From the mill the cinnabar undergoes the refining, which consists in digesting the cinnabar in potash lye.

As soon as the cinnabar charge has settled in the refining vat, the solution is drawn off and the cinnabar is washed with water until the water runs off perfectly clear. The pulpy mass is placed in glazed drying vessels and dried.

The dry vermilion is then sifted and packed.

The greater part by far of the vermilion, as well as cake cinnabar, is packed in tanned sheepskin in packages of 12 1/2 kg., of which a pair are placed in a wooden keg. Only a small part of the vermilion comes in boxes of 0.5 kg., which again are packed in larger boxes of twenty-five and fifty kg.

SULPHUR: ITS OCCURRENCE AND EXTRACTION.

By C. G. WARNFORD LOCK.

THE following notes relate exclusively to native sulphur (brimstone). Though the amount of sulphur annually mined in the form of sulphides of various metals (e. g., iron and copper pyrites, galena, blende, etc.) probably far exceeds that obtained in the uncombined state, still the separation of the sulphur in an unoxidized condition from such compounds is never attempted, for the simple reason that, in the processes for extracting the several metals from their ores, the first step necessary is the elimination of the combined sulphur, which is most easily effected by a roasting or oxidizing operation, whereby the sulphur is at once converted into sulphurous acid, itself a valuable commodity, and, moreover, capable of being readily oxidized one step further to form sulphuric acid, the chief purpose for which sulphur is consumed.

OCCURRENCE.

It will be most convenient to discuss the occurrence of sulphur deposits under geographical headings, leaving geological differences to be noted as they are met with.

Austria-Hungary.—There are two mines of sulphur worked in this empire, one not far from Cracow, and the other at Radoboi in Croatia; both deposits are of considerable extent, but the annual yield is insignificant. The whole district around Mount Büdös, in Transylvania, is rich in sulphur. The deposits are situated at the south and west of the mountain, the principal localities being Kis Soosmezö, Vontala feje Bálványos, and a little above the chalet Gál András; some thirty or more diggings have been undertaken in a circuit of 18 miles, but the area covered by the deposits is more than three times this size. The sulphur occurs in unequal strata 1 to 9 inches thick, beneath 1 to 3 feet of mould. The soil is everywhere saturated with sulphur, and in this permeated earth pieces of the pure mineral are found. The whole is the result of living solfataric action, and the accumulation will continue to grow as long as that action survives. Samples of the impregnated earth, taken over an area of 16,000,000 square fathoms, yielded from 41 to 64 per cent. of sulphur. Allowing for interruptions in the deposits, and taking these at an average thickness of 3 inches instead of 9, Boer estimates that 200 pounds of sulphur might be obtained from each square fathom, assuming 50 per cent. of sulphur in the deposit; continuing the calculation, he thinks the district should afford over 700,000 tons. He reckons the probable cost, at £10 per ton, including carriage from Büdös to Kronstadt; this, he says, is less than the prices paid in the places where it is produced in Poland, Slavonia, and Bohemia.

The total sulphur output of the Austrian empire, in 1863, was 1,754 tons, at an average rate of £12 15 s. per ton. The imports are about 5,000 tons per annum.

Banda Islands.—Large quantities of sulphur are found in and about the crater of Gunong Api, and attempts have been made to collect it for exportation. It is said, however, that the labor of ascending the mountain is too great to render the speculation profitable.

China.—Sulphur is one of the most important products of Formosa. When taken from the mine, the ore is boiled in iron pans till it assumes a treacly consistence. This is constantly stirred till every impurity is separated from the sulphur, which is then ladled out into wooden tubs shaped like sugar loaves. In these it is left to cool, and the conical cakes are freed from the tubs by the simple process of knocking out the bottoms of the latter.

Sulphur is procurable in salable quantities from the mountains around Ta-Chien-la, in Western China; the inhabitants of the ravines may often be seen engaged in the manufacture of matches of the Guy Fawkes pattern, which they split from a pine plank, with a spokeshave, and tip with sulphur. During his penniless residence at Na-erh-pa, Baber generally used these sulphur chips to procure a flame.

France.—Near the hamlet of Tappets, about 3 miles north-east of Apt, in the department of Vaucluse, is a bed of sulphur ore yielding about 20 to 25 per cent. It consists of a sulphur-impregnated marly limestone, and accompanies the lignite beds of the Tertiary system. The deposit is neither very extensive nor very thick.

Iceland.—The sulphur deposits of Krisuvik, in the south of Iceland, were the subject of a paper by C. W. Vincent, published in the *Journal* of Jan. 17, 1873 (No. 1,032, vol. xxi., pp. 137-144); and those situated in the north of the island were described by me in the *Journal* for April 30, 1880 (No. 1,432, vol. xxviii., pp. 508-9). The interested reader may refer to these for details; it will suffice here to give a general idea of the deposits as a whole. They belong to the recent solfataric group, and, though often compared with the Sicilian mines, bear very little analogy to them. The sulphur occurs in a fine state, intimately associated with earthy impurities, as a superficial layer of no great depth, but having recuperative powers that render them practically inexhaustible. They are now the property of an English company, and give promise of being worked to advantage in the future.

India.—The sulphur deposits of India, according to Professor V. Ball,* are unimportant and inconveniently situated. Near a village called Sura-Sany-Yanam, between the mouths of the Godavari in Madras, small heaps of sulphur are occasionally collected in the dried-up margin of a tidal swamp, where the mineral appears to result from a deoxidation of gypsum by contact with organic matter. Another trifling deposit is reported to occur at Ghizri Bandar, near Karachi. A considerable mine, worked by adits and chambers, exists at Sunnee in Cutchi, Balochistan, and affords the chief supply for Candabar; petroleum is said to be mixed with the refuse of the workings to produce an inferior quality of sulphur, while the pure sulphur is boiled in oil to prepare it in the form of commercial brimstone. This practice recalls the method adopted in Iceland about three hundred years ago, when the crude ore was boiled in train oil, to effect separation of the dross.

Sulphur is obtained in some abundance from near a hot spring called Pir Zinda, in the Soree Pass of the Suleiman Hills, Afghanistan. The native Kusranis and Bozdars treat

the crude ore, consisting of amorphous gypsum traversed by streaks of sulphur, by distilling it in a retort improvised out of two gharras, one on the fire and the other inverted as a condenser. A "vast quantity" of sulphur is said to occur at Hazara, North Afghanistan. On the southern flanks of the Gunjully Hills, in the Kohat district of the Punjab, a large amount of sulphur is constantly being deposited as a result of the decomposition of pyritiferous alum shales. As much as 1,000 tons a year are said to have been gathered.

At Luni-ki-Kussi, on the west side of the Indus, sulphur is obtained by roasting the loose earth.

The sulphur mines at Nakband (Kushalgarh), on the Indus, 8 miles from the mouth of the Kohat, are 30 to 40 feet deep, and have yielded largely, the ore being sublimed as in Balochistan.

Other localities mentioned as affording sulphur in the Punjab are Gumbat and near Panoba, 4 miles from Shadipur, on the Indus; Jaba, 14 miles from Kalabagh, in the Bannu district, and Jeura, near Simla. None of these seem to possess any industrial importance.

The sulphur at Puga, in Kashmir, occurs massive, and as a lining in the clefts and fissures of a sort of quartz schist, often accompanied by gypsum. The process of formation seems to be still at work, judging by hot springs in the neighborhood. The deposits are worked by pits about 8 feet deep, and adits of the same length; but the production is small. A trifling quantity of sulphur is deposited by hot springs in the beds of the Ramgunga and Garjia rivers, in the Kumaun district of the northwest provinces; and a considerable amount is found in the galleries of the lead mines at Meywar, on the Tons River, in the Jaunsar district. Little is known of the Nepalese sulphur mines. In Upper Burma the chief localities are Mooda Myo, Tsein Goon, Kyoukboo, Bawine, Dybayan Myo, Pagan Myo, Toogthoo Einlay, and Bhamo district. The dormant volcano of Barren Island affords small quantities of sulphur, the result of solfataric action.

Italy.—The sulphur deposits of the Romagna are situated in the Miocene lacustrine formation, and lie amid the sub-Apennine hills. The mines worked in the province of Forlì, by the Cesna Sulphur Company, cover an area of about 260 square kilometers. Their average annual production for the seven years, 1873-79, was 27,780 tons. The cost of extraction, refining, and royalties comes to about £4 per ton, according to Consul Colnaghi. The mineral is worked by blasting, each miner having to bore three holes in six hours, when all are fired simultaneously. At Pergola, some 60 kilometers distant from Ancona, is a sulphur mine worked by a German company, which shipped 90 tons of refined sulphur to England in 1880. In Central Italy, near Bologna, a vein is worked which extends over 15 miles in length. The ore is poor, and has to be raised from a considerable depth.

Japan.—Sulphur is said to be abundant in the island of Yezo.

Philippines.—A good deal of sulphur is collected at Camiguin.

Sicily.—Some notes on the sulphur mines of Sicily have appeared in the *Journal* (see Feb. 17, 1882). They may be supplemented by the following:

At the end of the middle Miocene period, the sulphur-bearing area was raised, and lakes were formed in which occurred the deposition of the sulphur rock and its accompanying gypsum, tripoli, and silicious limestone. The sulphur rock is composed of sulphur and marly limestone, the sulphur being sometimes disseminated through the limestone, and at others forming thin alternate layers with it. These sulphur-bearing seams are often separated by layers of black marl, 20 inches to 6 feet thick, some seams attaining a thickness of 28 feet. The total aggregate thickness of the sulphur seams reaches 100 feet in one case, but the average total is 10 to 12 feet only. All the seams are decomposed at their outcrop, and show only an accumulation of whitish, friable earth, called *briscate* by the miners, and mainly composed of gypsum. This has resulted from the oxidation of the sulphur to sulphuric acid by atmospheric agency, the acid in turn attacking the lime carbonate, and forming sulphate (gypsum). The most plausible supposition as to the origin of the sulphur seams would appear to be that the lakes received streams of water containing calcium sulphide in solution, this calcium sulphide probably resulting from a reduction of the masses of calcium sulphate (gypsum) by the action of volcanic heat. Gradual decomposition of the calcium sulphide in the presence of water would finally result in a deposition of sulphur and of lime carbonate in the relative proportions of 24 to 76 per cent. As a matter of fact, much of the Sicilian ore actually has this percentage composition. Whatever the process has been, it is no longer in activity, and there is no growth nor renewal of the beds, in this respect differing essentially from recent deposits due to "living" solfataric action.

Almost all the Sicilian ore is carried to the surface on boys' backs, consequently it does not pay to work below about 400 feet, as it then becomes necessary to employ hauling machinery. Hence the deposits lying below that horizon are hardly touched, and as many of the beds are nearly vertical, and do not diminish in yield as they descend, the still untouched resources must be very great. Various estimates have been made as to the period for which the supply will last at the present rate of consumption; these range from fifty to two hundred years. There are said to be about 250 mines in the island, and no less than 4,367 *calcaroni* were reported in operation fifteen years ago. The average yield is stated not to exceed 14 per cent.

Spain.—In the province of Murcia and at other places the existence of fine beds of sulphur has been ascertained. One is worked by an English association, the Hellin Sulphur Company. The quality is very good.

Suez.—A sulphur deposit exists at Djemsa, in a perfectly rainless desert on the African coast, very near the sea, and constituting a hill 600 feet high, whose sides are blasted down as in quarrying stone. Some two hundred Arabs, employed under French engineers, succeeded in mining 10 tons a day. A similar deposit occurs at Ranga, 500 miles from Suez, also near the coast of the African continent, which differs only in being buried under other strata, so that mining is necessary.

Sunda Islands.—The Gunong Jollo, or sulphur mountain, lies south-west of the village Prado, and south-east of Dampo. The sulphur is dug from three places in an old crater now in the solfataric stage of its existence. Each spot is 160 to 120 rods long, and 50 to 60 broad. The sulphur collects between masses of white stone (perhaps decomposed trachyte), and sometimes covers a space of 1 to 3 rods square. On the liquid and warm sulphur a hard crust forms 2 inches thick. Digging is only carried on at morning and evening, the heat being too great at mid-day. Round holes are made, 8 to 9 feet apart, 2 feet deep, and with an outlet from above of 1 foot, and from below of 3 or 4 feet. Sulphur is also found in the solfataras of Gunong Prewa, but in trifling quantity. A great deal exists on the sides of Tambora.

Tripoli possesses a sulphur deposit important both for extent and richness, but it is not worked.

Turkey.—Native sulphur is found in some quantity adjacent to the lead lodes at Devrent (Derbend), near Alashehr, Salyklo, and Nymphi. A sulphur mine exists two days' ride from Arta, and four from Butrinto, Albania. Some Italians are said to have secured a concession of a "basalt vein containing sulphur" near the Dardanelles. This has a very doubtful look, and if the mine alluded to be the same as the one examined in 1873, the formation is the exact counterpart of that met with in Sicily, and the neighboring basalt has nothing to do with the sulphur. This mine exists at a place known as Komarla, and the mineral affords about 40 per cent. of sulphur. A similar mine occurs at Alaitan, about six hours from Kassaba.

United States.—Sulphur is found native in Nevada, California, Utah, Virginia, Louisiana, and other States, occurring in beds of considerable bulk in Uintah County, Wyoming, near Evanstown, where it is said to be quite pure; also in some quantity in the Yellowstone Park, Montana, and in various localities in New Mexico. It is only worked to any extent in Nevada and California, and even there not on a large scale, the total production in 1880 being stated at under 600 tons. Locally produced sulphur cannot compete in price with imported Sicilian, on account of the cost of land transport; it is, moreover, found to be often contaminated with arsenic, which greatly reduces its market value and limits its application. At the most important mine, called the Rabbit Hole, in Humboldt County, Nevada, the sulphur occurs as an impregnation in a white volcanic tuff or breccia, of Miocene age. The deposit is worked by regular mining, and the mineral, containing 15 to 40 per cent. of sulphur, is dealt with by the steam process, the production being sometimes six tons a day. At the Pluton mines, California, the sulphur is found as a crystalline body scattered through a confused mass of decomposed rocks, and intimately associated with cinnabar, apparently occupying an ancient crater. The mineral is removed altogether, and the sulphur is either recovered by steam process, or, if both sulphur and cinnabar are in paying quantities, the mass is put into a mercury distilling furnace, and the sulphur is separated from the mercury by passing superheated steam into a chamber situated in front of the mercury-condensing chamber.

EXTRACTION.

Sulphur is extracted from the earthy materials with which it is intimately associated in nature, by the following several means: (1) Dry heat (roasting the ore in mass); (2) wet heat (melting out by the aid of aqueous solutions of salts, the salts being added to heighten the boiling point); (3) superheated steam; (4) chemical solvents. The great bulk of all the sulphur produced is extracted by apparatus belonging to the first class, and including the *calcarelle*, *calcarone*, and *doppione*.

Calcarelle.—The earliest system adopted in Sicily was the *calcarelle*. This consisted simply of a stack of ore, 6 to 15 feet square, built in a ditch 3 or 4 inches deep, and whose floor was beaten hard and sloped to a single point, permitting the molten sulphur to flow out by an opening termed the *morto*. In building the stack, care was taken to put the largest pieces of ore at the bottom, selecting lumps of gradually diminishing size as the top was approached. The mass was ignited at the summit. The construction of the stack usually occupied two days; on the third day the sulphur escaped by the *morto*, and on the fourth the *calcarelle* was pulled down. The air necessary for the combustion of a portion of the sulphur (to afford the heat required to smelt the remainder) was freely admitted at all sides; only the mineral in the center of the heap was heated without actual contact with the air, so that its sulphur was melted out instead of being burned (oxidized). Consequently about 6,700 lb. of sulphur mineral were needed to afford 385 lb. of sulphur, or a yield of 5.7 per cent.; as the ore contained 35 per cent. of sulphur, the consumption of sulphur as fuel was 1,960 lb., in order to extract 385 lb. In addition, the immense volumes of sulphurous acid emitted from the stack caused a terrible destruction of the agricultural crops in the neighborhood.

Calcarone.—Nearly all the sulphur prepared in Sicily is now extracted by the *calcarone*, (or *calcherone* as it may also be spelled). This, as is shown in the Figs. 1 and 2, is formed by building a circular stone wall on an inclined sole. In front is the *morto* or outlet, having a height of 4 to 6 feet, and a width of 2 feet; over it is erected a wooden shelter for the workman in charge. *Calcaroni* may contain from 200 to 400 *casse* (each *casse* being equivalent to about 6 tons, and giving 12 to 16 cwt. of sulphur). The durability of the *calcarone* is governed by the care exercised in its construction; ten years is not an unusual period. The charging of the *calcarone* is a matter of primary importance, as on it depends the yield of sulphur. The largest pieces of ore are selected for the first layer, leaving interstices between them; the size of the lumps gradually diminishes as the height increases, care being taken to form the walls of the *morto* with calcareous stones, so as to insure a passage being maintained for the escape of the liquefied sulphur. In adding the finest portions on the top, narrow channels, about two feet apart, are left for the draught to carry the heat down. The whole is covered with a layer of the refuse from previous operations. This layer is more or less thick, according to the state of the weather, because the *calcarone* being built in the open air, variations of temperature and wind influence the progress of the operation; consequently means have to be adopted to prevent an undue access of air rendering the combustion too rapid. For instance, during a *sirocco* (local hot wind) there is danger of the sulphur contained in the ore lying at the side facing the wind being completely converted into sulphurous acid, and thus lost. The employment of a roofed shed would prevent much of the waste occasioned by climatic causes.

When the charging is completed, the *morto* is closed by a stone slab, and fire is communicated to the mass by means of little bunches of dried herbs, dipped in sulphur, which are thrust into the vertical channels before mentioned. Some six or eight days afterward, a hole is pierced in the top of the *morto*, by means of an iron rod; later, a second hole is made near the floor. By these two openings the sulphur escapes, and is collected in wooden buckets (*gratte*), shaped like a truncated cone, and holding about one hundredweight of sulphur. These buckets cost over 2s., and serve only for three or four castings without wanting repairs. The outflow of sulphur lasts for a fortnight or a month. Commonly, the *calcarone* is left to itself when once the mass has been ignited, but then the loss of sulphur is much more serious. To insure good results many precautions have to be observed, mainly connected with the nice adjustment of the draught, so as to effect the maximum degree of fusion with a minimum of oxidation. When the operation is conducted during winter, the product is less

* "Economic Geology of India."

abundant, and of inferior quality. After the charge is exhausted, a new one cannot be introduced till the mass has cooled down, occupying a period of ten days to a month, according to the size of the *calcarone*. The discharging has to be done slowly and cautiously, on account of the sulphurous fumes liberated. The consumption of sulphur (as fuel) in the heating is about 50 per cent. of the total amount contained in the ore. Thus, to obtain one ton of sulphur, there is consumed as fuel about another ton, worth, say, £5, and performing a duty which could be much more satisfactorily accomplished by two hundredweight of coal, costing, perhaps, 5s.

Calcarone, Foster's Improved.—A great improvement in the Sicilian *calcarone* has been introduced by P. Le Neve Foster, and worked with good results, showing an increase of yield of 30 per cent above the ordinary plan. According to his description, the waste heat from an ordinary *calcarone*, after all the sulphur has been run off, is utilized to heat to the required temperature the charge of ore placed in his kiln, and as soon as the moisture has been driven off and the heat is great enough, the charge is fired from the top. The combustion, fed with hot air containing some sulphurous acid gas, is very slow, hence the loss of sulphur by burning is less than when, as in the ordinary *calcarone*, the ore has to be heated entirely by the combustion of the sulphur. The apparatus (shown in Fig. 3,* prepared from a drawing kindly furnished me by the inventor) consists essentially of three parts: (1) the flue, or conductor of heat;

FIG. 1.

(2) the kiln, in which the ore is treated; (3) the chamber for the condensation of the sulphur that is volatilized during the fusion, and in which it is collected.

The kiln may be of any suitable form to contain two charges of ore, but a rectangular chamber is found to be most convenient, with floor sloping toward the front. The chamber consists of four walls, preferably not covered with an arch, as affording greater facility for charging and discharging. The kiln communicates, by means of a flue, A, with the back of an ordinary *calcarone*, B, which furnishes the heat necessary for melting the sulphur from the ore contained in the kiln, C. The upper portion of the *calcarone* should be covered with a layer of *genese* (spent ore), so as to prevent the dispersion of heat by any other channel than that offered by the flue, A, which is provided with a damper, D, so as to regulate of heated air by openings, E, at the upper back part of the kiln. A rectangular opening, F, is left in the front wall of the kiln, from which the melted sulphur is run. This opening, if of sufficient size, may serve for discharging the spent ore at the termination of the fusion. From the upper part of the opening, and also in the front wall, slightly above the level of the floor, flues, G, communicate with a horizontal passage, H, which is made large enough to serve as a condensation chamber, on the walls of which the sublimed sulphur collects. At one end of the chamber is a vertical chimney, I, provided with a damper, K.

The kiln is charged in the usual way by placing the large pieces of ore on the floor in such a manner as to leave passages for the flow of the liquid sulphur; the small pieces are next filled in, and the finer ore at the top. A few blocks of rough stone, or burnt ore, are placed at the opening in front in such a way as to leave a vacant place for the melted sulphur to collect before being run off. When charged, the ore is covered with bricks laid flat, and on these is put a layer of *genese*, well rammed and wetted, so as to form a nearly impermeable coating, with a slight slope toward the walls, in order that the rain water may run off. The opening, F, in the front wall should be closed with a thin wall of plaster of Paris. The ore in the kiln, which is now read for fusion, is put in communication with the spent *calcarone*, B, by opening the damper, D, and at the same time a small hole, N, is made in the wall that closes the opening in front, from which the melted sulphur has been run off from the *calcarone*, B. The current of air entering by the hole, N, and passing through the incandescent mass of ore, is thus heated, and enters the kiln by the flue, N, at a sufficient temperature. In this manner the heated mass of spent ore in the *calcarone* becomes a regenerator of heat, to be utilized in the

FIG. 2.

kiln for the fusion of the sulphur that it contains. In the upper covering, two or more tubes, O P, are placed, and serve not only for observing the internal temperature by a thermometer, but also for firing the mass.

The combustion of the sulphur supplied with hot air, mixed with a considerable proportion of sulphurous acid gas, proceeds slowly in the upper part of the kiln, and the liquid sulphur dropping to the floor, over the already heated ore, cannot solidify and choke the passages, and so prevent the circulation of the heated air and products of combustion of the sulphur to the chimney; in this manner the operation proceeds with regularity. The success of the kiln is principally due to the manner in which it is heated from the top

and back toward the front and bottom, imitating to a certain degree the manner in which the heating of an ordinary *calcarone* proceeds, with this difference, that the heat is better utilized in the kiln, and, therefore, with less consumption of sulphur as fuel.

When the wall that closes the front opening, F, begins to heat, and the kiln is ready for running, a small hole is made with a pointed instrument, so as to allow the melted sulphur to flow off into wooden moulds. The horizontal flue or condensing chamber, H, should have a sloping floor, and when the temperature in it reaches the melting point of sulphur the flowers that have been deposited on the sides are liquefied, and run off. Toward the end of the operation it will be found prudent to close all the dampers as well as the hole, N, to prevent the overheating of the kiln, in which case the sulphur would become thick, and difficult to run off, and the yield would consequently be lessened.

The first cost of the structure is slight, as the materials necessary are usually at hand. The yield too is much increased; but on the other hand the extra cost in charging, discharging, and attendance, as compared with the ordinary *calcarone*, make a large hole in the increased returns.

Doppione.—It will require little reflection to see that only a small quantity of the finely pulverized mineral, necessarily produced in the operations of mining and breaking down the ore, could be dealt with in the *calcarone*; consequently for a long time the bulk of this portion of the ore was simply thrown away, though it often assayed 70 per cent. of sulphur. The *doppione* was one of the earliest successful structures designed to remedy this state of things. As shown in Fig. 4, it consists of a set (generally six) of cast-iron pots, holding about 30 to 40 gallons each, arranged in a gallery furnace, e, so as to be completely enveloped by the heated vapors from a fire beneath. Each pot, a, communicates

FIG. 3.

by a long arm, b, with a cooling condenser, c, for the distilled sulphur, placed outside the furnace. The apparatus is generally employed on rich material, or on that obtained from the *calcarone*; but it is also applicable to ores which are too poor to burn in the *calcarone*, though the profit in that case must be small. The heat generated in the *doppione* is likely to encourage chemical action between the sulphur and any lime carbonate that may chance to be present in the mineral, creating a further loss of sulphur. The pots are charged and discharged by opening the lids, which are kept luted during the distillation. The volatilized sulphur is conducted by the cast-iron tube, b, into the receptacle, c, over which a small current of cold water constantly flows, reducing the sulphur to a fluid condition; it then escapes into the dish, d, beneath, whence it can be ladled into the moulds. The pots last for about 300 working days, and the furnace serves about the same time with a couple of repairs. The workman is expected to turn out 100 lb. of clean sulphur from every 109 lb. of *calcarone* sulphur.

Calcium chloride.—The principle underlying the use of calcium chloride is that, while raising the boiling point of water to about 239° F. (115° C.), the melting point of sulphur, it is cheap and inert in the presence of sulphur. The water to be used in the melting process is charged with 66 per cent. of the calcium chloride, and heated to boiling, in which state it is run into the vessel containing the sulphur to be melted. No doubt the sulphur is efficiently melted, but the very slight difference in specific gravity between the sulphur and the associated impurities from which it had been melted out practically precludes any real separation taking place. Consequently the process is virtually a failure, as I am assured by those who have worked it.

Steam.—At the Rabbit Hole mines, Humboldt County, Nevada, advantage is taken of the liquidity of sulphur at 232° F. (111° C.) to use steam at 60 to 70 lb. pressure for melting the sulphur out of the gangue. The apparatus employed consists of a cylindrical iron vessel, about 10½ ft. high, divided into an upper and lower compartment, by means of a horizontal sheet iron diaphragm perforated with ¼ in. holes. As soon as the upper compartment is charged with ore (about 2 tons), steam is introduced for about half an hour, and the sulphur, liquefied by the heat, flows down through the diaphragm into the lower compartment, kept at the proper heat by injection of steam, and escapes by an outlet, opened at intervals into a receptacle placed outside. When water commences to flow out with the sulphur, steam

FIG. 4.

is injected at full pressure for a few minutes, to clear out as much as will come, and the solid residue is afterward removed through a door above the diaphragm. Each charge requires about three hours for its treatment. The process is adapted to ores which, for poverty and other reasons, cannot be economically worked by *calcarone* or other recognized methods.

Carbon Bisulphide.—While hot water and steam have no solvent action upon sulphur, but merely change it from a solid to a liquid state by the action of their heat, carbon bisulphide actually dissolves the sulphur and redeposits it by evaporation. The plant necessary for carrying out this process is shown in Fig. 5. It is designed of dimensions suitable for dealing with 20 tons of raw sulphur mineral per diem,

yielding 50 per cent. of pure sulphur. The four extracting pans, a, b, c, d, have each a capacity of 5 tons, and are made of ¾ in. wrought iron plate; they measure 6 ft. long, 4 ft. wide, and 4 ft. deep internally; and are fitted with a perforated bottom diaphragm, with connecting pipes, m, leading to the underground solution tank, f, with another set of pipes, k, for admitting steam from the boiler, i, and with a third set of pipes, l, communicating with the store tank, g. The still, e, is a steam jacketed "wrought jacket" pan, 6 ft. long, 4 ft. wide, and 4 ft. deep, with cast-iron ("loam casting") oval-shaped bottom and ends, ½ in. thick,

FIG. 5.

and provided with a dome shaped lid, having an inlet pipe, n, and outlet pipe, o; its capacity is 3 tons. The store tank, g, measures 10 ft. in diameter, by 7 ft. deep, has a capacity of 10 tons, and is constructed of ½ in. wrought iron plates. The worm, h, is a coil of two in. pipe. The boiler, i, is of twenty horse power nominal, and must be placed where it will be impossible for bisulphide vapors to find their way to the fire hole. Force pumps are required to pump the bisulphide from the store tank, g, into the extracting vats, a, b, c, d, previously charged with the sulphur mineral. When the sulphur has been completely dissolved, the solution is run into the tank, f, and thence pumped into the still, e, where, by the application of steam in the jacket, the bisulphide is evaporated, and passes into the store tank, g, for future use, while the sulphur forms a deposit in the still, and is collected therefrom. When the extracting pans have been emptied of solution, steam is let in so as to force any remaining bisulphide vapors into the worm for condensation and recovery, thus avoiding waste of bisulphide and consequent risk of fire and explosion by ignition of its dangerous vapors. The bisulphide is allowed to remain all night in contact with the charge. The diaphragm at the bottom of each extracting vat may advantageously be covered with bagging cloth to filter flocculent matters from the bisulphide.

Making Roll and Flowers of Brimstone.—For the preparation of "roll" and "flowers of" brimstone, the crude sulphur has to be again subjected to heat. The fusing apparatus, Fig. 6, generally consists of two cast-iron cylinders, e, measuring three ft. long by 1 ft. in diameter, closed at one end by a door, e, and prolonged into a tube at the other, which leads into a brickwork condensing chamber, d. The retort, heated by a fire made immediately beneath, is completely surrounded by flues traversed by the heated vapors, which latter, before escaping to the chimney, heat a little pot, a, placed above the retort, and in direct communication with it by means of the pipe, b. Into the pot, a, is introduced the sulphur intended for distillation. It is raised to a temperature of 257° to 302° F. (125°-150° C.), at which point the sulphur fuses, and flows, drop by drop, into the retort, c, where it is vaporized and whence it passes into the chamber, d. The floor of this chamber is an inclined plane, converging to an aperture, g, by which the liquid sulphur flows

FIG. 6.

out, while the "flowered" portion attaches itself to the walls of the chamber. These two forms (the liquid and the flowered) possess the same degree of purity, and their molecular difference depends only upon the varying grades of temperature under whose influence they are produced. An operation lasts about four hours. The door, e, facilitates the removal of spent refuses from the retort; the damper, f, regulates the draught and temperature in the chamber, d; and the door, h, gives access to the interior of the chamber, for the purpose of collecting the flowers of brimstone from the walls. The liquid sulphur, escaping at g, flows into a little pan, gently heated by a separate fire, and is thence ladled into wooden moulds suspended in a bath of cold water, to form the so-called "roll" or "stick" brimstone.—*Jour. Soc. Arts.*

* This block is kindly lent by the editor of the *English Mechanic*.