Having obtained C, we put the instrument in the direction A B C. Then each point of C F describes a circumference of the same center o.

16. If the distance of the points A and B were too great, then it would be easy to determine a series of points belonging to the arc of circumference sought (Fig. 4).

Being given C, the direction C I, and C I = R, on C I I lay off C E = d, draw A E B perpendicularly, and calculate C A or A E. I shall have

$$d = (R - \bar{d}) = \bar{A} E^2;$$

or, as absolute value, $A E = \sqrt{d(R - \bar{d})}$. (10)

The instrument being arranged according to A C B, I prolong C B and take B C' = B C, when C' will be one of the points sought. It will be readily understood how, by repeating the above operations, but by varying the value of d, we

obtain the other intermediate points, and how we may continue the operation to the right of C' with the process pointed out.

17. If the three rulers were three arcs of a large circle of a sphere, the instrument might serve for drawing the meridians on such sphere.

18. If we imagine, instead of three axes placed in one plane and converging at one point, a system of four axes also converging in one point, but situated in any manner whatever in space, and if we rest three of them against three fixed points, we shall be able to solve in space problems analogous to those that have just been solved in a plane. If we had, for example, to draw a spherical vault whose center was inaccessible, we might adopt the same method.—*Le Génie Civil*.

FEED-WATER HEATER AND PURIFIER.*

By GEORGE S. STRONG.

In order to properly understand the requirements of an effective feed-water purifier, it will be necessary to understand something of the character of the impurities of natural waters used for feeding boilers, and of the manner in which they become troublesome in causing incrustation or scale, as it is commonly called, in steam boilers. All natural waters are known to contain more or less mineral matter, partly held in solution and partly in mechanical suspension. These mineral impurities are derived by contact of the water with the earth's surface, and by percolation through its soil and rocks. The substances taken up in solution by this process consist chiefly of the carbonates and sulphates of lime and magnesia, and the chloride of sodium. The materials carried in mechanical suspension are clay, sand, and vegetable matter. There are many other saline ingredients in various natural waters, but they exist in such minute quantities, and are generally so very soluble, that their presence may safely be ignored in treating of the utility of boiler waters.

Of the above named salts, the carbonates of lime and magnesia are soluble only when the water contains free carbonic acid.

Our American rivers contain from 2 to 6 grains of saline matter to the gallon in solution, and a varying quantity—generally exceeding 10 grains to the gallon—in mechanical suspension. The waters of wells and springs hold a smaller quantity in suspension, but generally carry a larger percentage of dissolved salts in solution, varying from 10 to 650 grains to the gallon.

When waters containing the carbonates of lime and magnesia in solution are boiled, the carbonic acid is driven off, and the salts, deprived of their solvent, are rapidly precipitated in fine crystalline particles, which adhere tenaciously to whatever surface they fall upon. With respect to the sulphate of lime, the case is different. It is at best only sparingly soluble in water, one part (by weight) of the salt requiring nearly 500 parts of water to dissolve it. As the water evaporates in the boiler, however, a point is soon reached where supersaturation occurs, as the water freshly fed into it constantly brings fresh accessions of the salt; and when this point is reached, the sulphate of lime is precipitated in the same form and with the same tenaciously adherent quality as the carbonates. There is, however, a peculiar property possessed by this salt which facilitates its precipitation, namely, that its solubility in water diminishes as the temperature rises. This fact is of special interest, since, if properly taken advantage of, it is possible to effect its almost complete removal from the feed-water of boilers.

There is little difference in the solubility of the sulphate of lime until the temperature has risen somewhat above 212° Fahr., when it rapidly diminishes, and finally, at nearly 300°, all of this salt, held in solution at lower temperatures, will be precipitated when the temperature has risen to that point. The following table† represents the solubility of sulphate of lime in sea water at different temperatures:

Temperature. Fahr.	Percentage Sulph. Lime held in Solution.
217°	0.500
219°	0.477
221°	0.452
227°	0.395
232°	0.355
236°	0.310
240°	0.267
245°	0.226
250°	0.183
255°	0.140
261°	0.097
266°	0.060
271°	0.023
290°	0.000

These figures hold substantially for fresh as well as for sea water, for the sulphate of lime becomes wholly insoluble in sea water, or in soft water, at temperatures comprised between 280° and 300° Fahr.

It appears from this that it is simply necessary to heat water up to a temperature of 250° in order to effect the precipitation of four fifths of the sulphate of lime it may have contained, or to the temperature of 290° in order to precipitate it entirely. The bearing of these facts on the purification of feed-waters will appear further on. The explanation offered to account for the gradually increasing insolubility of sulphate of lime on heating, is, that the hydrate, in which condition it exists in solution, is partially decomposed, anhydrous calcic sulphate being formed, the dehydration becoming more and more complete as the temperature rises. Sulphate of magnesia, chloride of sodium (common salt), and all the other more soluble salts contained in natural waters are likewise precipitated by the process of supersaturation, but owing to their extreme solubility their precipitation will never be effected in boilers; all mechanically suspended matter tends naturally to subside.

Where water containing such mineral and suspended matter is fed to a steam boiler, there results a combined deposit, of which the carbonate of lime usually forms the greater part, and which remains more or less firmly adherent to the inner surfaces of the boiler, undisturbed by the force of the boiling currents. Gradually accumulating, it becomes harder and thicker, and, if permitted to accumulate, may at length attain such thickness as to prevent the proper heating of the water by any fire that may be maintained in the furnace. Dr. Joseph G. Rogers, who has made boiler waters and incrustations a subject of careful study, declares that the high heats necessary to heat water through thick scale will sometimes actually convert the scale into a species of glass, by combining the sand, mechanically separated, with the alkaline salts. The same authority has carefully estimated the non-conducting properties of such boiler incrustations. On this point he remarks that the evil effects of the scale are due to the fact that it is relatively a non-conductor of heat. As compared with iron, its conducting power is as 1 to 374, consequently more fuel is required to heat water in an incrustated boiler than in the same boiler if clean. Rogers estimates that a scale 1-16th of an inch thick will require the extra expenditure of 15 per cent. more fuel, and this ratio increases as the scale grows thicker. Thus, when it is one-quarter of an inch thick, 60 per cent. more fuel is needed; one-half inch, 112 per cent. more fuel, and so on.

Rogers very forcibly shows the evil consequences to the boiler from the excessive heating required to raise steam in a badly incrustated boiler, by the following illustration: To raise steam to a pressure of 90 pounds the water must be heated to about 320° Fahr. In a clean boiler of one-quarter inch iron this may be done by heating the external surface of the shell to about 325° Fahr. If, now, one-half an inch of scale intervenes between the boiler shell and the water, such is its quality of resisting the passage of heat that it will be necessary to heat the fire surface to about 700°, almost to a low red heat, to effect the same result. Now, the higher the temperature at which iron is kept the more rapidly it oxidizes, and at any heat above 600° it very soon becomes granular and brittle, and is liable to bulge, crack, or otherwise give way to the internal pressure. This condition predisposes the boiler to explosion and makes expensive repairs necessary. The presence of such scale, also, renders more difficult the raising, maintaining, and lowering of steam.

The nature of incrustation and the evils resulting therefrom having been stated it now remains to consider the methods that have been devised to overcome them. These methods naturally resolve themselves into two kinds, chemical and mechanical. The chemical method has two modifications; in one the design is to purify the water in large tanks or reservoirs, by the addition of certain substances which shall precipitate all the scale-forming ingredients before the water is fed into the boiler; in the other the chemical agent is fed into the boiler from time to time, and the object is to effect the precipitation of the saline matter in such a manner that it will not form solid masses of adherent scale. Where chemical methods of purification are resorted to, the latter plan is generally followed as being the least troublesome. Of the many substances used for this purpose, however, some are measurably successful; the majority of them are unsatisfactory or objectionable.

The mechanical methods are also very various. Picking, scraping, cleaning, etc., are very generally resorted to, but the scale is so tenacious that this only partially succeeds, and, as it necessitates stoppage of work, it is wasteful. In addition to this plan, a great variety of mechanical contrivances for heating and purifying the feed-water, by separating and intercepting the saline matter on its passage through the apparatus, have been devised. Many of these are of great utility and have come into very general use. In the Western States especially, where the water in most localities is heavily charged with lime, these mechanical purifiers have become quite indispensable wherever steam users are alive to the necessity of generating steam with economy.

Most of these appliances, however, only partly fulfill their intended purposes. They consist essentially of a chamber through which the feed-water is passed, and in which it is heated almost to the boiling point by exhaust steam from the engine. According to the temperature to which the water is heated in this chamber, and the length of time required for its passage through the chamber, the carbonates are more or less completely precipitated, as likewise the matter held in mechanical suspension. The precipitated matter subsides on shelves or elsewhere in the chamber, from which it is removed from time to time. The sulphate of lime, however, and the other soluble salts, and in some cases also a portion of the carbonates that were not precipitated during the brief time of passage through the heater, are passed on into the boiler.

Appreciating this insufficiency of existing feed-water purifiers to effectually remove these dangerous saline impurities, the writer in designing the feed-water heater now to be described paid special attention to the separation of all matters, soluble and insoluble; and he has succeeded in passing the water to the boilers quite free from any substance which would cause scaling or coherent deposit. His attention was called more particularly to the necessity of extreme care in this respect, through the great annoyance suffered by steam users in the Central and Western States, where the water is heavily charged with lime. Very simple and even primitive boilers are here used; the most necessary consideration being handiness in cleaning, and not the highest evaporative efficiency. These boilers are therefore very wasteful, only evaporating, when covered with lime scale, from two to three pounds of water with one pound of the best coal, and requiring cleansing once a week at the very least. The writer's interest being aroused, he determined, if possible, to remedy these inconveniences, and accordingly he made a careful study of the subject, and examined all the heaters then in the market. He found them all, without exception, insufficient to free the feed-water from the most dangerous of impurities, namely, the sulphate and the carbonate of lime.

Taking the foregoing facts, well known to chemists and engineers, as the basis of his operations, the writer perceived that all substances likely to give trouble by deposition would be precipitated at a temperature of about 250° F.

His plan was, therefore, to make a feed-water heater in which the water could be raised to that temperature before entering the boiler. Now, by using the heat from the exhaust steam the water may be raised to between 208° and 212° F. It has yet to be raised to 250° F.; and for this purpose the writer saw at once the advantage that would be attained by using a coil of live steam from the boiler. This device does not cause any loss of steam, except the small loss due to radiation, since the water in any case would have to be heated up to the temperature of the steam on entering the boiler. By adopting this method, the chemical precipitation, which would otherwise occur in the boiler, takes place in the heater; and it is only necessary now to provide a filter, which shall prevent anything passing that can possibly cause scale.

Having explained as briefly as possible the principles on which the system is founded, the writer will now describe the details of the heater itself.

In Figs. 1 and 2 are shown an elevation and a vertical section of the heater. The cast-iron base, A, is divided into two parts by the diaphragm, B. The exhaust steam enters at C, passes up the larger tubes, D, which are fastened into the upper shell of the casting, returns by the smaller tubes, E, which are inside the others, and passes away by the passage, F. The inner tube only serves for discharge. It

FIG. 1.—Elevation.

FIG. 2.—Vertical Section

will be seen at once that this arrangement, while securing great heating surface in a small space, at the same time leaves freedom for expansion and contraction, without producing strains. The free area for passage of steam is arranged to be one and a half times that of the exhaust pipe, so that there is no possible danger of back pressure. The wrought iron shell, G, connecting the stand, A, with the dome, H, is made strong enough to withstand the full boiler pressure. An ordinary casing, J, of wood or other material prevents loss by radiation of heat. The cold water from the pump passes into the heater through the injector arrangement, K, and coming in contact with the tubes, D, is heated; it then rises to the coil, L, which is supplied with steam from the boiler and thus becomes further heated, attaining there a temperature of from 250° to 270° F., according to the pressure in the boiler. This high temperature causes the separation of the dissolved salts; and on the way to the boiler the water passes through the filter, M, becoming thereby freed from all precipitated matter before passing away to the boiler at N. The purpose of the injector, K, and the pipe passing from O to K, is to cause a continual passage of air or steam from the upper part of the dome to the lower part of the heater, so that any precipitate carried up in froth may be again returned to the under side of the filter, in order more effectually to separate it, before any chance occurs of its passing into the boiler.

The filter consists of wood charcoal in the lower half and bone black above firmly held between two perforated plates, as shown. After the heater has been in use for from three to ten hours, according to the nature of the water used, it is necessary to blow out the heater, in order to clear the filter from deposit. To do this, the cock at R is opened, and the water is discharged by the pressure from the boiler. The steam is allowed to pass through the heater for some little time, in order to clear the filter completely. After this operation, all is ready to commence work again. By this means the filter remains fit for use for months without change of the charcoal.

* A paper read before the Franklin Institute.

† Vide Burgh, "Modern Marine Engineering," page 176 et seq. M. Cousté, *Annales des Mines*, V. 69. *Recherches sur l'incrustation des Chaudières à vapeur*. Mr. Hugh Lee Pattison, of Newcastle-on-Tyne, at the meeting of the Institute of Mechanical Engineers of Great Britain, in August, 1880, remarked on this subject that "The solubility of sulphate of lime in water diminishes as the temperature rises. At ordinary temperatures pure water dissolves about 150 grains of sulphate of lime per gallon; but at a temperature of 255° Fahr., at which the pressure of steam is equal to about 2 atmospheres, only about 40 grains per gallon are held in solution. At a pressure of 3 atmospheres, and temperature of 302° Fahr., it is practically insoluble. The point of maximum solubility is about 95° Fahr. The presence of magnesium chloride, or of calcium chloride, in water, diminishes its power of dissolving sulphate of lime, while the presence of sodium chloride increases that power. As an instance of the latter fact, we find a boiler works much cleaner which is fed alternately with fresh water and with brackish water pumped from the Tyne when the tide is high than one which is fed with fresh water constantly."

LA ARCHITECTURA.—STATUE BY JULI MONTEVERDE.

ERECTED IN MEMORY OF THE ARCHITECT, CARLES SADA.

Where a jet condenser is used, either of two plans may be adopted. One plan takes the feed-water from the hot well and passes the exhaust from the feed pumps through the heater, using at the same time an increased amount of coil for the live steam. By this means a temperature of water is attained high enough to cause deposition, and at the same time to produce decomposition of the oil brought over from the cylinders. The other plan places the heater in the line of exhaust from the engine to the condenser, also using a larger amount of coil. Both these methods work well. The writer sometimes uses the steam from the coil to work the feed pump; or, if the heater stands high enough, it is only necessary to make a connection with the boiler, when the water formed by the condensation of the steam runs back to the boiler, and thus the coil is kept constantly at the necessary temperature.

In adapting the heater to locomotives, we were met with the difficulty of want of space to put a heater sufficiently large to handle the extremely large amount of water evaporated on a locomotive worked up to its full capacity, being from 1,500 to 2,500 gallons per hour, or from five hundred to one thousand h. p. We designed various forms of heaters and tried them, but have finally decided on the one shown in the engraving, Fig. 3, which consists of a lap welded tube, 13 inches internal diameter, 12 feet long, with a cast-iron head which is divided into two compartments or chambers by a diaphragm. Into this head are screwed 60 tubes, one inch outside diameter and 12 feet long, which are of seamless brass. These are the heating tubes, within which are internal tubes for circulation only, which are screwed into the diaphragm and extend to within a very short distance of the end of the heating tube. The exhaust steam for heating is taken equally from both sides of the locomotive by tapping a two-inch nipple with a cup-shaped extension on it in such a way as to catch a portion of the exhaust without interfering with the free escape of the steam for the blast, and without any back pressure, as it relieves the back pressure as much as it condenses. The pipe from one side of the engine is connected with the chamber into which the heating tubes are screwed, and is in direct communication with them. The pipe from the other side is connected with the chamber into which the circulating tubes are screwed. The beat of the exhaust, working, as it does, on the quarters, causes a constant sawing or backward and forward circulation of steam without any discharge, and only the condensation is carried off.

The water is brought from the pump and discharged into the lower side of the heater well forward, and passes around the heating tubes to the end, when it is discharged into a pipe that carries it forward, either direct to the cbeck or into the purifier, which is located between the frames under the boiler, and consists of a chamber in which are arranged a live steam coil and a filter above the coil. The water coming in contact with the coil, its temperature is increased from the temperature of the exhaust, 210°, to about 250° Fahr., which causes the separation of the lime salts as before described, and it then passes through the filter and direct to the boiler from above the filter, which is cleansed by blowing back through it as before described.

One of these heaters lately tested showed a saving in coal of 22 per cent. and an increase of evaporation of 1.09 pounds of water per pound of coal.—*Franklin Journal*.

MONTEVERDE'S STATUE OF ARCHITECTURE.

THIS precious statue forms the noble figure that adorns the monument erected to the memory of the architect Carles Sada, who died in 1873. This remarkable funeral monument is 20 feet high, the superior portion consisting of a sarcophagus resting upon a level base. Upon this sarcophagus is placed the statue of "La Architectura," which we reproduce, and which well exemplifies the genius of the author and sculptor, Juli Monteverde.—*La Ilustració Catalana*.

DESIGN FOR A GARDENER'S COTTAGE.

THE illustration shows a gardener's cottage recently erected at Downes, Devonshire, the seat of Colonel Buller, V.C., C.B., C.M.G., from the designs of Mr. Harbottle, A.R.I.B.A., of Exeter. It is built of red brick and tile, the color of which and the outline of the cottage give it a picturesque appearance, seen through the beautiful old trees in one of the finest parks in Devonshire.—*The Architect*.

PAPER MAKING "DOWN EAST."

WRITING from Gilbertville, a Lewiston journal correspondent says: Gilbertville, a manufacturing community in the town of Canton, twenty-five miles from Lewiston, up the Androscoggin, is now a village of over 500 inhabitants, where three years ago there was but a single farmhouse. If a town had sprung into existence in a far Western State with so much celerity, the phenomenon would not be considered remarkable, perhaps; but growths of this kind are not indigenous to the New England of the present era. Gilbertville has probably outstripped all New England villages in the race of the past three years. It is only one of the signs that old Maine is not dead yet.

Gilbert Brothers erected a saw mill here three years ago. A year later, the Denison Paper Manufacturing Company, of Mechanic Falls, erected a big pulp mill, which, also, the town voted to exempt from taxation for ten years. The mills are valuable companions for each other. The pulp mill utilizes all the waste of the saw mill. A settlement was speedily built by the operatives. Gilbertville now boasts of a post-office, a store, several large boarding houses, a nice school house, and over 500 inhabitants. The pulp mill employs seventy men. It runs night and day. It manufactures monthly 350 cords of poplar and spruce into pulp. It consumes monthly 500 cords of wood for fuel, 45 casks of soda ash, valued at \$45 per cask, nine car-loads of lime, 24,000 pounds to the car. It produces 1,000,000 pounds of wet fiber, valued at about \$17,000, monthly. The pay roll amounts to \$3,500 per month.

The larger part of the stock used by the mill consists of poplar logs floated down the Androscoggin and its tributaries. One thousand two hundred cords of poplar cut in four-foot lengths are piled about the mill; and a little further up the river are 5,000 cords more. The logs are hauled from the river and sawed into lengths by a donkey engine, which cuts about sixty cords per day, and pulls out fourteen logs at a time. All the spruce slabs made by the saw mill are used with this poplar. The wood is fed to a wheel armed with many sharp knives. It devours a cord of wood every fifteen minutes. The four-foot sticks are chewed into fine chips as rapidly as they can be thrust into the maw of the chopper. They are carried directly from this machine to the top of the mill by an endless belt with pockets attached,

There are hatchways in the attic floor, which open upon rotary iron boilers. Into these boilers the chips are raked, and a solution of lime and soda ash is poured over them.

This bath destroys all the resinous matter in the wood, and after cooking five hours the chips are reduced to a mass of soft black pulp. Each rotary will contain two cords of chips. After the cooking, the pulp is dumped into iron tanks in the basement, where it is thoroughly washed with streams of clean cold water. It is then pumped into a machine which rolls it into broad sheets. These sheets are folded, and condensed by a hydraulic press of 200 tons pressure. This process reduces its bulk fifty per cent., and sends profuse jets of water flying out of it. The soda ash, in which, mixed with lime and water, the chips are cooked, is reclaimed, and used over and over again. The liquor, after it has been used, is pumped into tanks on top of large brick furnaces. As it is heated, it thickens. It is brought nearer and nearer the fire until it crystallizes, and finally burns into an ash. Eighty per cent. of the ash used is thus reclaimed. This process is an immense saving to the pulp manufacturers. The work in the pulp mill is severe, and is slightly tinged with danger.

Three thousand four hundred pounds of white ash to 2,100 pounds of lime are the proportions in which the liquor in each vat is mixed. One does not envy the lot of the stout fellows who crawl into the great rotaries to stow away the chips. The hurry of business is so great that they cannot wait for these boilers to cool naturally, after they have cooked one batch, before putting in another. So they have a fan pump, to which is attached a canvas hose, and with this blow cooling air currents into the boiler, or "rotary," as they call it. The rotary is subjected to an immense pres-

particles that lodge in the throat of the visitor, and by the frequent coughing of the sorters. They protect their hair with turbans of veiling, occasionally decorated with a bit of bright color. These turbans give the room the appearance of an industrious Turkish harem. Short, sharp scythe blades, like Turkish scimeters, gleam above all the girls' benches. When a sorter wishes to cut a rag, she pulls it across the edge of this blade, and is not obliged to hunt for a pair of shears.

Curious discoveries are frequently made in the rags. Old pockets, containing small sums of money, are occasionally found. A foreign coin valued at about \$3 was found a few days ago. In the paper stock, quaint and valuable old books or pictures are found often. One of the workmen has a museum composed of curiosities found amid the rags and shreds of paper. Rev. Dr. Bolles, of Massachusetts, makes an annual pilgrimage to Mechanic Falls for the sake of the rare old pamphlets, books, and engravings that he may dig out.

Stuffed in hogsheads, the rags are lowered from this room through a hatchway, and are given a red hot lime bath. They are placed in ponderous cylinders of boiler iron, which revolve horizontally in great gears high above the floor. A mixture of lime and water, which has been prepared in large brick vats, is poured over them. An iron door, secured by huge bolts, is closed on them. The cylinder slowly turns around, and churns the rags in the lime-juice twelve hours. This process is called bleaching. When the rags come out they are far from white, however. They are of a uniform dirty brown hue. But the colors have lost their gripe. When the rags shall have been submitted to the grinding and washing in pure water, as we shall see them presently, they are

Gardener's Cottage at DOWNES for COLONEL BULLER V.C., C.B., C.M.G. E. Harbottle, Architect.

sure, and is very stoutly made of thick iron plates, bolted together.

Describing the business as carried on at Mechanic Falls, the same paper says: There are six of these mills on the three dams over which the Little Androscoggin falls. These are the Eagle, the Star, the Diamond, the Union, the pulp, and the super-calendering mills. The Eagle and the Star mills run on book papers of various grades. The Union mill runs on newspaper. The old Diamond mill now prepares pulp stock. The pulp mill does nothing but bleach the rag pulp and prepare for the machines in the other mills; while the super-calendering mill gives the paper an extra finish when ordered. There is practically but one series of processes by which the paper is made in the various mills.

It is a curious fact that America is not ragged enough to produce the requisite amount of stock for its own paper mills. Nearly all the rags used by the Denison Mills (and by others in various parts of the country as well) are imported from the old countries. All the rags first go through the "duster." This is a big cylindrical shell of coarse wire netting. It is rapidly revolved, while a screw running through its center is turned in the opposite direction. Air currents are forced through it by a power fan. The rags are continuously fed into one end of this shell, which is about ten feet long and four feet in diameter. The screw forces them through the whole length of the shell, while they are kept buzzing around and subjected to breezes which blow thick clouds of dirt and dust out of them. The air of the room is thick with European and Asiatic earth. It is swept up in great rolls on the floor. The man who operates the duster should have leather lungs.

Overhead is a long room where thirty girls are busily sorting the rags for the various grades of papers. That the dusting machine is no more perfect than a human machine is evinced by the murky atmosphere of this room, by the

easily whitened. The lime bath is the purgatory of the paper stock.

Before we go any further, we must see what becomes of those soft and lop-sided bundles which are going into the mills. These contain chemically prepared wood fiber, a certain percentage of which is used in nearly all the papers made now. It gives the paper a greater body, although its fiber is not so strong as that made of rags. The pulp comes down from Canton in soft brown sheets. These are at once bleached. The brown fiber is placed in a bath of cold water and chlorate of lime. There it quietly rests till a sediment settles at the bottom of the tank. At an opportune moment the workman pours in a copious libation of boiling water. This causes the escape of the chlorine gas, which destroys all the color in the pulp. In half an hour it comes out, a mass of smoking fibers as white as a snow heap. The drainers into which it goes are large pens with perforated tile floors. The pulp remains in the drainers till it so dry it is handled with a pitchfork.

We are now ready to look at the beating machines, which have to perform a very important part in paper making. These are large iron tanks with powerful grinders revolving in them. Barrow loads of the brown rags are dumped into them, and clear cold water is poured in. The grinders are then started. They chew the rags into fine bits. They keep the mass of rags and water circulating incessantly in the tanks. Clean water constantly flows in and dirty water is constantly flows out. In the course of six hours the rags are reduced to a perfectly white pulpy mass. There is one mill, as we have said, devoted exclusively to the reduction of rags to this white pulp. It is dried in drainers such as we saw a few moments ago filled with the wood fiber.

There are other beating machines just like these, which perform a slightly different service. Their function may be compared to that of an apothecary's mortar or a cook's