

ELECTROSTATIC DUST PRECIPITATION
AND THE MIAMI SMELTER

A THESIS SUBMITTED TO THE FACULTY OF
THE GRADUATE SCHOOL OF
THE UNIVERSITY OF KANSAS

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR
THE DEGREE OF ELECTRICAL ENGINEER

BY

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1916



Current On



Current Off

The same stack under the same working conditions except that in the one case the electric current was switched off for a few moments to photograph it with the smoke escaping.

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ELECTROSTATIC DUST PRECIPITATION
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With smelters come noxious fumes, fatal to vegetation and harmful to public health. These, in turn provoke damage suits and adverse legislation. The abatement of the "smoke nuisance" in smelters alone has assumed large proportions. (1) The plant of the International Smelting and Refining Co. in Miami, Arizona, is situated in a section where agriculture is limited. The copper ores coming to the smelter are largely sulphides but the quantity of objectionable gas, mainly SO_2 , from its furnaces is relatively so small that the management felt safe in turning it into the atmosphere under proper precautions. (2)

On the other hand, the low grade ores, here, are finely ground at the mines; the concentrates, though wet, come to the smelter pulverized. Hence, solids in the

(1). One smelter at Ducktown, Tennessee, is devoting a plant covering $2\frac{1}{2}$ acres, and said to have cost millions, to purifying its smoke and recovering values therefrom.

(2) The smelter was placed upon a hill, some 600 or 700 feet high, and two great stacks carry the smoke 300 feet higher.

smoke is a serious matter. The wide experience of the International, in smelter construction and operation enabled it to anticipate problems in this type of concentrates well. The precipitation plant was built with the smelter, not afterwards. The company had not tried the Cottrell system in any of its other smelters, nor had anyone connected with the installation here had experience with it save the representative of the selling company. (1)

(1). Ample demonstration of the success of the new scheme was to be seen in California. The Balaklala Smelter was equipped with the Cottrell treaters in 1911.

The Riverside Portland Cement Co. was collecting nearly a hundred tons of dust a day from its smoke stacks and, I understand, has since considerably increased its treaters in conformity with the enlargement of the cement plant. This company had spent upwards of a million dollars buying orange groves, most of which had been allowed to die, but had not cleared itself of legal entanglements, which threatened the very life of the plant. Groves not completely ruined before the precipitation plant began operations, are now reviving. A few months ago, a large section of the "dying" groves appeared in full bloom and had apparently completely recovered from its dust bath. The material recovered from the smoke contains potash and sells as fertilizer for but little less than the cement brings. The cost of installation was within \$200,000. The plant is run by one man (i.e. three carry it through 24 hours). Instead of driving the company out of business, the dust is paying a handsome profit.



a

a b c d e f

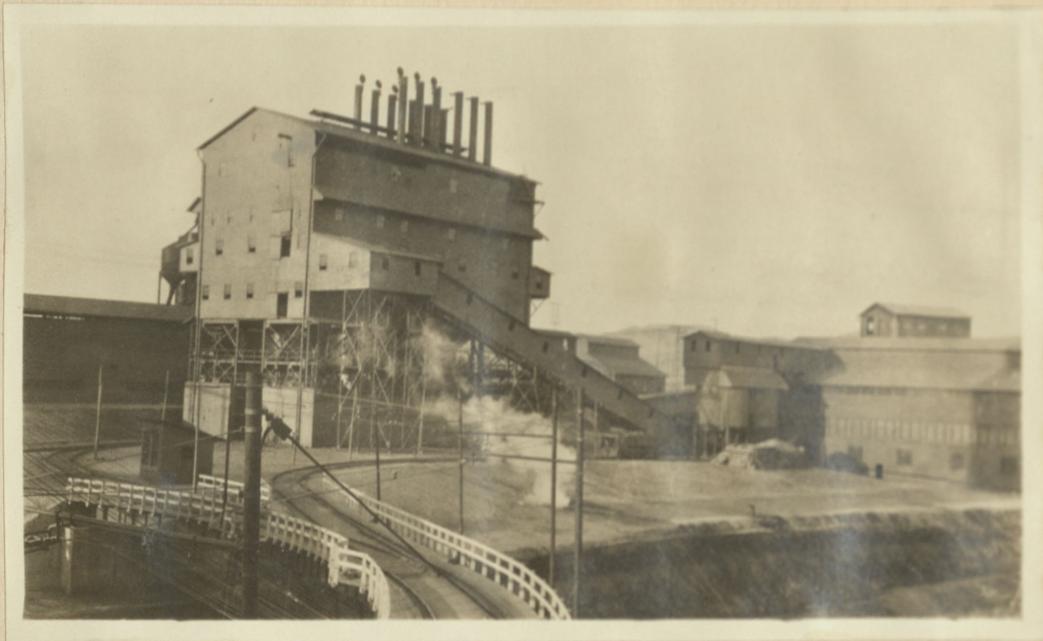
The Northeast Group.

(a) Power House; (b) Waste Heat Boiler Shed; (c) Reverbratory Shed; (d) Converter Building; (e) Converter Treater Building; (f) Machine Shop.

Taken after the first fires were started and before the treaters were running.

The plan of smelting here, involves three principal sets of fires. First the roasters, where the concentrates are dried from mud to powder, and where the greatest amount of dust is recovered. Second, the reverberatory furnaces, whose products of combustion pass downward through large brick flues to the waste heat boilers where water tubes, with the passages etc. entrap so much dust that no precipitation plant was installed here. However, experiments and smoke analyses, ⁽¹⁾ carried on since the plant is in operation, indicate that added treaters at this point would probably pay for themselves. Third, the converters, which yield the most valuable flue dust; and perhaps fourth might be mentioned the purifiers and casting machines, which are without chimneys and produce nearly no dust. California crude oil is used for fuel throughout the smelter. There are five Wedge roasters, three reverberatory furnaces and five converters. The smelting capacity of the plant is determined by its reverberatory capacity. The plan is to run two of these furnaces at a time. The first was "blown in" May 12, 1915, which date may taken as the beginning of operation.

(1). Aside from furnishing a little material, the writer had no part in this interesting work, hence omits description of it.



Roaster Building

Six treaters and four roasters are in full operation and no smoke comes from the chimneys. Note that the chimneys in use have the dampers raised, while the others have these doors down.

THE COTTRELL SYSTEM.

The dust is collected by electrostatic attraction and repulsion of the particles passing between charged electrodes. In experimental days, attention was given to the shape of the electrodes with reference to their electrical efficiency. The inventor had in mind the value of many sharp points on one electrode for driving a stream of dust against the other one.

Suppose the collecting electrode be the inside of a large, round, vertical pipe, and the repelling one, a wire hung axially through it, then the wire might require a many pointed covering. An ordinary cotton covered wire gives a beautiful brush discharge along its entire length. Two wires, with mica or asbestos twisted into them, offer a continuous succession of points and bear heat and working conditions. The inventor found, however, that a high voltage gave results where rough electrodes failed-- he must provide a unidirectional current of 50,000 to 100,000 volts. Alternating E.M.F. has a dust settling tendency but does not drive the particles to the electrodes nor do the flakes of adhering particles settle, in the face of a working flue draft.

Experiments on electrodes of wire and of chain, varying in size, shape and conductivity, carried on at this smelter, seem to justify the original contention of the writer that it is unimportant what the central electrode is made of; it will soon be but the core of a mass of flue dust in any event. A No. 20, high resistance wire hanging down the center of a 14-inch flue, after nine days' use had become the center of a stick of dust, in places five inches thick, and arcing to the inside of the flue, though the flue itself had been jarred free from dust every four hours during the time. Ordinary telephone wire is in the flues now. The main body of the dust settles on the inside of the flues and is knocked down by striking them with the pendulum hammers, but it is necessary to occasionally jar the frame to which the wires are attached. Meanwhile the inventors dream of charging and repelling the particles from the wire and attracting them all to the inside of the flue, remains beautiful, theoretical and unessential.

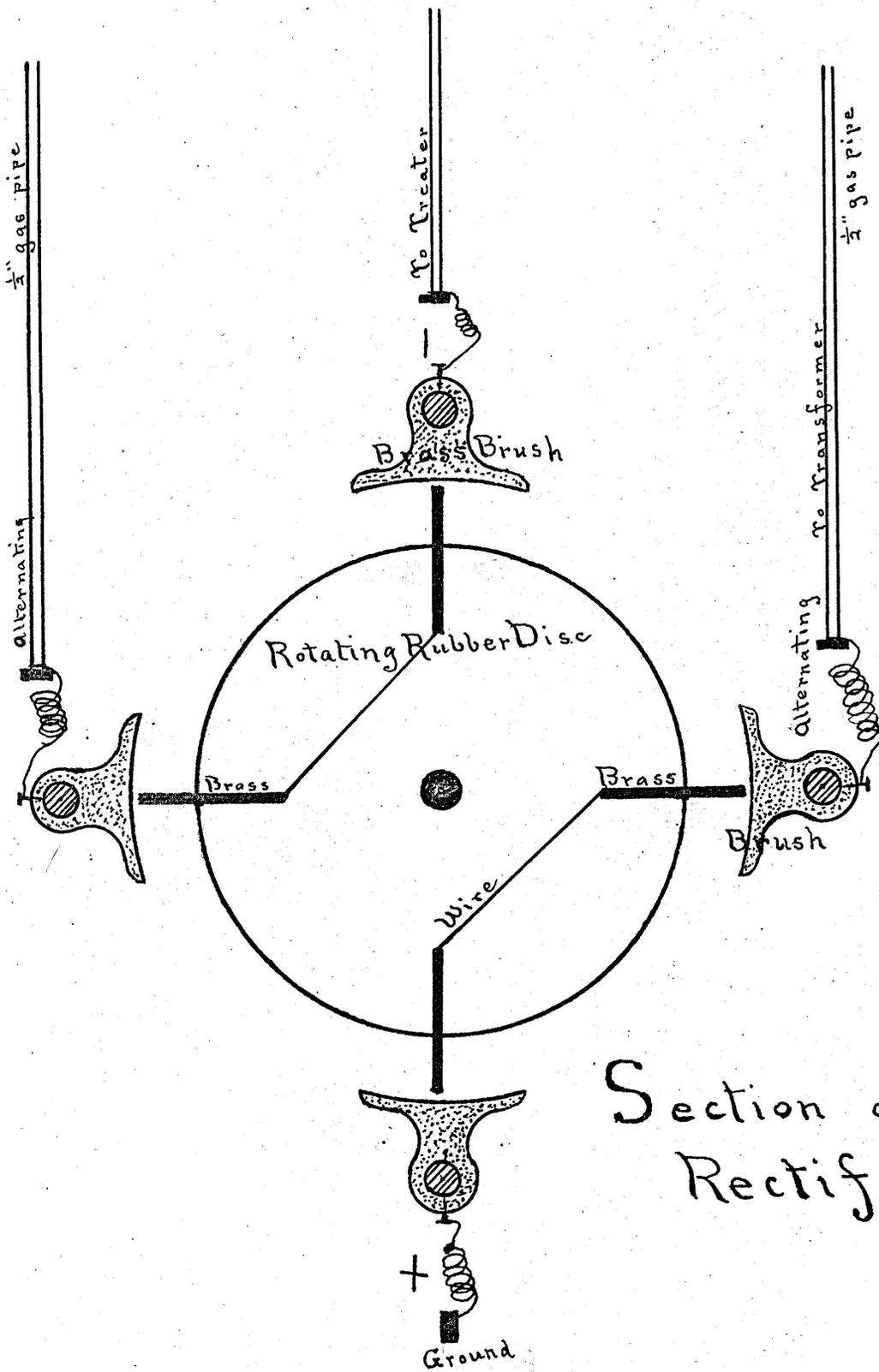
GENERATING PLANT.

The generating equipment occupies about half the sixth floor of the Roaster Building (see blue prints)

and includes ten generating, transforming and rectifying units, two motor-dynamo exciters, a 12-panel switch board and their electrical connections. All circuits of 440 volts and under are carried in conduit within the concrete floor. The high potential ones are carried overhead.

Each generating unit consists of a Westinghouse auto-starter; a 3-phase Westinghouse induction motor, 20 HP, 440 volts, 23.5 amperes, 1450 RPM; a single-phase Westinghouse generator, 4 poles, 250 volts, 60 amperes, 47.7 cycles; a 4-pole rectifier and a single-phase Westinghouse oil transformer 100,000 and 220 volts, 15 KVA, 50 cycles. The motor, generator and rectifier are on the same shaft. The 250-volt current goes to the switch board and to the transformer where it is stepped up to approximately 50,000 75,000 or 100,000 volts according to transformer connections. It then returns to the rectifier on the same shaft with the generator and becomes a pulsating direct current of the high E M F desired. The positive pole is grounded and the negative connected to the wire electrodes of the treaters.

The 4-pole rectifier consists of (a) a hard rubber



Section of Rectifier

disk rotating with the generator; it is two feet in diameter and carries two conductors, each connecting two adjacent points of the four brass collector points, placed 90 deg. apart around its circumference, and corresponding to commutator segments; and (b) a roomy rocker-frame carrying the cast brass brushes and the connections. There is a gap space of about $3/16$ inches between collector point and "brush". Of course there is beautiful sparking. While the secondary electromotive force lags behind the primary one, it does so, for a given load, by a definite angle, determining a definite position of the rocker-frame. Very small loads require the rocker frame to be set forward. Two or more machines are not run in parallel.

HANDLING A HUNDRED THOUSAND VOLTS.

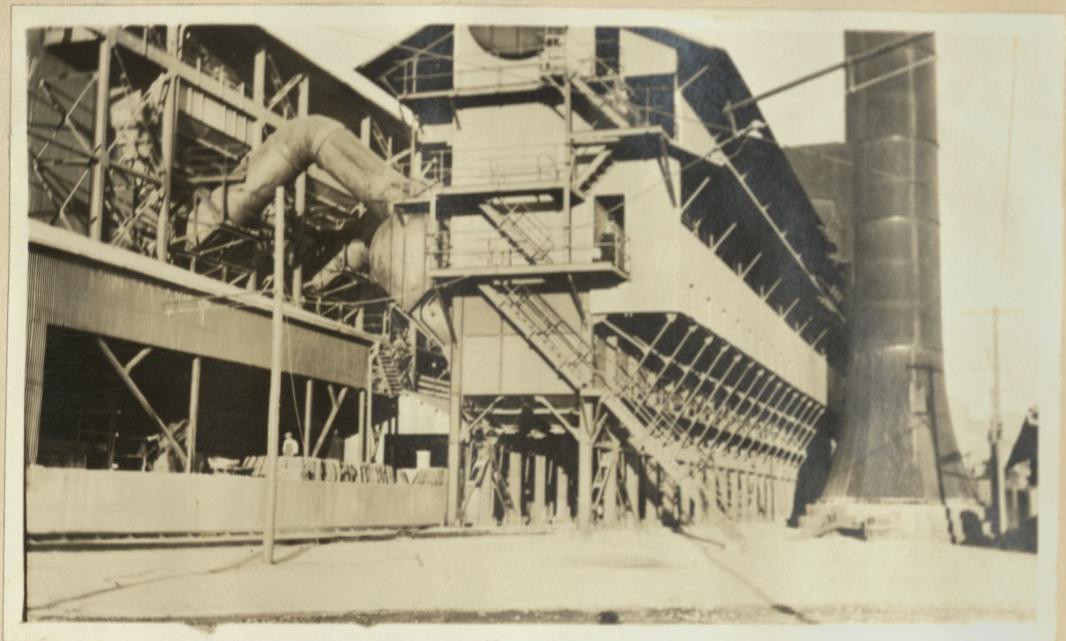
The high tension conductors are $\frac{1}{2}$ and 1-inch gas pipe coated with aluminum paint. Connections with the rocker-frame are made with stout copper wire coiled as a spiral spring, not with the sliding arrangement shown on the blue print No. 10-67. The pipe is carried overhead, on large three petticoat insulators, to the roaster treaters and to the wires leading to the Converter Build-



The large Insulators carrying a switch below. Above are parts of the Iron Boxes and to the left, part of a Cage. The Flues are behind the corrugated background.

ing. All conductors clear the nearest metal work of the buildings by at least 15 inches. The conductors to the treaters are just 18 inches above those coming from the generators and cross them at right angles to permit the switching from one generator to another (see blue print 10-67). The switch is a strap of sheet copper with two hooks 18 inches apart and bent 90 degrees out of line, so as to hook over the pipes. Below the hooks is a long cap to take the end of an 8-foot pole, with which the operator sets the switches from the floor.

The conductors from the Roaster to the Converter Treater Building pass over the higher Converter Building and rest on it. The span (Roaster to Converter) is about 580 feet. The wires are about 120 feet above the ground at the nearest point. There are five No. 6, bare, hard drawn copper wires. Just below these conductors are two steel messengers carrying cross wires to keep any high tension wire from reaching the ground, if it should break. The two buildings are also connected by trolley, the bonded track coming in contact with the metal work of both buildings. This incident insures very good ground return for the positive side.



Converter Treater Building

About half of this building is visible, for the smokestack stands beside the center. To the left is seen a portion of the Converter Building, and one of the 5-foot elbows leading from the first converter to the great pipe, in the rear of the Treater Building, running the length of the house, and having connecting flues to the bottoms of the several treaters. At the top is a similar pipe (almost cut out of the picture) which receives the treated gases and delivers them to the stack.

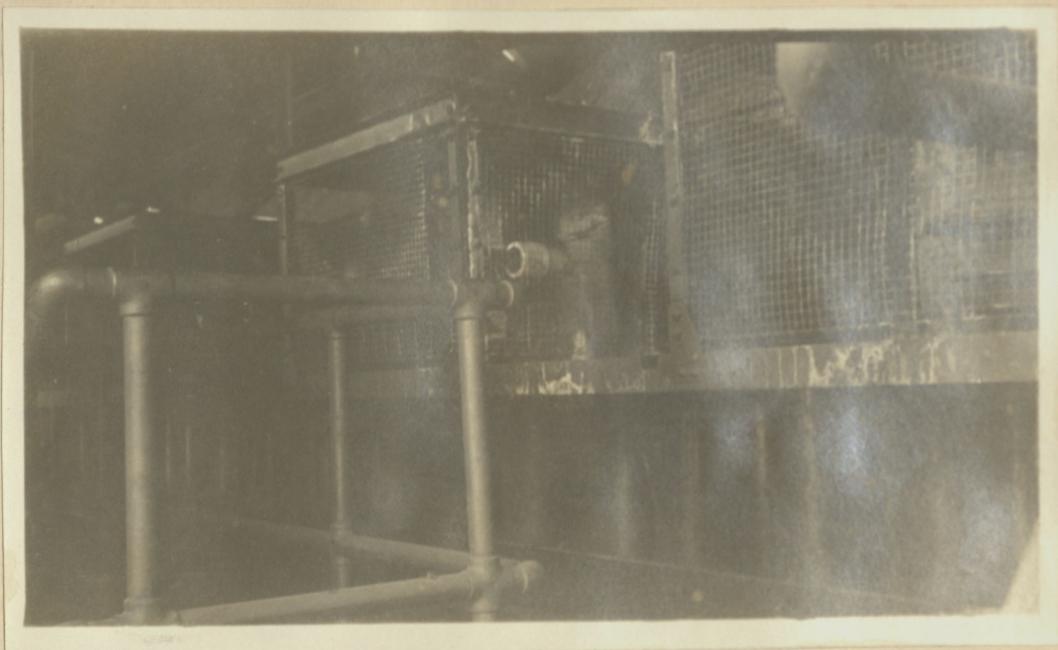
On the platform, where the man is standing, are copper ingots ready to go into freight cars. There are two parallel tracks here: only one shows in the picture.

TREATERS.

The bank of converter treaters is a building of itself, being 212 feet long, 30 feet wide and about 80 feet in height. It is situated 50 feet north of the Converter Building and parallels it. This Treater Building is steel throughout. It stands over a trolley track where the dust bins dump directly into the cars. The lowest enclosed part of the building is the bins, at the top of which are the dampers, connecting with the 5-foot flues, one from each of the five converters in the adjoining building. From the bins rise the vertical treater flues, then come the head rooms with the dampers to the great 300-foot chimney. The flues are of boiler plate 15 feet high and 14 inches in diameter. There are four rows of eight flues each in each unit and two units to a treater, making sixty-four flues to each treater. Although each unit has its own dampers above and below for shutting off and "knocking down" while the other unit is in operation, there are two 32-inch round holes connecting the two head rooms. Through these pass two small I-beams which form parts of the head frame or grid-iron.

(1)

(1). This internal connection accounts for the notation on the blue print 12-53 "No Switch Here".



Cages and Upper Parts of Treater Flues
In the Roaster Building

In the cage on the right, the large insulator is visible. In the center, the sleeve and one of the two panes of glass can be seen.

This head frame is, mainly 2 by 2-inch angle iron, and to it are fastened the sixty-four wire electrodes, one hung down the center of each flue. It is two feet above the floor of the head room to clear dust accumulation between the flues. It rests on 2-inch I-beams, one passing entirely through each unit and extending about 18 inches outside. Each end of an I-beam rests on a three petticoat insulator such as is used generally for carrying these high tension conductors. Around this insulator and the beam end is a somewhat less pretentious "cage" than that described with the roaster treaters below. To allow the beam to pass through the side of the head room and clear it by about 15 inches, a 32-inch hole is required. Around the beam, (1) the hole is closed, or partly so, by insulating material. It should be as nearly closed as practicable, for any draft entering the head room carries a small amount of dust up the chimney, and worse than that, the admission of cool air facilitates the formation and condensation of sulphuric acid, especially SO_3 , which attacks the electrodes

(1). Stopping this hole illustrates how we have taken up details here in the field. There have been plenty of such little fussy matters.

Cottrell supplied a sleeve of insulating compound to go on the I-beam and two panes of glass running in slides above and below the hole to close it. A round hole (semi-circle in each pane) permits the sleeved beam to go through. Dust settled on the sleeve and panes and "shorted" the treater. We drew the panes back till they were in some instances six inches or more apart. Result: appreciable loss of dust and frequent arcing across from pane to sleeve. Whenever a sleeve burned out, I put in a joint of vitrified sewer pipe-- smoother, cheaper and incombustible. The Cottrell man tried stopping the gap between the panes with sheet asbestos, and even substituting it for the glass. We could tap on this freely but a worse dust collector would be hard to find. With a view to pounding on the insulator to jar the dust off, he also tried and rejected thick marble and slate slides instead of the glass. The 32-inch hole is about seven inches deep, and the glass on the outside: if the panes be not separated to admit a little draft, dust piles on the inside "window sill", clear up to the beam. Now the current is shut off and a hose with compressed air is admitted between the panes and everything is blown clean. When the treater is down long enough to cool, the glass is removed and wiped.

The plant is accepted, the selling company's agent gone and experimenting resumed. The next trial was in the Roaster Building where conditions are substantially the same except that the head frame is supported by a 2½-inch WI pipe instead of an I-beam. A circular piece of vulcanized fiber 3/8 inches thick, fitting the 32-inch hole and carrying a small hole in the center fitting the pipe (no sleeves on the pipe) was cut in half and provided with snap catches for instantly fastening it in place at the in-

ner end of the hole, leaving no "window sill" inside. Unlike the sheet iron bin, it does not get too hot to handle, and with the current off, it can be removed, wiped and returned in two minutes time.

The pipes carrying the head frames are not centered exactly in the large holes and cannot be, without throwing the electrodes out of center. Nice work is required in cutting the fiber and at best it will fit but one hole and often in one position only. So we made two rings of treated wood, one fitting the large hole and carrying an 8-inch central one; the other a foot in diameter, fitting the pipe and sliding against the larger one.

In the Roaster Building, glass, fiber and wood are in use side by side. All giving some bother, the best results seeming to come from the wood around a porcelain sleeve on the pipe. But at the converter treaters, we have broken out in a new place. Here the bins and head rooms are too hot to permit handling insulating doors and slides as we have been doing in the roaster. The new plan involves external connection of the two units of each treater, and a sheet-iron box enclosing the place where the large insulator originally stood. The connection is made with a 3-inch I-beam, its ends bolted to the ends of the 2-inch ones. The supporting insulators are under this 3-inch beam and are removed from the ends far enough to clear the boxes well. This box is about 36 inches square and encloses the rectangular elbow (where the I-beams join) and the hole in the side of the head room or bin. This hole is left open, but where the larger I-beam passes through the side of the box, the hole is closed by black vulcanized fiber fitting closely on a mica

frames, etc.. Housing the flues with corrugated iron has preserved the heat, and almost obviated this nuisance, besides improving the draft. The same conditions obtain with the bottom frame coming through the upper part of the bin.

The electrodes are No. 10 iron wire fastened, as before remarked, to the head frame, passing down the flues and through the holes in the bottom frame, which holds them to center, and terminating in window weights, one hung on each wire, to prevent buckling out of center. Some dust settles on the wires and it is necessary to shut down the treater every few days and shake the head frame. This of course, does not interfere with the continuous operation of any other part of the smelter; dampers throw the draft from one treater to the next and switches control the current. The main body of the dust

sleeve over the I-beam. On the front of the box is a glass window permitting the operator to see the (head or bottom) frame from the gallery. The box being grounded, he may bring his face clear up to the window. So many little advantages exist in this arrangement that it is likely to be introduced into the Roaster treaters also. If we ever know just how best to operate the precipitation plant in this smelter, the problem will not be solved for any other one.



Roaster Treater Flues

Showing also (a) the pendulum hammers operated by handles on the other ends of the square shafts, and (b) tricks played on the film by invisible rays, due to the presence of electrostatic forces.

settles on the ^{large} electrode, the flue, and is knocked down every four hours. The picture shows the pendulum hammers hung so as to strike two rows of flues. Each flue has its protruding lug to receive the blows. Before knocking down, the dampers at top and bottom of the unit are closed. At the Roaster, the upper dampers are on top of the stacks as seen in the photo.

The treaters at the Roaster Building are similar to those at the Converter. There are sixteen units of twenty flues each. Doors enter the tops of the dust bins from the main (sixth) floor; the bottom frames are just above these doors. The bins are so enclosed that it was most expedient to support each of these frames from one side and through only one hole. The $2\frac{1}{2}$ -inch pipe carrying the frame is brought out five feet into the room and hung by two insulators, one below it and next to the hole, and the other above it, out at the end, and bearing downward. This exposes five feet of high tension conductor. Around this, enclosing doors, insulators and all, is the "cage" of angle iron and heavy wire screen, 6 by 7 feet, by 8 feet high, one for each protruding pipe end. As the head frames are supported at both ends, the

cages above are smaller. They are of course grounded on the steel building of which they are a part and effectually prevent persons coming in contact with high tension conductors,

The concentrates should be heated in the roasters to about 150 degrees centigrade. The temperature is taken in the trolley car at the time of weighing, when on the way to the reverberatory. Some lumps are not fully dried through, and some few particles were at white heat, or nearly so, for a moment, while passing through the flame. There is no copper sulphate in the concentrates (which contains sulphides) entering the roaster: there is considerable in the flue dust. The plant was accepted in summer time when Arizona's August sun was working for the selling Company. Later on, cold snows started a precipitation not in the specifications: the water in the concentrates went over into the flue dust, (for electrostatic attraction makes no distinction between solid and liquid particles) clogged with "soup" the long 12-inch pipes running from the bin bottoms on the fifth floor to the trolley cars on the first; gummed the slides at the bottom so that they would not

open, hung beautiful blue stalactites about the slides and inspired western workmen to fill the air with a deeper blue.

Heating all the concentrates to 250 or 300 degrees centigrade, reduced this water greatly but did not render the dust dry enough to prevent serious clogging. However, it had another effect, it filled the Roaster Building with sulphur gas and made the job of hauling calcine ⁽¹⁾ very offensive, not to say unhealthy. The steel trolley car, in charge of two men, enters the Roaster Building almost every half hour, day and night, and remains about ten minutes, allowing the hot calcine to run from the bins overhead into the car, and incidentally, liberating gas from the calcine. The car then delivers its load to the reverberatory, six hundred feet away. One trip a day sufficed for flue dust until this product was no longer kept separate.

Hauling flue dust was always most disagreeable. At best, the dust would clog in the pipes so that the switchman always got upon the car to pound the pipes,

(1). " Calcine" is the name here used for dried concentrates though no change is supposed to take place except drying.



Unloading a Car of Flue Dust

It was impossible to photograph the car while being loaded: the dust was so thick that the car could not be seen from a point distant enough to get the car in the picture.

while the motorman on the floor manipulated the slides and moved the car from pipe to pipe. The car is enclosed and sleeves on its top join the dust pipes and make them practically continuous. Nevertheless when the dust would come down both men would be immersed in a cloud of poisonous dust through which they could not see for a yard ahead if they kept their eyes open. The work of "taking flue dust" often occupied more than half an hour and involved at least one great puff of dust from each of the nine slides. The men came out each day with red eyes and sore nostrils. They wore respirators, to be sure, as in fact some of them do now in taking calcine, but a better plan of handling flue dust was loudly called for. A most simple one was adopted: the pipes from the dust bins were run into the calcine bins instead of around them to the car below. This makes the pipes short, straight, vertical and always open at the bottom. The last condition is a very great aid in preventing the damp stuff sticking to the pipes. The "dust" comes down damp but continuously in small quantities (say one per cent of the total) on the hot calcine and dries without even forming large lumps.

In very bad weather it is necessary to run the calcine so hot as to liberate sulphur gas: in ordinary winter weather it is not. ⁽¹⁾ For the first five months of operation all flue dust was weighed on its way from bins to furnace. This is impossible now and gives rise to the only objection to the present greatly improved arrangement.

OPERATION AND ECONOMY.

No public complaint, no suggestion of damage and no formal mention pertaining to the dust or gas from this Smelter has yet been made. The dust recovered pays a good profit on the cost of catching it. With two reverberatory furnaces going, this Smelter has a capacity of 16,000,000 pounds of copper per month. The first furnace began turning out commercial copper in May, 1915, but was not brought up to its full working capacity until November. The second one was "blown in" early in December. Flue dust figures were no longer obtainable. Those given below were taken at a time when the output was small in proportion to expense, but at any rate, no at-

(1). Careless firing; the convenience of the roaster men and the fact that calcine runs better when hot, and must be dry, cause the stuff often to be much hotter than there is any good excuse for, even yet.

(1)
 tempt is here made to publish the company's books. Suffice it to show that with all our troubles of newness and experimentation, the dust saved was worth four or five times its cost of recovery, and is yielding a materially better profit now.

Smelter employees are paid on a sliding scale, depending on the price of copper. At present (2) "Cottrell operators" are getting more than five dollars a day; last September they were getting less. Four regular men are required for the precipitation plant; three operators, each working eight of the twenty-four hours, and one additional day man who keeps up the treaters. This does not include any of those engaged in experimental work, or the completion of the plant, last September. It is a sufficient force when the Smelter is working at its greatest capacity. When two reverberatories are working

(1). During September with a view to this article, the writer weighed every car of roaster dust and obtained the converter dust figures from the weigher's reports. The latter are not quite accurate, owing to the largeness of the bins and the fact that they were not quite empty September 1. The actual haulage was a few pounds more than the round figure, 58,000 pounds.

(2). May, 1916.

up to their maximum, the precipitation plant will require about eighty horsepower. It was consuming thirty to forty during September at a cost of \$.0075 per kilowatt hour, or about \$165.00 for the month. However, allowance for interest on the investment and depreciation on the plant will not be excessive at \$1200.00 a month. We may say it cost the company \$2,000.00 to run the precipitation plant during September, and will cost \$2300.00 when the output is over three times as great.

During the month under consideration, the Smelter turned out about 5,893,600 pounds of copper, sold under a large contract at 20 cents a pound. The Roaster flue dust recovered was 172,310 pounds, running a trifle over 34% copper; and figured at 34%, it yielded 58,585 pounds of copper. The converter dust amounted to 58,000 pounds which ran 64% copper, or 37,120 pounds of that metal. Thus the dust obtained by the precipitation plant contained 95,705 pounds of 20-cent metal, worth \$19,141.00 and returned a net profit of upwards of \$17,000.00: to say nothing of keeping peace with our neighbors. A striking figure deduced from the above shows that the copper in the flue dust recovered by the precipitation

plant amounted to over 1.6 % of the entire smelter output. To be sure if there were no treaters, the dust going over with the smoke could be somewhat reduced; but at present, roaster and converters are operated in the manner that seems most convenient and economical. There is another and smaller source of flue dust that is slighted in this article. It is from the reverberatory furnaces called "boiler dust" and obtained by cleaning the waste heat boilers.

With this showing before us, it is apparent that nothing short of bag houses could even approach this Cottrell precipitation plant for the recovery of values, or clarification of the atmosphere. While in reliability or cost of maintenance or of operation they cannot compete with the precipitation system. In view of the large sulphur content of many ores, and close proximity of some smelters to fertile agricultural country, the problem of purifying the air around all smelters is by no means solved, yet it appears that this smelter is removed from danger of damage suits and legislative interference and at the same time is making a profit by the use of this modern safety device.

BIBLIOGRAPHY

The only work on the subject under consideration, that I have read, is the pamphlet sent out by the Western Precipitation Co., 1016 West 9th Street, Los Angeles, California. It contains some of Mr. Cottrell's writings for the Smithsonian Institution.

A good description of the smelter at Ducktown, Tennessee, I read in the newspapers. The cement plant at Riverside, California, I visited in a cursory way before coming here, as I had visited two other cement plants and several other smelters where the Cottrell system is not used.

While I have given first attention to brevity and some also to dignity in the body of the thesis, I have said what I pleased in the somewhat copious foot notes.