Chemistry and the World's Food.

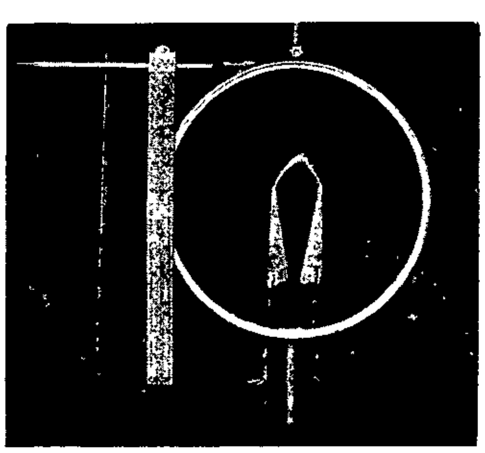
By Robert Kennedy Duncan.

Synopsis.

In the previous article on this important subject Professor Duncan enlarged upon the various forms of fixed nitrogen which we have with us, and which we are continuously using up, and must continuously restore. The author showed how we consume fixed nitrogen in the form of animal food or of certain plant products, such as wheaten bread; but, as pointed out, plants and animals themselves depend upon the soil for every trace of the nitrogen they contain, and the soil is so inadequately charged with this nitrogen that we and the lower animals filch what it contains much faster than it can be restored by natural processes. Meanwhile, the land grows sick and barren and refuses to grow our crops; consequently, we have to cure the land and mix with it manure or fertiliser. The natural manure of the world is, however, a "mere drop in the bucket of our wants;" and Professor Duncan goes on to say that in Professor Adolph Frank's wonderful discovery "we see the unwilling nitrogen, fixed by the genius of man into the active and useful form, working not only in the thousands of nitrogenous substances used in our civilisation, but in the soil, in the plant, and causatively in the actions and thoughts and feelings of men, until, freed of its energy, it sinks back into the Nirvana of the empty air."

SECOND PAPER.

Now, resting on every seven acres of earth there are 237,000 tons of nitrogen, sufficient, if we could burn it, to replace the 1,500,000 tons of saltpetre consumed last year. That we could burn this amount we know, but how to burn it in the cheapest way has still to be discovered. The whole question of its economic burning bristles with difficulties. Not only is the ignition point above the temperature of its flame, but the temperature of the union of the nitrogen and oxygen of the air is perilously close to the temperature of its dissociation, and there results an awkward equilibrium point at which the nitrogen oxides are decomposed as fast as they are formed under the action of the arc. The prize of burning the air is certain riches, but how to proceed is the present question. Is it wise to employ arcs depending upon great electric intensity and small volume, or great volume and small intensity? What kind of electrodes should be used—carbon or platinum, or what? Should the air be compressed,



FLAME OF BURNING NITROGEN. THE IGNITION POINT IS ABOVE THE TEMPERATURE OF THE FLAME

should oxygen be added to it, or should it be dealt with as it is; and, moreover, how shall we be rid of the equilibrium point?

Among the race of chemists and chemical engineers, many men have been busy in the attempt to solve this momentous problem. There is the Atmospheric Products Company at Niagara Falls, where, through their earnest and intelligent efforts to solve this problem, Messrs. Bradley and Lovejoy have won high praise and cordial recognition from all the other workers in this field of investigation. The fact of this recognition is significant; it means that there is room enough for all. These gentlemen believe in sparks of high intensity, and they seem to have perfected their method to the limit of its powers.

The operation is carried out in a sparking chamber which consists of a large cylindrical metal box lined in the interior with vertical rows of contact points, each one of which is in connection with the positive pole of a dynamo generating a direct current of 8,000 volts. Now, inside the chamber rotates a central shaft provided with a similar set of negative contacts in the form of long rods, and all connected, of course, with the negative pole of the dynamo. But this cylinder is rotating at the rate of 500 revolutions a minute, and as each negative contact comes up to a positive, it strikes an arc which is drawn out and extinguished as the negative contact moves past and away from the positive.

In the illustration we see the cylinder at work at the instant of revolution, and since there are many revolutions and many contacts, there are no less than 400,000 arcs a minute. It is like the inner cylinder of a music-box ringing out sparks instead of sounds. But air is drawn through these multitudinous sparks, and each spark as it forms burns a small per cent. of the incoming air into oxide of nitrogen. The result is that some two per cent. of the outgoing air is converted into oxides, which are caught in absorbing towers of water with the formation of nitric acid, or of soda with the formation of saltpetre or sodium nitrite.

From data based upon the actual running of this plant, nitric acid may thus be produced from air and water at a cost of about one penny a pound, and since the market price is about twopence halfpenny, it ought to be a profitable operation. But this is for nitric acid, and large as is the market for this substance, it is not limitless, as is the case with saltpetre. Whether the acid may be combined with soda to form artificial nitrate, at a rate capable of competing with the natural product, is still a matter of doubt; it depends on the price of soda.

Away off on the coast of Norway, where they have cheap water-power and cheap labour, other men are still engaged in the practical elucidation of this same problem. Professor Kr. Birkeland and Dr. S. Eyde, of Christiania, have developed a process by which the air is conveyed into a series of ovens. Each one of these ovens contains two metal electrodes, between which plays a high-pressure flaming electrical arc. The arc is moved rapidly hither and thither by a powerful magnet, in such a way that the maximum amount of oxidation is obtained. In accordance with data submitted by the company, about 2000 pounds of nitric acid may thus be synthesised with an energy expenditure of only one kilowatt-year.

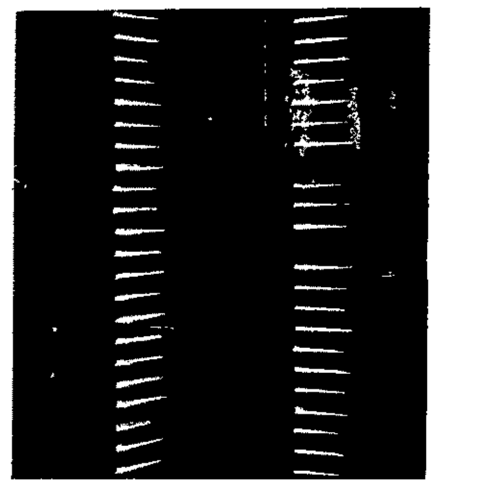
At the present price of nitric acid this means a most respectable profit, and it is not surprising, therefore, to learn that they already employ 2000 horse power for burning the air.

E. Rossi, of Italy, proceeds in still another way. He obtains improved results by oxidising the air under heavy pressure. The oxidation is brought about by an incandescent substance similar to the filament of a Nernst lamp, and the equilibrium point is avoided by absorbing the burnt nitrogen oxides with concentrated sulphuric acid flowing constantly through the interaction chamber. Among the Germans the great firm of Siemens and Halske has been intermittently busy ever since 1884, when old Werner Siemens sent a letter to his assistant directing him to experiment on the fixation of nitrogen. Dr. George Erlwein, who has present charge of this investigation, does not hold with the experiments just described. Instead of a multitude of intense little sparks of high-potential flaming arcs, he employs an arc formed by an enormous current at low voltage. He points out, and very truly, that increasing the size of these other plants will not increase their efficiency, while, in his own case, he finds that the greater the size of the arc he can form (the greater the unit in his factory), the greater is the per cent. of the nitrogen burnt. He has also provided against the easy decomposition of the burnt nitrogen into free nitrogen, by mixing the carbon of his huge electrodes with powdered fluor-spar, thus decreasing the temperature of the arc.

At present this firm is resting on what they have so far accomplished, and for a most significant reason. They have no more doubt than other people that they can profitably make nitric acid out of air and water, and at a rate concurrent with the present market price, but they are not satisfied with the market thus afforded, immense though it is. They demand the exploitation of the whole saltpetre industry as well, and nothing else will satisfy them. They deny that at present the electric nitre can compete with the natural product; hence they prefer to wait until a little further advance in pure science brings it within their grasp.

Calcium is one of the few elements that have the power to unite directly with nitrogen. It is a silver-coloured metal, which with comparative ease burns nitrogen, to form a nitride, and this nitride, on being thrown into water, yields ammonia and lime. Hence, if we could obtain calcium cheap enough, we could obtain ammonia cheap enough, and this would solve the problem of nitrogenous manure. Ten years ago this would have been visionary nonsense; to-day, were there no other means at our disposal, this is the very scheme we should quickly take measures to cheapen and adopt. Two years ago calcium was worth three pounds a thimbleful; to-day it is worth about five shillings a pound, and its price might be greatly reduced.

It is a very common metal, because every bed of limestone contains nearly forty per cent. of it; in the past it was very rare because of the difficulties of its extraction. To-day, calcium is made by



INTERIOR OF CYLINDRICAL SPARKING CHAMBER FOR THE ECONOMICAL BURNING OF NITROGEN. CYLINDER ROTATING AT THE RATE OF 500 R.P.M.

the ton, by decomposing the melted chloride of calcium by a current of electricity. The metal attaches itself to the cathode, and by slowly lifting the cathode a long "cabbage stalk" of the metal is produced. Fortunately we do not need to worry over the still cheaper production of calcium, for, working in one of its compounds, this same metal has solved our problem in another way and with such success that it has temporarily thrown into secondary importance all the other processes we have so far considered.

Everybody has heard of calcium carbide, and of the bright illuminating gas, acetylene, which it evolves when thrown into the water. The story of the carbide discovery, its manufacture, the fond hopes of the investing public that they could displace by acetylene the ordinary illuminating gas which the manufacturers could afford to sell for nothing, their disappointment, the revivification of the industry, and the latest phase of its usefulness, is a story of high romance and high finance. We are concerned here only with its latest phase.

It occurred to Professor Adolph Frank, of Charlottenburg, that the easy manufacture of carbides pointed out a way to the commercial fixation of nitrogen. In order thoroughly to test his schemes, he took refuge under the broad ægis of the restless, experimenting, progressing firm of Siemens and Halske, whose means and resources were adequate to every human purpose. At first he had in mind only the manufacture of cyanides, by passing atmospheric nitrogen over the heated carbide of barium and converting the cyanide of barium obtained subsequently into the most valuable of the nitrogen compounds, the cyanides of sodium and potassium. He was entirely successful in this operation; but, in order to still further improve it, he resolved to make a stubborn attempt to utilise the analogous carbide of calcium instead of barium, for it happens that it is not only cheaper, but much more efficient, weight for weight.

His attempt resulted in a complete surprise. He found, as a matter of fact, that atmospheric nitrogen reacted with red hot calcium carbide in accordance with a little equation, which, with apologies to the lay reader, we shall insert:

$$CaC_2 + 2N = CaCN_2 + C.$$

The result of the reaction is the complete conversion of the carbide into carbon, and into a substance which, while its name sounds something like the calcium cyanide expected, is wholly different from it—calcium cyanamide.

Next he discovered that this calcium cyanamide, on being heated with high-pressure steam, passed easily into limestone and ammonia, and finally he found that, on merely spreading out the material in the moist air, it slowly evolved this same substance, ammonia. This led him to the natural