or delivery pipe leads, and second, by a rotary blower, twenty eight inches in diameter, made by Sturtevant of Boston.

The rotary blower supplies the six furnaces nearest the engine room, while those towards the other end of the works are blown by the force pumps. The main air pipes are of cast iron one foot in diameter and one half inch thick. The one leading from the blower, extends along the building near the roof, and immediately in rear of the furnaces, furnishing the supply near the ground by branch pipes leading down; the other, is placed one foot below the ground and three feet in rear of the furnaces, in order to be well clear of the foundations and communicates with the furnaces through the vertical pipe and air box from whence the tuyeres lead, as shown in the Side and Rear Elevations of furnace.

The blast is admitted by raising a horizontal plate, which fits air tight in the vertical pipe, above the point where the pipe that leads to the box joins the upright one; this being accomplished by means of a screw, the draught can be regulated with nicety. The pressure with which the air enters the furnaces is about three fourths of a pound on the square inch.

The object of the air box is to provide a way for inspecting the interior of the furnace during the process of smelting. The openings of the tuyeres are in the furnace immediately opposite the orifices in the air box, shown in the Rear Elevation which are fitted with eye pieces of glass, and the workman looking in at them sees through the tuyères into the furnace. The detail drawings, on the same plate, show the parts of the air box. It is made entirely of cast iron, with the exception of the bolts. Pieces of rubber are placed on the bolts, which fasten the box to the cast iron uprights, in order to admit of the small movement occasioned by the expansion of the parts by the heat, without opening the joint of the pipe and box. The box does not seem to be of economical construction as it extends much beyond the tuyeres on both sides, for which there is no need, and it requires also to be cast in at least six pieces. Cast iron pipes, five inches in diameter, bent at right angles, with openings at the elbows for the eye pieces, would answer as well and be cheaper.

The blast is cold and although it is generally recommended that it be hot, it does not appear that it would be economical to heat it here, since the fusion is obtained well enough with the cold, and the saving of fuel in the furnaces by using a hot blast would not compensate for heating the air, unless it would be possible to use for the purpose the waste heat from some of the necessary processes.

Preparation of the Coke.

In the treating of Copper ores in Cupola furnaces a fuel is required devoid of those constituents which melt and volatilize at a low temperature, producing a clotting or thickening and preventing proper combustion by the exclusion of the necessary air. Coke and charcoal are the fuels possessing these qualities in a high degree. Coke, owing to its greater cheapness, is used at Point Shirley, and is prepared there also, since it can not be obtained cheaply otherwise.

A series of six closed ovens or furnaces of bricks, ten feet by twelve feet, arched at the top and strongly bound together with iron ties is employed for the coking.

The ovens have each a circular opening in the top, through which the coal is thrown, and a door in front where it is withdrawn after being coked. They are arranged in a row and communicate with each other at the sides. Twenty four hours suffices for the process, so that the ovens are drawn and charged again each day. Each oven is capable of coking one ton of coal at a time.

When the proper charge has been added, it is soon fired by the heat radiated from the sides of the oven; enough air is then admitted to consume the gases given off, and thus a high temperature is maintained. The coal soon melts and those portions which can of them=selves form gaseous compounds at a high temperature are liberated. The coke is then not liable to waste unless more air is admitted, and if it is left exposed to the heat for awhile after being formed, it becomes harder and works better in the furnace, being less liable to crumble and decrepitate. When combustion ceases the process is considered finished, and the entire mass is pushed out at the doors and quenched by dashing water upon it.

Good coke contains about eighty five per cent. of Carbon, and may be known by its clear bright colour, its homogeneousness, and freedom from earthy or incombustible ash.

The hotter the oven or furnace is during the coking, the better the coke, since then but little loss of carbon is sustained.

When the coal is melted the hydrogen present in it combines with the carbon forming bicarburetted hydrogen gas (C_2H_2), which at once escapes passing upward through the red hot coke, which should be at a higher temperature than the coal that emits the gas. When bicarburetted hydrogen is exposed to a bright red heat it is decomposed forming carburetted hydrogen gas (CH_2) and solid carbon, therefore if the furnace is managed well and the coke kept hot, the carbon is liberated and detained in its upward passage, being either absorbed by the coke or crystallized upon it.

The coal used for making the coke is a good caking one, from Cumberland Nova Scotia. The supply of coal on hand at the works is left uncovered and entirely exposed to the weather. The escape of the volatile ingredients, which is known to be occasioned thereby, is of no great loss since the process of coking itself is to get rid of them, but it is also an established fact, that coke made from weathered coal, loses its coherence and is of an inferior quality.

Treatment of the Ore.

The ore, containing much Sulphur, arsenic and iron, a small quantity of Antimony and from fifteen to twenty per cent. of Copper in a siliceous gangue, is heaped in the yard, uncovered, in quantities of about seventy-five tons, preparatory to the first operation, called Roasting.

The heaps for roasting are made upon a bed of clay, by placing first a layer of fine ore, four inches thick to protect the clay foundation, then a quantity of wood for kindling, and the ore in lumps on top. Over the heap, thus formed is spread a coating of fine ore, three inches thick, as a protection from the weather. The wood is then lighted and serves to ignite the sulphur, arsenic, etc, of the ore which continue to burn slowly for three or four months.

It is well to have the ore moist when heaped, as it burns better, for the water evaporating leaves the mass loose and permeable for the air. It is quite probable, also, that some of the water takes an active part, chemically, in the combustion.

The product of the combustion, is in the main, sulphurous and arsenious acid, which pass off in dense white vapors. Some of the antimony is also expelled, probably in the shape of sulphide of antimony.

About fifteen per cent. of those parts of the ore, volatile at a moderate temperature, are got rid of in the roasting, little or no loss in weight is sustained, however, as the sulphur, etc, expelled are substituted by oxygen absorbed. A good part of the iron present thus changes from the sulphide to the oxide.

The fine ore used for covering the the heaps, being incapable of roasting, is calcined in a small reverberatory furnace by the waste heat of the coke ovens. It was once the practice of the Company to calcine a considerable part of their ore in reverberatory furnaces, but finding it unprofitable, abandoned it. The ore had to be pulverized, considerable fuel was required, and an extra engine was necessary to create sufficient draught. On the other hand, for roasting in heaps no breaking of the ore is demanded. and fuel enough to start the burning, is all that is required. The plan of the furnaces themselves was not of the best, as the ore was charged at doors in the side, instead of through hoppers at the top, the arrangement usually adopted, thereby losing much time and labor.

The saving in time by calcining ore is considerable, it taking but from nine to twelve hours; while the roasting occupies, as before said, some three or four monts, yet, where space for the heaps can be obtained, it must be economy to keep a large amount of ore on hand and roast in heaps.

After combustion in the heap ceases, the roasted ore is ready for the next process, that of Smelting, which takes place in the Cupola furnaces.

The separation of Copper by Smelting depends upon two of its marked peculiarities, which are:- first, its attraction for Sulphur, which is stronger than that of any of the metals with which it occurs; and second, its slight affinity for oxygen less than that of any of the metals likely to be found with it, except, silver and gold,

By keeping it in combination with the sulphur present in the ore, the metallurgist obtains a comparatively fusible compound which on account of its peculiar specific gravity, easily separates from many of its less fusible, and lighter or heavier impurities. By roasting, the furnace products, the sulphur, which is undesirable in the subsequent and final operations, is expelled. and the impure metal being subjected to the oxidizing agency of the air, while fused, combinations advantageous for the separation, are produced in the adulterating substances, without materially attacking the copper.

In starting the operation of smelting. two or three hundredweights of coal are placed in the furnace. towards evening and kindled. The door is then closed with fire bricks and a couple of tiles, which are placed at the bottom for greater strength, luted together with fire clay mortar, and braced by means of rods which are held by the bars, marked A, in the drawings of the Front and Side Elevations.

A small hole or eye is left at the bottom of the door, through which the melted metal and slag, formed in the furnace, may discharge into the box in front.

The coal fire burns over night and heats the furnace thoroughly; in the morning coke is filled in as high as the window, and several hundredweights of slag, rich in copper, from a previous smelting, also added. The air or blast is then admitted and in about half an hour the slag begins to flow out at the eye. When the first charge sinks, the furnace man fills in ore and fuel, in the proportions previously determined, keeping the furnace, thereafter, always full to the bottom of the window.

The object of this smelting is to separate as much of the iron as possible and all the earthy matter. The aim is to supply only enough coke to insure good combustion as it is desirable to use as much of the sulphur for fuel as possible. A bulk of fuel, equal to that of the ore reduced, is on an average necessary.

The condition of fusion is determined by the inspection of the interior of the furnace through the tuyeres. If there is not sufficient heat, the fire is examined to see whether it is due to an excess or deficiency of fuel, or an improper draught, and the irregularity immediately corrected.

The chemistry of the operations which take place in the furnace, is principally, the formation of a complex silicate of iron and other bases, such as alumina and lime, and the oxidation and expulsion of sulphur and other volatile ingredients. Iron, at a high temperature has a strong tendency to unite with silicic acid, especially in the presence of a fusible flux, such as fluor spar and silicate of iron combined.

Fluor spar is never used at these works since it is expensively obtained and the mixture of foul slag, which contains much silicate of iron, is found to be a sufficient flux. Some lime, however in the shape of carbonate, is occasionally added; and the carbonic acid being expelled, it combines with the silica, forming silicate of lime, and tends to render the slag fluid. There is usually silica enough in the ore to combine with the iron etc. when there is not, a sufficient quantity of carbonate, or silicate of copper, having a quartz gangue is used to supply the needed silica.

It is best to add no more flux than is absolutely necessary, as a greater quantity of slag is thereby created, and consequently a greater loss of copper sustained by the retention in the slag of minute particles of the metal.

The fusion having taken place, the mass of regulus, or ore metal, and slag flows out from the furnace into the box in front filled with steps, where the separation of the parts takes place. The regulus being the heavier, sinks below the slag, and the box soon filling; the slag is discharged, from the spout in front, into iron pots, fastened upon wheels, and after cooling slightly is conveyed to the slag heap in the yard, preparatory to being picked over and assorted. The portions of slag which are foul, that is contain any considerable amount of copper, are returned to be re-smelted.

The iron pots are covered, on the inside, with a thin coating of fire clay, by dashing a mixture of fire clay and water into them while hot, to prevent the silica of the slag from attacking the metal of the pot and sticking to it.

As soon as there are indications that the regulus has nearly reached the top of the box, the tap in the side is opened and the regulus flows out upon a flat bed of sand, divided into several portions, called the sand moulds.

The separation of the slag and regulus is never perfect and the quantity of metal left in the slag is varied by many circumstances, it being quite a difficult matter to attain the exact composition of a charge to produce the best result.

If the regulus be very poor, and the slag of about the same degree of fluidity as the metallic bath upon which it rests in the box, there will be a greater mixing of the two, than if the regulus was richer or the difference in their fluidity greater. The important point, therefore, is to make such a mixture of ore, flux, &c that the resulting regulus, or matt, may be of such a specific gravity, that it will readily subside and exactly separate from the slag.

The oxide of iron in the foul slag added is an important agent in attaining this result, while much also depends on the earthy matter of the gangue, the best results being obtained when they are so proportioned as to form a highly crystalline slag. It is usual to vary the proportions of the different ingredients of the charge until the right mixture is hit upon, after which nothing is required but to add the charge in the determined proportions.

Under the best conditions there is always a small loss of metal, estimated at one half of one per cent. of the copper in the ore, in the slag denominated clean slag, and which is thrown away.

The regulus from this first smelting contains from thirty-five, to forty per cent. of copper in the form, principally, of sulphide mixed with some, metallic, and a little as oxide; the remaining portion consists in the main, of iron and other metals, combined with sulphur, and some free sulphur. The earthy matters, some of the sulphur, and much of the iron, has been slagged off.

The amount of ore fed, in one furnace, per day, is about 25000 pounds, producing from 2500 to 3000 pounds of regulus. The furnaces are worked, during the day only, for a week, at the end of which time the interior is all melted, or eaten out as it were, and it becomes necessary to repair it. After cooling it is cut out to the sound bricks, and the form restored, which requires on an average about 500 new bricks. One, only, of a pair of furnaces is worked at a time, so that one may be undergoing repair while the other is in operation.

After the regulus has solidified it is removed from the sand moulds, water, dashed upon it to render it brittle, and then, broken into pieces convenient for handling, with sledge hammers.

After cooling it is loaded upon cars, on the track in front of the furnaces, and removed to undergo the third process, namely: that of, Roasting in kilns.

The kilns consist of brick stalls six feet high, and broad, and seven feet deep, lined with fire bricks, closed at the back and entirely open in front. The bottom is one foot from the ground and composed of an iron grating, the bars of which extend the whole depth, are one and a half inch square in section and placed one inch apart.

There are fifty five kilns, in all, used. They are arranged in five rows, two pairs of the rows being placed back to back, so that the flues, which traverse the tops of the kilns communicating with each one, from both rows may lead to the same chimney. The vapors from six or eight of the kilns are thus conducted to the same outlet. The odd row can have another built in rear of it when necessary.

The regulus, in pieces of about one pound weight, is charged upon the bars in quantities varying from 1000 to 1200 pounds according as there is more or less sulphur present. About half a hundredweight of coal and a dozen sticks of wood are necessary to start the roasting, and the sulphur then continues to burn for about thirty-six hours, in twelve hours more it is cooled sufficiently to be taken from the kilns, broken up, mixed, and returned for another roasting.

The front of the kiln, when charged, is closed by a loosely laid wall of refuse fire-bricks at the bottom, and a sheet iron screen at the top. This is done in order to produce a strong draught of air upward, through the regulus during the roasting.

The action which takes place in the

kilns, is the oxidizing of the metals and sulphur. Some of the sulphur passes off as sulphurous acid, while another portion is oxidized to sulphuric acid and combines with the copper and iron. At some works it is the practice to remove the sulphate of copper thus formed, by a process of lixiviating and subsequent crystallizing. Such is not the custom here, as they do not desire the copper as blue vitriol, and it is cheaper to reduce it all together and make but one operation.

The regulus after undergoing five or six roastings, becomes, in the main, a mass of oxides, containing but little sulphur, and is then ready for the final smelting.

After leaving the kilns, the regulus is taken back to the same furnaces and is submitted to another smelting similar to the first, except that more fuel is used since there is not much sulphur present. The carbonic oxide supplied by the fuel in conjunction with the great reducing power of the strong heat produced in the furnace serves to separate much of the oxygen from the copper. The slagging off of the iron and other metals takes place as before.

The same manipulation of the charge is practiced, with the exception that the regulus, which is now nearly pure copper, is run into small iron moulds instead of into the sand. The copper settles to the bottom and whatever slag accompanies it floats above and when cool, is easily knocked off

All the slag from this last, with the foul slag from the first smelting is worked over, since the amount of copper contained is too great to be neglected. It is smelted by itself, a small amount of ore being added to serve as a flux.

This second smelting completes the process performed at Point Shirley and the impure or black copper obtained, consisting of about ninety five per cent. copper with a small admixture of iron, sulphur, and oxygen, is next removed to the Company's works at Canton, refined in reverberatory furnaces, and is then fit for commercial or manufacturing purposes.

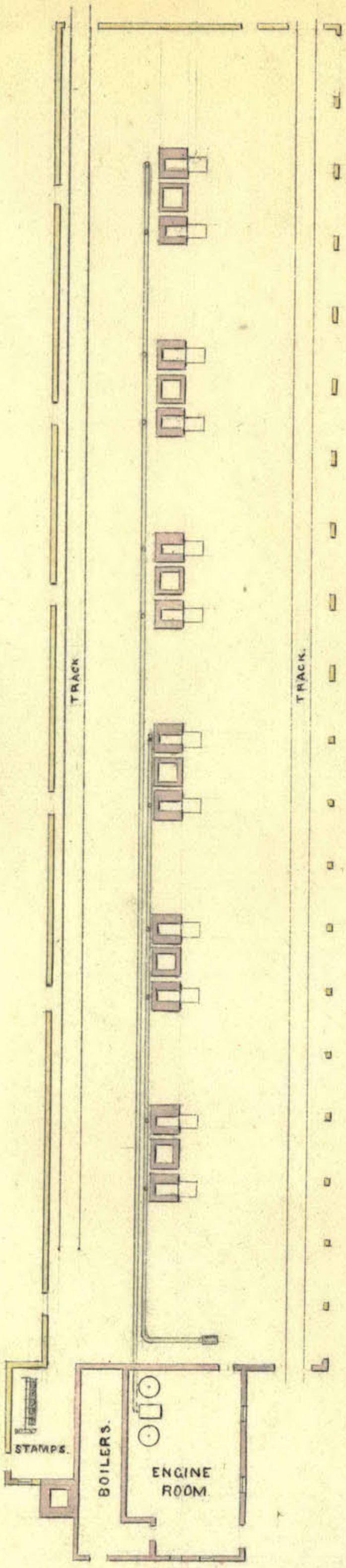
The works have been in successful operation for about twenty five years. Some forty men, in all departments, are required to carry them on.

The quantity of ore smelted per annum varies from 6000 to 10000 tons, which produces from 1000 to 1800 tons of Copper. Owing, however, to the low price of the metal of late, the company have smelted only enough for supplying their business of manufacturing copper and yellow metal sheathing, and ships' fastenings.

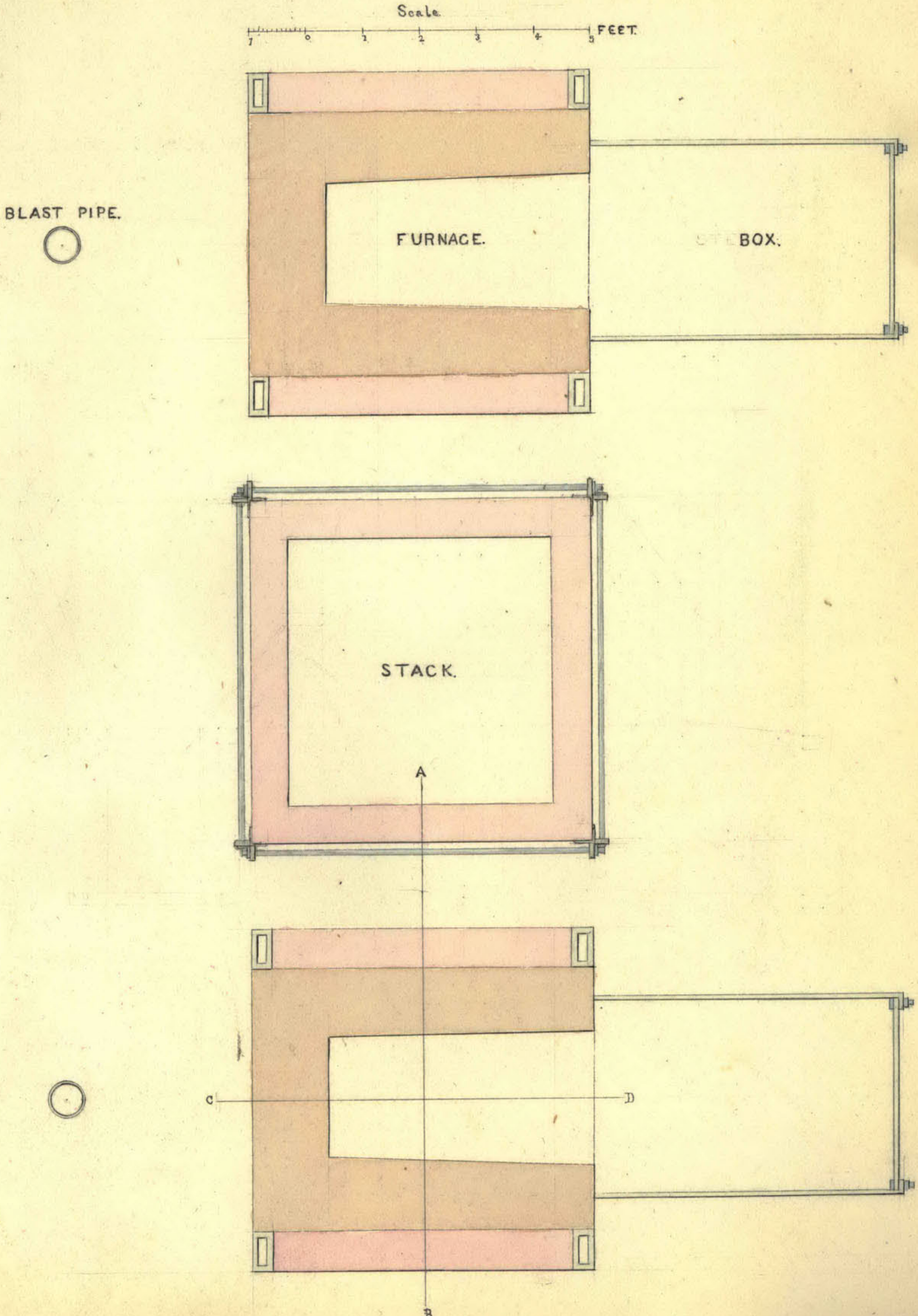
PLAN
OF
MAIN BUILDING.

Scale.

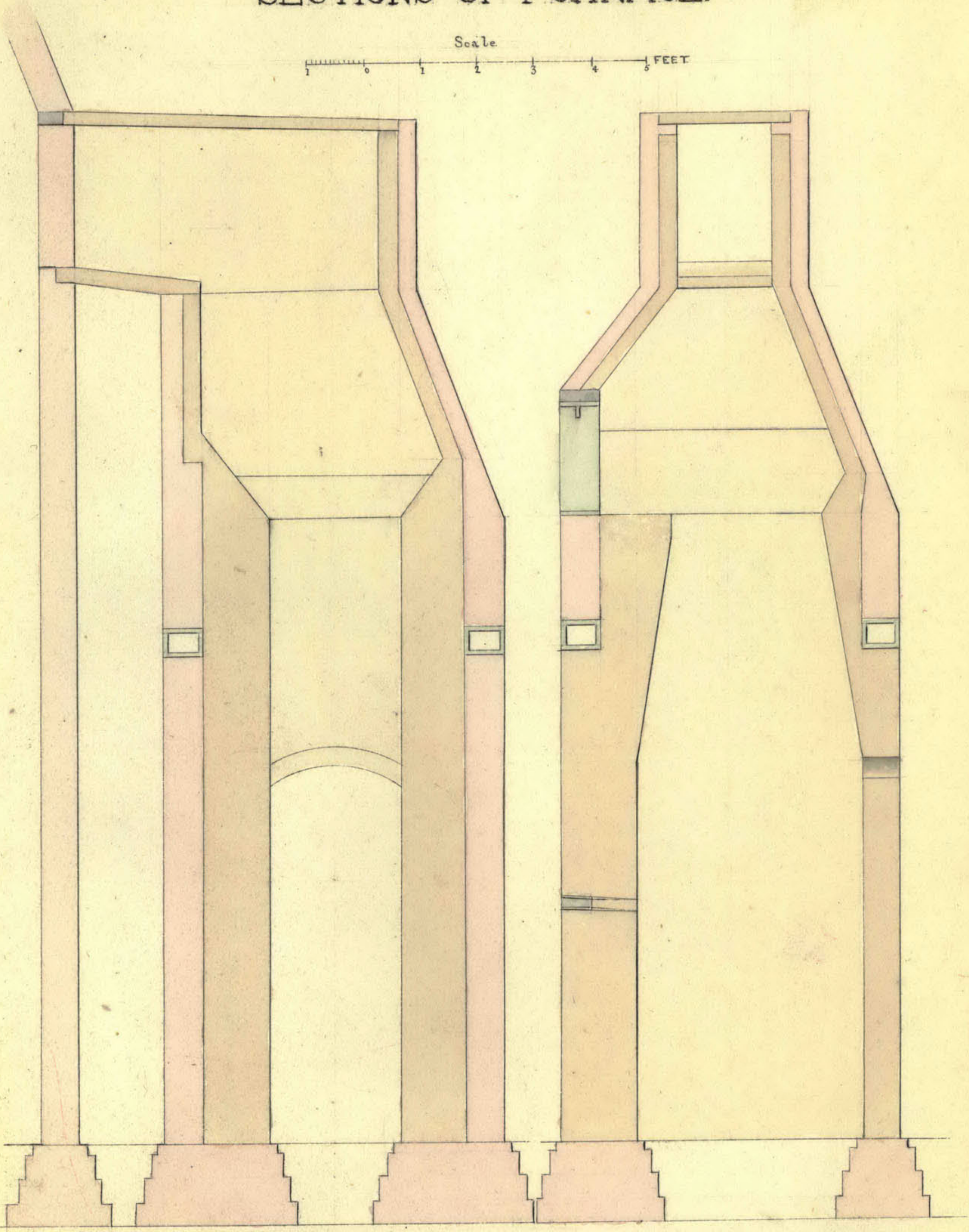
10 0 10 20 30 40 50 FEET.



PLAN OF FURNACES AND STACK.



SECTIONS OF FURNACE.



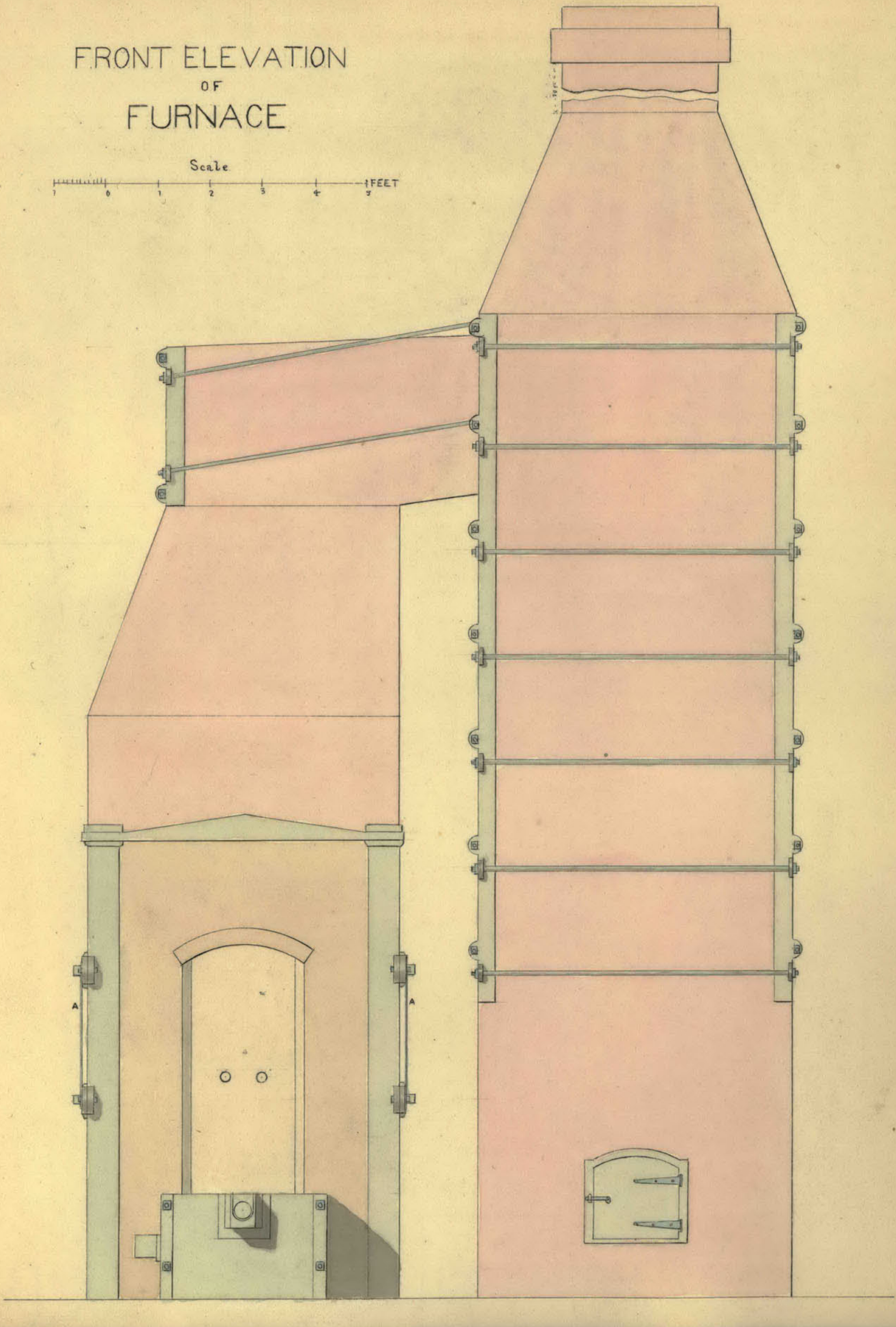
SECTION ON LINE A_B.

SECTION ON LINE C_D.

FRONT ELEVATION OF FURNACE

Scale

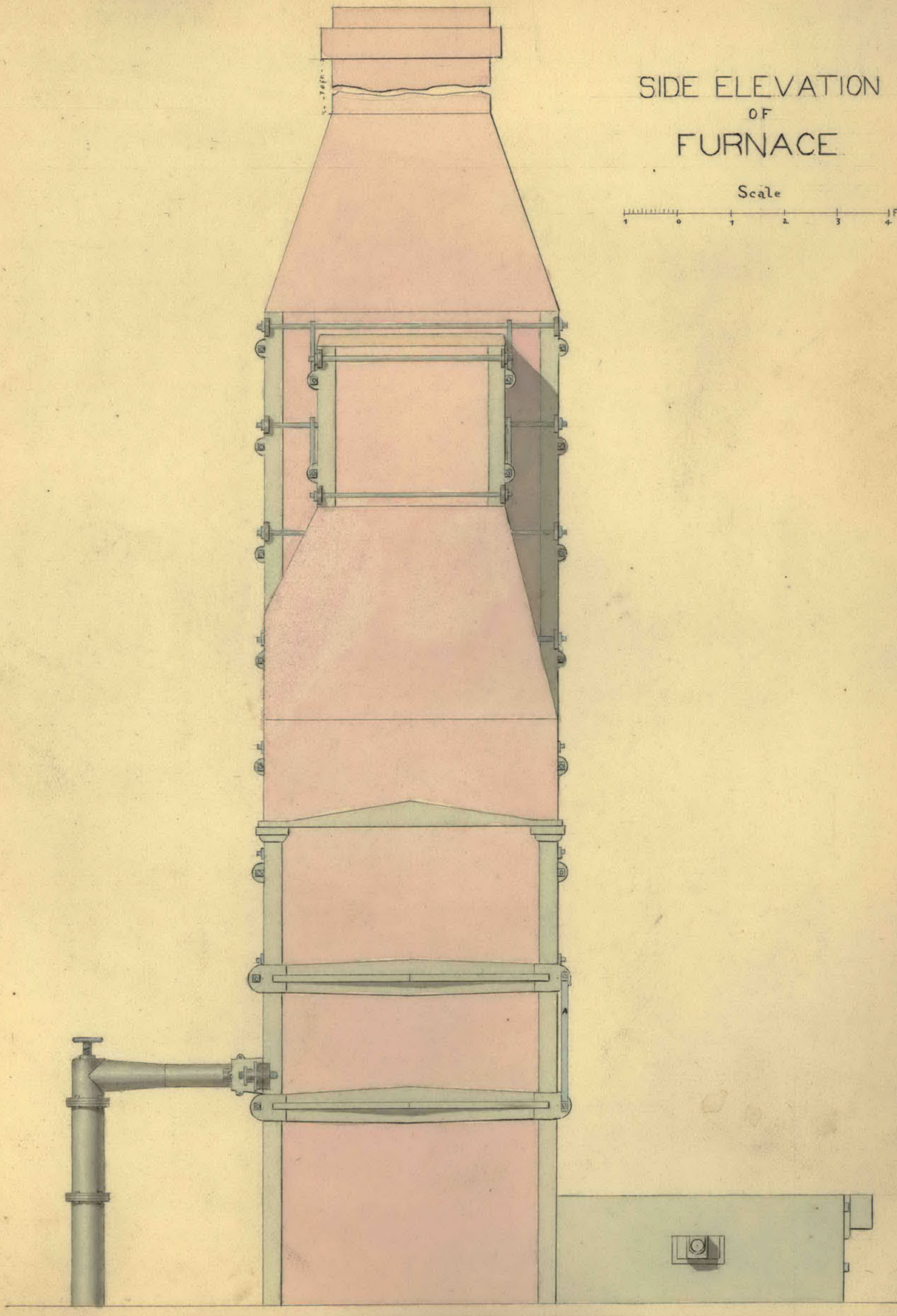
1 0 1 2 3 4 5 FEET



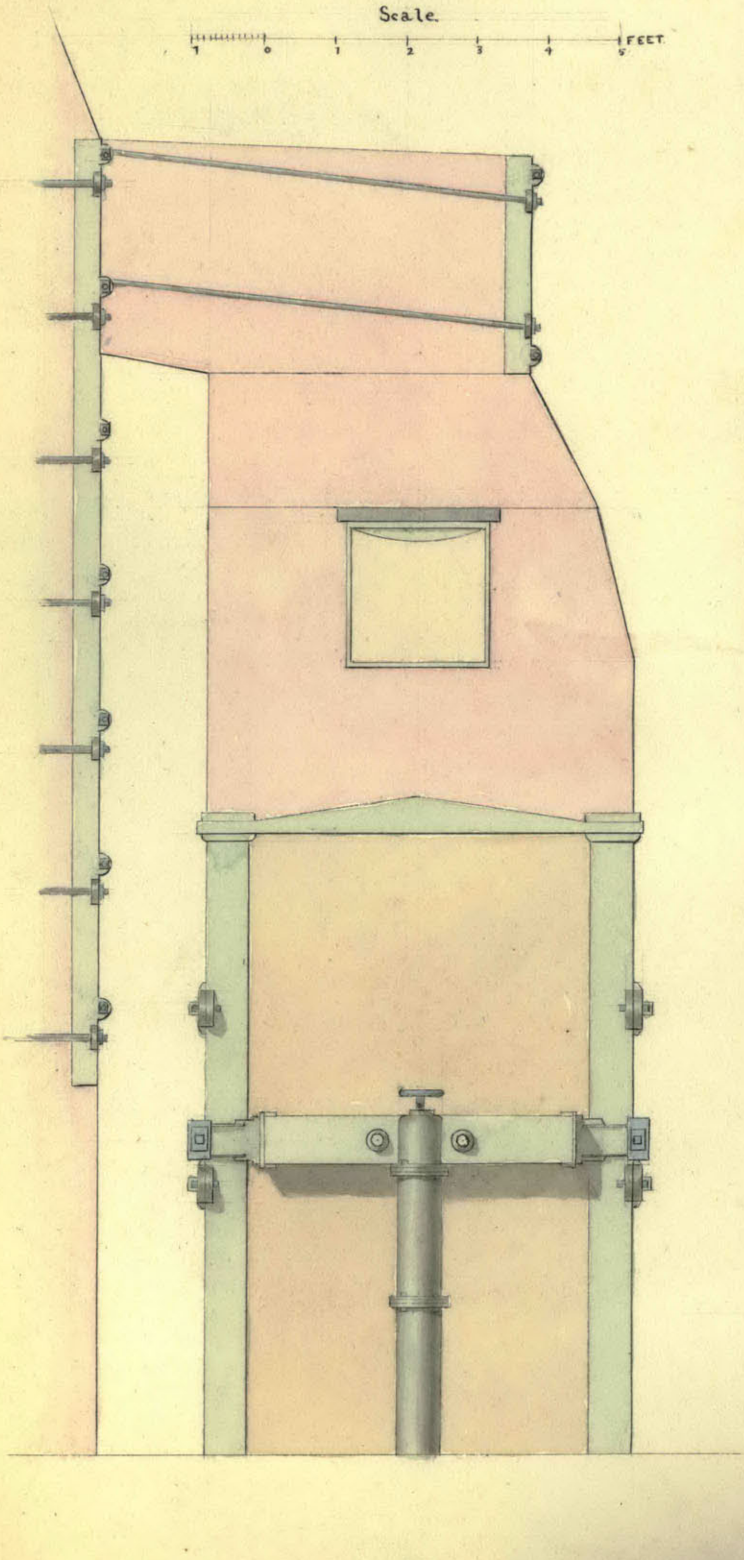
SIDE ELEVATION
OF
FURNACE

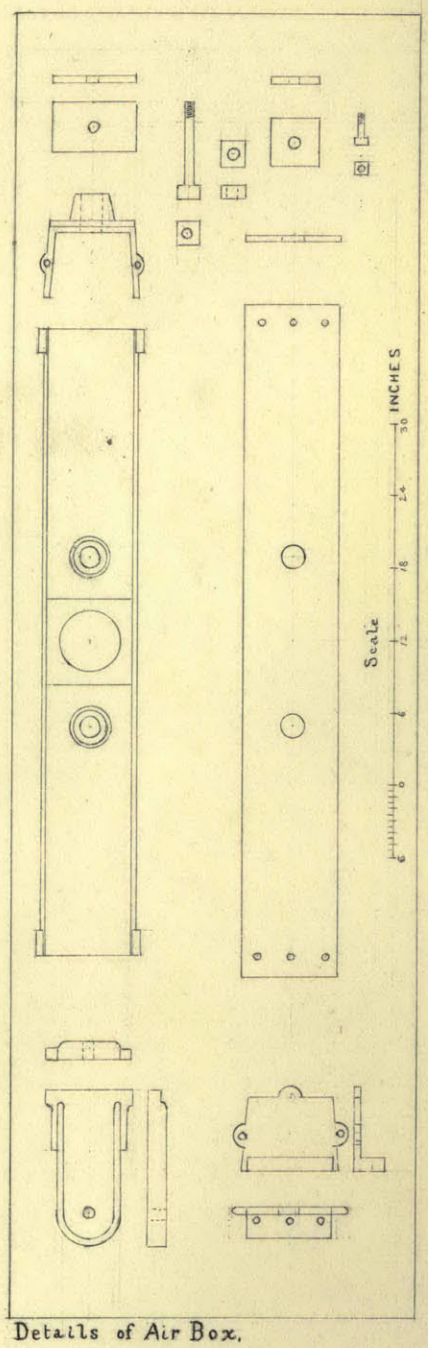
Scale

1 0 1 2 3 4 FEET



REAR ELEVATION OF FURNACE





Details of Air Box.