on an endless chain of plates. The salt so prepared is distributed in a range of not less than eight cast-iron cylinders, which are per­vaded successively by a current of mixed superheated steam and sulphurous acid given off by pyrites. The reaction begins at about 400° C. and increases in energy with the rise of temperature, but it is impracticable to force the heat beyond 500° to 550°, as the charge then begins to fuse and ceases to be permeable by gases.

The condensation of the hydrochloric acid given off in these processes is effected by a variety of means according to the purpose in view in securing the gas. In Continental works a favourite method is to pass the gas through a range of Woulfe’s bottles arranged in an ascending series,—fresh water entering the topmost and passing through the whole, till in the last and lowest, highly charged with acid, it meets the gas coming direct from the roaster. After leaving the last and highest bottle the gas is generally washed thoroughly out by passing it into a small coke tower, in which it meets a downward trickle of water. In English works Woulfe’s bottles are not employed, and the gases are commonly conducted by a long range of piping, in which they are cooled, to one or a series of coke towers, in which they are exposed to an enormously extended condensing surface of water trickling over the coke, stones, or brick with which the interiors of the towers are filled.

*Black Ash Making.—*The conversion of the crude sulphate or salt cake into carbonate of soda, peculiarly the process of Le Blanc, is conducted in what is termed a “ balling furnace.” In its simplest form this consists of a long reverberatory furnace in which the fuel occupies a lower grating at one extremity of the flat sole, on which the whole reaction is carried out. This sole has usually two beds, that more distant from the fire-bridge being a little higher than the front division ; and on front and back beds two separate charges at different stages of advancement are treated simultaneously. The salt-cake is taken as it comes from the roaster, mixed with lime­stone or chalk (crushed to pieces not bigger than a walnut) and with coal or anthracite in the form of slack or culm. The proportions of these ingredients used in different works vary widely ; but, generally stated, to each 100 parts of sulphate there are added from 100 to 140 parts of chalk or limestone and from 40 to 70 of coal. These ingredients roughly mixed are passed by a hopper into the back bed of the furnace, where they become dried and heated, while a previous charge is being finished on the hot front or working bed. When the charge on the working bed has been withdrawn, the mixture on the back bed is pushed forward and spread over the highly heated sole. During the time it is exposed to the flames the ball-furnaceman is constantly at work with a paddle or rake turning over and exposing equally the whole charge to the action of the flame. Very soon the mixture begins to soften and fuse on the surface, and by degrees the whole mass assumes a stiff pasty form. Meantime bubbles of carbonic acid gas are copiously given off, the material becoming of thinner consistence ; but afterwards the charge becomes again stiff, and carbonic oxide instead of carbonic acid is evolved, which as it is given off burns in long pointed flames, called “pipes” or “candles.” The copious appearance of these flames indicates the completion of the operation, and the ball of black ash must now be withdrawn without delay. The time required for working off a charge is from forty to fifty minutes.

The manual labour of black ash balling is extremely hard and trying, while it demands for its success considerable judgment and experience. On these accounts the efforts of manufacturers were early directed to the introduction of mechanical furnaces ; and in 1848 W. W. Pattinson patented a rotating ball-furnace, which, how­ever, owing to severe tear and wear, was unsuccessful. Improve­ments on the revolving furnace were effected by Elliot & Russell, Stevenson & Williamson, Mactear, and others, which have rendered the working of revolvers a complete success. In its general features a revolver consists of a large boiler-like cylinder of cast iron, lined internally with fire-bricks, and suspended horizontally so that it can be made to rotate about its axis. One of the two open ends communicates with a furnace, which sends its flame through the cylinder. From the other end the hot gases are led away for evapo­rating black-ash liquor. The cylinder is surmounted by a platform or railway from which it receives the charge through a manhole in its side. The charge is made in two separate instalments,—the whole of the chalk and two-thirds of the coal being first introduced, and the cylinder slowly rotated till a portion of the chalk has been burned to lime. Then the sulphate and the remainder of the coal, well mixed, are added, the revolver going slowly at first, but more rapidly as the end approaches, the whole balling being completed in from two to two and a half hours. The manhole door being opened, the revolver is turned round to allow the fluid black ash to pour out by it into a series of vessels placed beneath it. Under Mactear’s improved process the whole of the charge is introduced into the revolver at first, and after the decomposition is complete a small proportion of caustic lime is thrown in and quickly mixed with the charge, which is thereon at once drawn.

The lixiviation of the black ash is conducted in a systematic manner so as to extract all the soda with the minimum of water. The apparatus generally employed—the Buff-Dunlop system—

consists of a series of at least four tanks each provided with a false bottom and two outlet pipes, and so arranged that the liquid part of the contents can be made to flow from any one of the tanks into any other. The method of working consists in making fresh water meet nearly exhausted ash, and the liquid, passing on through the series of tanks and becoming gradually stronger, meets ash less and less exhausted, till in the last tank of the series the watery solution in its most concentrated state comes in contact with fresh black ash. As soon as the ash in the first tank is completely exhausted the waste residue is withdrawn and a fresh charge introduced. It then be­comes the last of the series, number two taking the first place ; and so the work goes on in regular rotation. The lye obtained is allowed to clear in large tanks, from which it is drawn for evaporation.

*Boiling Down.—*The evaporation of the tank-liquor is generally effected in flat iron pans, heated from the top by the waste heat of the black-ash furnaces. So soon as a certain degree of concentra­tion is passed, soda begins to separate out in the form of granular crystals. These are ladled out and allowed to drain for subsequent calcination and conversion into soda ash. The purity of the granular salt decreases as the evaporation proceeds, chloride and sulphate of sodium, with the sulphides of iron and sodium, separat­ing out with the carbonate. The red liquor which remains with the salt owes its colour to the iron sulphide it contains. It is intensely caustic, containing much caustic soda. In draining from the soda it carries off with it much of the sulphide and minor impurities from the tanks. The impure soda obtained from the evaporating pans is known as black salt and consists essentially of a monohydrate, Na2CO3 + H2O. A process for evaporation from the bottom is also worked in Lancashire and on the Continent.

*Carbonating.—*Salts that are fished out of the evaporating pan in the early stage of boiling down, being comparatively pure, require little treatment for finishing as soda ash. They have simply to be dried at a moderate heat to expel the water of crystallization. But with the ordinary black salt, which contains a considerable amount of both caustic soda and sodium sulphide, a special purifying and finishing treatment, called “ carbonating,” has to be adopted. For carbonating black salt the strong lye in the evaporating tanks is mixed with sawdust and evaporated down to dryness. The mixture is then introduced into a carbonating furnace, where the heat is gradually raised till the whole of the sawdust it contains is burnt off, and by the agency of the carbonic acid given off in its com­bustion the sulphide of sodium and the caustic soda present are con­verted into carbonate. Mechanical carbonating furnaces have been introduced, the most successful of which is that of Mactear, in which there is a rotating circular hearth acted on by scrapers or ploughs. Ordinary soda ash is at best an impure product containing always some caustic soda, which, however, considering the purposes for which it is used, can scarcely be regarded as an impurity or defect. Its value is determined by analysis and is calculated from the amount of anhydrous soda (Na2O) it contains as carbonate or hydrate.

In many soda-works the black-ash process is purposely so con­ducted as to produce much caustic soda, and the red liquor is then worked up into caustic soda in the following manner. It is first highly concentrated by boiling in a deep iron pan. To the con­centrated solution nitrate of soda is added, which decomposes the sulphide present with evolution of ammonia and formation of sulphate, thus Na2S + NaNO3 + 2H2O = Na2SO4 + NH3 + NaHO. The evaporation is continued till practically all the water is ex­pelled, and the heat is forced till fusion sets in. Then the remain­ing sulphide of sodium with the cyanide is oxidized by the nitrate, which breaks up thus—2NaNO3 = Na2O + 2N + 5O, with formation of sulphate of soda and oxide of iron. Part of the carbon of the cyanogen separates as graphite (Pauli). The fused mass is allowed to stand, when the suspended matter, including, singularly, most of the alumina, settles down, leaving a perfectly clear liquid, which is run into iron drums, where it solidifies. By means of this process, which has been principally elaborated by Herr Ph. Pauli of Höchst near Wiesbaden, a remarkably pure product can be obtained from a very dirty liquor.

*Refined Alkali.—*Ordinary soda ash is sufficiently pure for most purposes for which the alkali is required in bulk ; but for glass making, &c., it is necessary to remove all traces of iron. For this purpose the ash is dissolved in water, and if a well-carbonated ash is under treatment it is merely well agitated and allowed to stand quietly till impurities settle. By some manufacturers a small amount of carbonate of lime is added to the settling tank to carry down the impurities. Ash containing iron salts, sulphide, and coloured impurities is treated with a small proportion of chloride of lime to oxidize the iron and cause its precipitation as hydrated ferric oxide. The settled liquor is boiled down, the crystals drained, dried, and heated in a reverberatory furnace, and finally ground for the market.

*Soda Crystals* (washing soda) are similarly prepared, by forming a strong solution of soda ash, allowing the liquor to settle, and running it into large coolers or crystallizing cones, in which the crystals form in from one to two weeks, according to the coolness of the position. When the crystallization is complete the crust is