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“On the Manufacture of Salt near Middlesbrough.”

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FOR something like 20 miles the River Tees flows through a country, before it reaches the North Sea, belonging, geologically, to the New Red Sandstone formation. Over the area with which the subject of this Paper is more immediately concerned (Plate 3, Fig. 1), this rock is rarely visible, owing to a covering of alluvial matter of great thickness. On the right bank of the river the New Red Sandstone underlies the Lower Lias beds, which form the Cleveland Hills at this point; and on the left bank it gradually rises until it reaches the surface near Hartlepool. After this the Magnesian Limestone, upon which the Red Sandstone rests, becomes the surface-rock over the eastern portion of the county of Durham.

In the year 1859 Messrs. Bolekow and Vaughan determined to sink a deep well at Middlesbrough, in the hope of obtaining water for steam and other purposes in connection with their ironworks in that town. The probability of any springs found in the New Red Sandstone being unsuitable for the requirements of this firm, and the possibility of meeting with a bed of salt, were mentioned to them before commencing operations.

Nothing daunted by these predictions, a well was begun and continued until water, of a very impure description, overpowered the workmen, and caused the ordinary method of sinking to be abandoned. An arrangement was then made with Messrs. Mather and Platt to bore a hole 18 inches in diameter. This it was proposed to continue until good water was reached, shutting off the top feeders by tubbing in the ordinary way.

This hole was sunk to a depth of 1,200 feet, during the

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whole of which the water was found to contain so much sulphate of lime, as to be useless for the objects Messrs. Bolckow and Vaughan had in view. At the depth just mentioned, a bed of rock-salt was struck, which proved to have a thickness of about 100 feet.

Having regard to the facts that 2,250,000 tons of salt are annually produced in England, that one-eighth of this weight was being brought from Cheshire for the soda works on the banks of the Tyne, and that large quantities are exported over sea, the substitution of salt for water near a navigable river was regarded at the time, by some, as the reverse of a disappointment. When, however, it was attempted to sink a pit in order to work the mineral by a regular system of mining, the influx of water was so great that the undertaking was momentarily abandoned, the intention being to resume the attempt hereafter with more powerful means of overcoming the difficulty which had been encountered.

Nothing more was done, and nothing more was heard of Middlesbrough salt for nearly a dozen years, when the firm of Messrs. Bell Brothers, at the suggestion of one of its members, Mr. Thomas Bell, considered the practicability of raising the salt to the surface by a method which will be described in the present communication. On further enquiry it was found that the plan in question was already in operation near Nancy, in France, where its details were investigated by the heads of the firm and their staff.

Before the mode of obtaining the newly-discovered mineral had been fully considered, an exploring hole had been put down on land adjoining the ironworks of Messrs. Bell Brothers, at Port Clarence. The locality selected for the purpose was 1,314 yards distant from the well of Messrs. Bolckow and Vaughan, in a direction a few degrees to the east of north.

The operation was undertaken by the Diamond Rock Boring Company, but its accomplishment was the work of nearly two years. By the method adopted, specimens of the strata gone through (Plate 3, Fig. 2) were obtained in short lengths of a cylindrical form. The salt, 65 feet in thickness, was reached at a depth of 1,127 feet, and it was estimated that the bed had a slight upward inclination in a northerly direction, the difference of level between it at this point and its position at Messrs. Bolckow and Vaughan's being about 80 feet. It may be convenient here to observe that all the wells, which up to this time have been sunk to the salt, are in a remarkably flat country, so that any estimates, of the depth of the bed from the surface, are not much disturbed by variations in the level of the latter.

While boring this trial-hole, gas escaped in abundance, which on examination proved to be nitrogen mixed with oxygen, the latter being in a much smaller proportion than that in which it is associated with the former gas in atmospheric air.

The Coal Measures of the county of Durham do not lie conformably with the Magnesian Limestone, and are, in consequence, cut off by the covering of this rock near Ferry Hill. A little to the south of this village, *i.e.*, near Bishop Middleham, the Millstone Grit was reached during a search for coal, proving that the Carboniferous Measures, if they ever existed in the locality, must have been removed by geological changes in prehistoric ages. An antichlinal axis to the south of Bishop Middleham might, however, restore the coal under the Magnesian Limestone. The importance of such an event has been immensely increased by the development of the iron trade near Middlesbrough, for which something like 5,000,000 tons of this mineral are annually consumed.

With this possibility before them, the owners of the Clarence Ironworks continued the bore-hole for 150 feet below the bed of salt (Plate 3, Fig. 3), in order to satisfy themselves of the existence of the Magnesian Limestone below the Red Sandstone. In confirmation of the truth of this expectation, two analyses, at different levels, are given of the bed of limestone passed through.

Depth from under-surface of the salt		154 feet.	193 feet.
Percentage of Carbonate of lime		54.71	94.48
"	magnesia	41.18	2.98
"	iron	0.81	0.78
"	Silica	2.00	1.20
"	Bitumen	0.22	0.36
"	Moisture	1.08	0.20
		100.00	100.00

A depth of 1,342 feet from the surface was thus reached ending in the limestone, the diameter of the bore-hole being as far as possible maintained the same throughout.

It will be observed that there are very great differences in the amount of carbonate of magnesia in the two specimens; this, however, is by no means an uncommon occurrence in this deposit. Also, it will be seen that there are traces of bitumen in the limestone, but there was, in addition, a constant escape of considerable quantities of inflammable gas, which, on the application of flame, took fire on the surface of the water which filled the hole. It consisted per 100 volumes of:—

Hydrocarbons (CH_4 76.9 vols., $\text{C}_2 \text{H}_6$ 6.3 vols.) . 83.2 vols.
 Nitrogen 16.8 „

Whether the presence of bitumen and these hydrocarbons are mere indications of bituminous shales, or whether they derive

TOP GEAR AT NO. 1 WELL, CLARENCE SALT WORKS.

their origin from the Coal Measures lying in their proper place under the Magnesian Limestone, there is not at present any means of deciding. It is probable that at some future time this investigation will be resumed.

The Author will now proceed to describe the method of raising the salt to the surface. This is performed by solution, in such a way that the column of descending water is made to raise the brine nearly as high as the differences of specific gravity between the two liquids will permit. Saturated brine contains $26\frac{1}{2}$ per cent. of its weight of salt, and has a specific gravity of 1.204; hence a column of such a solution of 997 feet will support one of pure water having a height of 1,200 feet. In other words, a column of fresh water of 1,200 feet will bring the brine within 203 feet of the surface.

A hole, say, 12 inches in diameter at the surface, is commenced and retained of this size as long as it is safe, on account of its weight, to let down a tube of wrought-iron having a diameter of something under 12 inches. This tube has a thickness of $\frac{1}{4}$ -inch, and is used for the purpose of supporting the sides of the hole. The boring is thus continued, and a second length of tube is lowered down the inside of the first, and so on, until the bottom of the salt-bed is reached. The portion of this outer or retaining-tube, where it passes through the bed of salt, is pierced with two sets of apertures, the upper edge of the higher set coinciding with the top of the seam, and the other set occupying the lower portion of the tube (Plate 3, Fig. 4). Within this tube so placed and secured at its lower extremity, by means of a cavity sunk in the limestone, a second one is lowered, having an outer diameter 2 to 4 inches less than the interior diameter of the first tube. This latter serves for pumping the brine. It is secured at its lower end in the same way as the other, and is then provided with snore holes, by which the brine is admitted. The pump itself is an ordinary one fitted with a bucket and clack, but, in addition, at the surface there is a plunger, which serves to force the brine into an air-vessel for purposes of distribution. The bucket and clack are placed some feet below the point at which the brine is raised by the column of fresh water descending in the annulus between the two tubes.

The rate at which the salt is dissolved depends, as will be easily understood, on the extent of surface exposed to the action of the water. This at first, of course, is very slow, and the quantity of salt for some months furnished by a well is inconsiderable, and the brine raised is very weak.

Suppose that the cavity formed by the water is sufficiently large to admit of a few hours' pumping of saturated brine. The machinery is put in motion, drawing at first the stronger brine, which, from its greater specific gravity, occupies the lower portion

of the cavity. As it is raised, fresh water flows in through the holes in the outer tube. The solvent power of the newly admitted water is of course greater than that of water partially saturated, and being also lighter it occupies the upper stratum of the excavated space. The effect of these two circumstances is, the removal of a much larger quantity of the salt on the upper surface of the seam than at the lower—a state of things which ought to give the cavity the form of an inverted cone. This, in point of fact, is what really takes place, as was verified by an examination of one of the Nancy wells after its abandonment, and similar information was afforded at the Clarence Ironworks in a different way.

In consequence of an accident at one of the pumping stations, a second hole was put down, in order to utilize the cavity which had been formed at the first one by pumping up the brine. The distance between the two is 60 yards, and when the bed was reached in the second bore a void was found in the salt. With the knowledge thus obtained, the cubical contents of the cone which had been excavated were calculated. This was found to correspond very closely with the quantity of salt which had been actually obtained from this particular well.

It is obvious that a mode of extraction, which removes the greatest quantity of the mineral where it is most wanted for supporting the roof, must always be accompanied by considerable danger from falls of the superincumbent rock. This danger is intensified in the Middlesbrough district by a layer of 40 feet of the sandstone, lying immediately above the salt, being interstratified with marls, which, being affected by the inflowing water, cause large masses to be detached, as is evidenced by occasional discolorations of the brine. After the first Clarence well had afforded about 56,000 tons of salt, the engine-man was alarmed by a dull sound proceeding from it, which was very quickly followed by the pump ceasing to deliver brine. After much trouble and considerable expense it was ascertained that both the tubes were broken, and all efforts to remove the 60 or 70 feet of double piping so as to insert a new pump have proved ineffectual. At this point the top of the seam of salt is 1,055 feet from the surface. Besides the difficulty just described, it has been found that some of the wells either afford weak brine, or the quantity of strong brine is considerably below the average of other stations. The first source of loss is, in some cases, probably due to the screwed joints of the pump not being tight, or the metal itself of the pipe containing a flaw. Either of these defects permits water from the annulus to enter the

pumping-tube, thus diluting the brine, which of course entails extra expense in evaporation.

The diminution in the yield of strong brine is possibly due to another cause. The rock-salt contains a good deal of earthy matter, distributed in layers throughout its mass. This varying character of the salt is exhibited by the following analyses taken from different portions of the bed:—

				Salt.	Earthy matter, &c.
Specimen No. 1 contained	.	.	.	98.42	1.58
" " 2 "	.	.	.	37.90	62.10
" " 3 "	.	.	.	45.30	54.70
" " 4 "	.	.	.	45.00	55.00
" " 5 "	.	.	.	92.50	7.50
" " 6 "	.	.	.	78.40	21.60

With so much sterile matter to deal with, it is not improbable that the sloping sides of the cavity may get covered with a coating of mud of greater or less thickness, which probably interferes with the action of the water on the salt.

A pump is considered to do good work if it is raising brine eight hours in the twenty-four, and producing enough to give 250 tons of salt per week.

So far as it has been possible to ascertain, there are at present twenty holes from which brine has been raised, but of these, seven are, owing to accidents of the nature described, doing no work. The quantity of brine raised per week is supposed to be equivalent to about 2,750 to 3,000 tons.

Soon after the practicability of obtaining brine from a depth of 1,200 feet had been demonstrated, the probable extent of the rock-salt which furnished it began to be considered. The first well at the Clarence Ironworks was sunk at a distance of nearly 1 mile (1,680 yards), almost due north from that where the bed was originally discovered by Messrs. Bolckow and Vaughan. A second hole was put down by Messrs. Bell Brothers, at a distance of 830 yards, a little to the north of east from the first one, and there the salt-bed was found, rather thicker than at the first, at a depth of 1,129 feet. The Newcastle Chemical Company selected a site close to the River Tees, about 1,400 yards in a north-westerly direction from Messrs. Bolckow and Vaughan's Middlesbrough well, and the same distance in a south-westerly direction from No. 1 pumping-station of Messrs. Bell Brothers. At this point the salt was found to be so thin, only a few feet, that the two holes which had been begun there were abandoned. It would thus appear that the western margin of the deposit had

been reached at 1,000 yards due west from a line, which may be designated the datum line, stretching between the Middlesbrough and Clarence No. 1 well, which line, it will be remembered, runs in a direction nearly due north and south.

At a point 1,300 yards almost due north of the Newcastle Chemical Company's unsuccessful trials, and 850 yards west of the datum line, are five wells sunk by the Haverton Hill Company. At these a bed of a workable thickness was found, from which a good deal of salt has been produced.

The Newcastle Chemical Company having failed in their first attempts, secured a district lying north of the area leased to Messrs. Bell Brothers, and proceeded to put down a well at a point 625 yards to the east of the datum line, and 1,235 yards, a trifle to the west of north, from the No. 2 well of that firm. At this point the salt-bed was found in a satisfactory condition, and it is from here that this company are supplying its salt-pans built on the site where the first trials were made. This firm has now seven wells within a comparatively small space of ground, in respect to which Mr. Alfred Allhusen, the Manager, has kindly given the following particulars:—

No.		Salt struck at feet below the surface.	Thickness of Salt.	
			Feet.	Inches.
1		1,091	112	9
2		1,087	115	4
3		1,089½	101	6
4		1,102	90	6
5		1,090	100	0
6		1,107	99	6
7		1,090	117	0

Only recently a new company, promoted by Mr. Casebourne, of Hartlepool, selected a place on the property of the Trustees of the Greatham Hospital for a trial. It was one originally chosen by the Author, soon after the discovery of the salt near Middlesbrough, on the ground that in all probability the bed would be nearer the surface than it was further south. This surmise has been proved by Mr. Casebourne and his partners to be correct, for the bed has been found at a depth of about 900 feet, with a thickness of about 100 feet. The position of this most northern trial is 4,700 yards from No. 1 pumping-station of Messrs. Bell Brothers, and close to the datum line running north and south through the district.

Some months before the discovery just mentioned, Messrs. Bolckow, Vaughan and Co. had sunk a well near their Eston works, 3,608 yards in an easterly direction from that at their Middlesbrough Works, from which they obtained brine until an

accident of the nature already described interrupted, for the time being, further operations. The bed at this point has a thickness of about 100 feet, and lies at a depth of 1,674 feet from the surface.

From the distances thus given as separating the various wells, the so-called datum line has a length of nearly $3\frac{3}{4}$ miles, over the whole of which the salt may be regarded as being, in all probability, of a workable thickness. In a direction east of this line, the bed has been proved at two points, one at a distance from it of about 800 yards, and the other of nearly 2 miles. West of the datum line reasons have been given for believing that the western edge of the deposit will be found at something like $\frac{1}{2}$ mile from it. How far it extends to the north, east and south of this area there are at present no means of knowing. This knowledge is, however, practically of comparative unimportance, for the existence of a parallelogram having a probable length of at least $3\frac{3}{4}$ miles and a probable breadth of at least 2 miles, has been demonstrated. This is equal to an area of $7\frac{1}{2}$ square miles, and as each square mile in all likelihood contains more than 100,000,000 tons of salt, any anxiety for the welfare of future generations, in connection with this branch of industry, may be considered as not meriting serious consideration. This opinion is given after making what is conceived a reasonable allowance for the bed of salt not being of a uniform thickness throughout; but no endeavour has been made to realize the effect on $7\frac{3}{4}$ square miles of surface, if an attempt were made to remove 100 feet of salt even at a depth of 1,000 or 1,500 feet below it.

There is, however, one question which at no very distant time may occupy the attention of those interested in the Middlesbrough salt trade, viz., the right of one manufacturer to obtain brine produced under the lands demised to his neighbour. As is well known, it is not lawful for A to trespass on ground held by B, and work, by any ordinary system of mining, the minerals it contains, whatever their nature may be. On the other hand, A may put down a well and pump water, or water containing salt, although his so doing may be prejudicial to the interests of B. In such a case the source of the water or brine is one of an unknown character, and the right to both of A may be equal to that of B. Matters stand on a very different footing in the instance in question. The existence of the salt in the solid form can be verified. A sinks a well 1 inch within the line which divides his royalty from that of B. It would be contrary to all reason and experience to deny that a portion, in all probability one-half, of the salt which went to form the brine was taken from

the lands of B, its removal being effected by water let down for the purpose by A. This is not the place to enter upon this subject beyond pointing out a difficulty which may arise hereafter.

A few words may now be said in connection with the purposes to which the brine obtained in the manner described is applied, the chief one being the manufacture of common salt.

As is well understood, most of the substances designated saline are more soluble in hot than in cold water. The ordinary way of obtaining such bodies in the crystalline form, a process employed to free them from any impurities they may contain, soluble as well as insoluble, is first to make a saturated solution in hot water. This is allowed to cool, when the difference in the quantity capable of being dissolved in hot water and in cold is deposited in the form of crystals. The crystals, so obtained, usually contain varying quantities of solidified water, known as the water of crystallization.

Common salt is one of the few exceptions to the law of relative solubility just named, for it is taken up almost as largely by cold water as by hot. It possesses the further peculiarity of forming crystals free from water of crystallization. The former property renders an entirely different process necessary for obtaining it in the crystalline form to that usually pursued in such cases. The brine, as it is delivered from the wells, is run into a large reservoir, where any earthy matter held in suspension is allowed to settle to the bottom. The clear solution is then run into pans, 60 feet long by 20 wide and 2 feet deep. Heat is applied at one end by the combustion of small coal, beyond which longitudinal walls, which serve to support the pan and distribute the heat, conduct the products of combustion to the further extremity, where they escape into the chimney at a temperature of 500° to 700° Fahrenheit. On the surface of the heated brine, which for salt intended for the soda-makers is kept at about 196° Fahrenheit, minute cubical crystals speedily form. On the upper surface of these, other small cubes of salt arrange themselves, in such a way that in the course of time there will be a small, hollow inverted pyramid of crystallized salt. This ultimately sinks to the bottom, where other small crystals unite with it, so that the ultimate shape frequently becomes completely cubical. Every second day the salt is "fished" out, and laid on drainers to permit the adhering brine to run back into the pans.

This process of evaporation appears very simple, but for its proper performance certain precautions are required. If, as happened at

first at the Clarence Ironworks, the water admitted into the brine-well contained vegetable substances, a fine covering, consisting of salt and this extractive matter, formed a pellicle on the surface of the brine which completely stopped evaporation, and, as a consequence, the generation of crystals.

For the production of table-salt, the boiling is carried on much more rapidly, and at a higher temperature, than for chemical salt. The crystals are very minute, and adhere together by the solidification of the adhering brine, effected by exposure on heated flues. The loaves so obtained require to be pounded, and then afford the fine table-salt in common use. For fishery purposes the crystals are preferred very coarse in point of size, and to produce these the evaporating process is conducted at a still lower temperature, and much more slowly than when salt for the soda-makers is sought.

As already mentioned, the usual mode of evaporating the brine is by means of coal burnt under the salt-pans. It happened that at the Clarence Ironworks there was more gas escaping from the blast-furnaces than that required for heating the air and raising steam. The extent of this excess having been ascertained, large pans were placed over properly constructed flues immediately behind the steam-boilers. From these, by means of the waste heat, about 200 or 300 tons per week of salt is obtained. This example has since been followed by Messrs. Bolckow, Vaughan and Co. at Middlesbrough, as well as at Eston.

The value of a substance having the properties possessed by potash and soda increased greatly with the advance of civilization. Among these the power of alkalies to fuse silica is one of the most important, for it affords the means of producing glass of different descriptions. Another is the saponification of fatty substances by which soap is produced.

For a long time incineration of vegetable matter, chiefly trees, lixiviation of the ashes so obtained, and evaporation of the aqueous solution, afforded the well-known potashes consisting almost entirely of carbonate of potash. As the demand for glass and the love of cleanliness increased, forests were speedily cleared, so that mankind had to look about for other sources of potashes, or for a substitute for this alkali.

The introduction of salt obtained from this newly-developed field has already proved very advantageous to the soda-makers on the Tyne, for the increased competition for their custom has been followed by a reduction of several shillings per ton in the price. Indeed, unless new markets be found, there seems a fair prospect

of the wells, already at work or in progress, being more than will be required for the demand of the immediate neighbourhood.

Common salt, a mineral occurring, as has been shown, in great abundance, was known to afford soda, it being, as had been demonstrated by Davy, a compound of chlorine and the metallic base of the alkali, and named in consequence *sodium* by that distinguished chemist. Different methods were tried, having for their object the separation of the chlorine, the other constituent of the salt, so as to obtain soda. Lord Dundonald, father of Admiral Cochrane, and William Losh, senior partner in the firm of Losh, Wilson and Bell of Newcastle, were among the early pioneers in this new industry. Both were men of scientific acquirements, Losh having enjoyed the advantage of studying chemistry at Paris under Lavoisier. At that time there was a duty of about £36 per ton on salt, but through the influence of Lord Dundonald, government permission was obtained to evaporate, free of this tax, a weak brine known to exist in the Walker Colliery, for the purpose of making soda. It was this circumstance which led to the establishment of the soda works at the village of that name on the banks of the Tyne. A French chemical manufacturer, Leblanc by name, towards the close of the last century, had discovered a method of converting the sodium in common salt into the carbonate, which speedily drove every other process out of the market. Leblanc added sulphuric acid to the salt, by which he obtained soda in the form of sulphate, the chlorine being expelled as muriatic or hydrochloric acid. The sulphate was then "furnaced" with coal and carbonate of lime, the product being black ash, or ball alkali, as it was called. It consisted essentially of carbonate of soda, and an insoluble compound of sulphur, of lime and of calcium, the metallic base of lime. By lixiviation the soluble salt of soda was separated from the calcareous compound and evaporated. The saline mass, so obtained, was then exposed to a high temperature to dry it, and to oxidize certain sodium and sulphur compounds, as well as to carbonate any caustic soda it might contain. For certain purposes the dried salt, or soda ash, was pure enough, but for many others it had to be re-dissolved and crystallized, or boiled down into what was known in the market as refined alkali. William Losh's knowledge of chemistry, not a common accomplishment in those days, enabled him to make himself acquainted with the details of Leblanc's process. He visited France for this purpose, and to his observations England is indebted for the introduction of a method of making soda, which since then has grown to be a very important branch of national industry.

The disadvantages of Leblanc's process were, the cost of sulphuric acid, the sulphur of which, having served to decompose the salt, was thrown over the waste heap, the loss of material incurred in three or four furnacings and contamination by certain portions of the salt, and subsequently of the sulphate of soda escaping decomposition. The extent of these impurities in the alkali was such that instead of one hundred parts containing about $58\frac{1}{2}$ per cent. of soda, it was considered good work to obtain it of 52 or 53 per cent.

With all these imperfections, however, Leblanc's invention stood its ground for three-quarters of a century. The Author has in his possession one of the earliest invoice books of the Walker Alkali Company, in which crystals of soda are charged £60 per ton. In thirty years from that time this same article was sold at about £6, and recently it has fallen to under 40s. This very low price was the result of two very important changes in the history of the soda trade. The first was the utilizing of the chlorine, which in the form of hydrochloric acid gas was for many years allowed to escape into the atmosphere, poisoning it and destroying vegetation in the vicinity of the soda-works. The practical use of chlorine as a bleaching agent was first made known by Charles Tennant, the grandfather of the head of the present firm of Messrs. Charles Tennant and Co. of Glasgow, by combining it with lime and introducing it into the market as bleaching powder. The profit derived from the manufacture of this substance was such that, in time of need, the makers were enabled, when selling it at a moderate price, to reduce the price of soda and still to carry on a fairly lucrative business.

In the years 1872 and 1873 soda enjoyed its full share of the prosperity which attended all industrial enterprises. Old works had their capacity increased, and new establishments were founded, so that the result was similar to that which befell almost every other branch of manufacture—over-production, as compared with the demand during a period of diminished activity.

In the case of soda, the second important change, already alluded to, greatly intensified the difficulties the manufacturers had to encounter from mere competition with a surplus of producing power in works all using the Leblanc process.

More than forty years ago Messrs. Hemming and Dyar made known an entirely new method of producing soda, to which they attached so much importance that the Author recollects it being stated, that they valued their patents at £1,000,000. The process consisted in presenting carbonate of ammonia to the common salt,

by which a double decomposition was effected, the products being carbonate of soda and chloride of ammonium. So far as the Author remembers, the sanguine expectations of the inventors were not at first permitted to disturb the minds of the soda-makers, any more than Sir Henry Bessemer's pneumatic process of producing steel terrified the manufacturers of iron rails. It is quite certain that, while the chemistry of Hemming and Dyar was not disputed, the belief of the soda trade was, that the loss of so expensive and so valuable a substance as ammonia would prove an effectual barrier to the new process ever displacing that of Leblanc.

For thirty-five years, or more, little or nothing was heard of sulphuric acid being superseded by ammonia in soda-works, when the idea was revived in a practical form by Mr. Solvay, of Brussels. This gentleman's method consists in using brine, by which the cost of evaporation is avoided. Into it he forces currents of carbonic acid and ammoniacal gases, in such proportions as to generate bicarbonate of ammonia, which, re-acting on the salt of the brine, gives bicarbonate of soda and chloride of ammonium. The brine is used in excess, because the bicarbonate of soda is only sparingly taken up by a solution containing common salt. The chloride of ammonium is then treated with milk of lime. Ammonia is returned in the gaseous form to the operation, and the chlorine is run to waste in the form of chloride of calcium. The soda obtained by the process, briefly described, is in the form of a bicarbonate. This is placed in a reverberatory furnace, where the heat drives off the adhering water and one equivalent of carbonic acid, which leaves the alkali as a monocarbonate.

Thus, then, the ammonia process, like Leblanc's, has a waste product; but instead of sulphur it is chlorine which is lost; and hitherto no plan has been proposed in which chloride of lime, or bleaching-powder, can be made as cheaply from chloride of calcium as it can be from free hydrochloric acid, both being regarded as by-products from the respective modes of obtaining soda.

This conflict between the two modes of producing soda, just referred to, has entirely changed the relations formerly held by soda and hydrochloric acid in the older process of the two. In it the alkali was regarded as the primary product, and the acid and the uses to which it was applied were held as of secondary importance. Now, the competition in the soda markets between the Leblanc and ammonia makers is so great that, so long as the former obtain a fair profit on the bleaching-powder they produce, they appear indifferent as to what becomes of the soda. This is, however, inconvenient, owing to the quantity of soda

given by a ton of salt being greater than that of bleaching-powder. Hence it may happen that, to make good a fall in the price of soda ash of 1s. per ton, a rise of 2s. on the ton of bleaching-powder may be required. When large quantities of ammonia soda began to appear in the market, the price of the old soda ash fell to about £5 per ton, while the quantity of bleaching-powder manufactured was sufficient to bring down the value to something under £4. These two prices left such a loss to the maker, that several of the Tyne works were discontinued, and this went on until the quantity of bleaching-powder produced was no more than the market required, and the soda made was diminished until it reached the equivalent of the bleaching-powder required in the market. Under these altered conditions the latter rose to nearly £8 per ton, which enabled the old works on the Tyne to dispose of their soda in competition with that obtained by the ammonia process.

Near Middlesbrough, the only branch of industry established, in connection with the salt trade, is the manufacture of soda by an ammonia process invented by Mr. Schloësing of Paris. This gentleman was the first chemist who revived the long-forgotten idea of Hemming and Dyar, which was abandoned owing to the then ruinous loss of ammonia. The works for conducting Mr. Schloësing's process are carried on in connection with the Clarence Salt Works. It is believed that the total quantity of dry soda produced by the two ammonia processes, Solvay's and Schloësing's, in this country is something under 100,000 tons per annum, but this weight is considerably exceeded by that of the continental makers.

The Paper is accompanied by several diagrams, from which Plate 3, and the Fig. in the text have been prepared.

[DISCUSSION.

[THE INST. C.E. VOL. XC.]

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Fig : 4.

SECTION OF TUBES.

Fig : 3.

SECTION OF ABOUT 150 FEET BELOW THE SALT, AT BOTTOM OF TRIAL BORE HOLE.

THE MANUFACTURE OF SALT NEAR MIDDLESBROUGH.

Fig : 2.

SECTION OF STRATA AT NO. 1 WELL, CLARENCE SALT WORKS.

Fig : 1.