

THESIS

ON

THE FIXATION of ATMOSPHERIC NITROGEN.

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by

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THE ELECTROLYTIC FIXATION of ATMOSPHERIC.
NITROGEN.

Introduction,

Much has been accomplished in the last few years toward the conservation of natural resources, and in this work the engineer has taken a leading part. The prevention of unnecessary waste, the utilization of hitherto useless by-products, and the economic production of the world's necessities are important features of this work.

It is the latter phase with which this subject deals. A large percentage of the world's commercial fertilizer comes from the immense beds found in the Atacama Desert, in Chile. But as the demand for Chili Saltpeter is increasing rapidly from year to year, scientists are already beginning to look around for another source of supply when these fields fail.

The following paper will be divided into three parts; First, A discussion of the theory and economic principles. Second, a resume of the current literature on the subject. Third, The construction and tests of a chamber patterned after the Thomas and Barry Process.

Part I.

Theory and Economic Principles.

If an electric discharge is passed through a gas or mixture of gases, different chemical reactions are produced according to the nature of the discharge. Thus, if a silent discharge is passed through atmospheric air, the oxygen (O_2 molecules) in the air is changed into ozone, (O_3 molecules). On the other hand, if a spark or arc discharge passes through air, the oxygen and nitrogen of the air are forced to combine; since the nitrogen of the air is thereby fixed in the form of a useful compound, this process is spoken of as the fixation of atmospheric nitrogen.

The combination of the nitrogen and oxygen in air by means of arc or spark discharges in air is apparently a purely thermal effect, so that one may speak of this process as an electric furnace process. The arc or spark simply produces the very high temperature which is required for the oxidation of the nitrogen, which would go on in the same way if the same temperature was produced in some other way.

The reaction is N_2 plus O_2 equal $2NO$. At temperatures between 500 or 600 degrees, the NO changes rapidly into N_2O_3 and N_2O_4 . Proper relations with either water or alkaline solutions (caustic soda, lime water, etc.)

give either dilute nitric acid, or nitrates, or a dilute mixture of nitrates and nitrites.

The higher the temperature, the greater is the content of nitric oxide produced, and the quicker is the transformation. Besides the necessity of producing a high temperature, the second chief requirement is to remove the nitric oxide formed as quickly as possible from the high-temperature zone, and to cool it down as quickly as possible. The reason is that with decreasing temperature the opposite reaction takes place, and the nitric oxide dissociates into nitrogen and oxygen, so that if the cooling of the gas mixture containing the nitric oxide is too slow, the latter will break up into its constituents.

Several commercial systems have been evolved as a result of experiment, and a brief review of them here will be inserted to give a general idea of the methods employed. They are treated more in detail in part two.

In the Bradley-Lovejoy process, by mechanical means, (rotation of a wheel carrying one set of electrodes which pass before a set of opposite and stationary electrodes), arcs are made and broken at the rate of 6900 per second in the space through which the air is passed. The process has not been commercially successful.

In the Birkeland - Eyde process, the arc is deviated magnetically by means of a single phase magnetic field, until the arc breaks, then a new arc is formed, and so on.

This process has been used commercially since 1905 in Norway, (electric energy being very cheap at the plant, costing .094 cents per K.W.H.)

Another method used by the Badische company, in a Norwegian plant is the Schonherr process, the characteristic feature of which is the use of a very long alternating current arc, around which the air moves in a helical path. The Paulding process, at a plant near Innsbruck, in Tyrol, uses an electric discharge quite similar to a horn lightning arrester.

The results obtained by these three commercial processes, as given by the Standard Handbook, were given in 1909 as follows:-

	Grams HNO ₃ per K.W.H.	Concentration
Schonherr	75	2.5
Birkeland Eyde.	70	2.0
Paulding.	60	1. to 1.5

It seems evident that the most important factor in any of these processes is the cheap cost of power. In the Northwest, altho waterpower abounds, it is not in the natural course of events, developed until there is a demand and market for it. And when so developed, other markets offer so much better remuneration that it would be unprofitable to sell power at a sufficiently low price at this time to compete with the natural product.

Another way of looking at it, however, is to consider the advisability of the power company installing furnaces to utilize the off-peak load. It is well understood that a power plant, to give satisfactory service must be designed with a sufficient capacity to carry the maximum winter load, which usually comes, at least for the lighting load, from four to twelve P. M., about Christmas time. Of course, the plant can run on overload for this short time, but the fact remains, that the average load factor of a up-to-date plant, ranges about fifty per. cent. This means that capital must be invested in machinery, equipment, etc. which works at its most efficient capacity only a small part of the time. Therefore, if some arrangement could be made whereby the off-peak load could be utilized to produce some commercial necessity, such as commercial fertilizer, the result would be almost clear profit, except for investment.

C.P. Stinmetz suggests another phase of this in the A.I.E.E. proceedings, May 1911, Vol X.X.X. No. 5 page 1021.

"Another subject is the utilization of spare power and off-peak power. I am interested in the data given on the power required for irrigation, and the relatively small amount of power it costs to operate a pumping plant for irrigation purposes.

"Another use for off-peak power is the fixation of atmospheric nitrogen. We are rapidly approaching a time when we shall have to ^erely on fertilizers to maintain the productivity of our soil. Now the commercial production of nitrogen compounds by electrical power has been conducted successfully and economically; but only where the development of the water power has been extremely cheap, and where there was no market available for it,--as for instance in Scandinavia.

We must however realize that the main part of the cost of installation of such industrial operations is due to the plant needed to convert the very dilute oxides into nitric acid, or solid nitrates for transportation. Therefore, a large part of the cost is due to the chemical side of the production.

When we come to intermittent use of the off-peak power, where the plant is used only for a part of the time, then the cost of the production rapidly increases,

due to the interest on the investment, and we find, very soon a point is reached where the production of nitrates would not be economical, even if the power cost nothing. Herein consists at present the great difficulty of utilizing electrical power for the fixation of nitrogen. But since this results from the cost of concentration, then if we could use the fixed nitrogen in a highly diluted state, we could save most of the investment, and so materially reduces the cost; and it would be economical. That means that this method of using off-peak power lends itself nicely to the combination with irrigation, We might use electrical power for irrigation and also for producing nitrates, and send out the nitrates as fertilizer with the irrigating water on a highly diluted state. In this way you could use a large amount of electrical power and get the benefit of intermittent and off-peak power available in arid districts."

UTILIZATION OF ATMOSPHERIC NITROGEN.

What it Means to the Farmer.

by

A. Bernthsen.

Director, Bradische Anilin-u Soda Fabrik,

Ludwigshafen, a/RH.

Note:- This article appeared in both the Scientific American Supplement for Nov. 13, 1909, and the Engineering and Mining Journals for Oct. 16, 1909. And is an abstract of an address delivered at the 7th International Congress of Applied Chemistry, London 1909.

Oxygen has hitherto been considered the most important element of the atmosphere, since it is indispensable to the existence of human life. Nitrogen, on the other hand has always been considered as an inert gas; in spite of this however nitrogen plays an important part in the nutrition of all living organisms, making it necessary to investigate new sources for obtaining nitrogen compounds.

The different methods employed in the fixation of atmospheric nitrogen may be divided into three groups:- First, the direct formation of ammonia from its elements, nitrogen and hydrogen, both of which have to be isolated for the purpose.

Second, those processes in which the nitrogen is isolated and then converted into metallic nitrates and cyanogen compounds, which in their turn can be subjected to chemical reaction and lead to the production of ammonia; and third, methods, which aim at the direct oxydation of atmospheric nitrogen, and the conversion there of into nitrates and the like. In the last case, the air itself is used directly and a previous isolation of the nitrogen is unnecessary.

Nitrogen may be produced from the air by passing it over red hot copper, forming copper oxides or by liquifying air and then separating the nitrogen by

fractional distillation.

The third method of combining nitrogen consists in converting it by direct oxidation into oxides of nitrogen which are then transformed into nitric acid and nitrates.

The first compound formed is nitric oxide N.O., a colorless gas. On mixing with oxygen or air, it assumes a yellowish red color, owing to the formation of a higher oxide of nitrogen, ~~which is termed nitrogen,~~ which is termed nitrogen tetroxide or nitrogen peroxide corresponding to the formulas NO_2 or N_2O_4 . This is then converted into nitric acid, or into some other form suitable for practical purposes.

One great difficulty is that the same high temperature which brings about the formation of nitric oxide also tends to decompose it back again into its constituents.

For this reason it is very important that, in order to work properly, the air must be heated to as high a temperature as possible and then cooled down again with the utmost rapidity, so that as little opportunity as possible is given for the nitric oxide, formed at the high temperature to decompose back again into its elements.

A brief description of the Bradley and Lovejoy follows, with the conclusion that the small yield coupled

with the complexity of the apparatus and the expense of keeping it in order sufficed to prevent the process being worked at a profit.

The Birkeland and Eyde process is next described. It is considered the first practical success in this field and was worked out in 1903 by Prof. Birkeland collaborating with the Norwegian Engineer, Samuel Eyde.

If an electric arc fed with an alternating current is made to burn between the poles of an ordinary electromagnet, or one excited by direct current, the arc appears to form a disk. Actually, the arc is blown into a half disk at every period, but the impression on the eye is that of a quietly burning disk, like the sun.

An arc of this nature operated in a flat iron clad furnace of fire proof clay, which was passed a strong current of air, produced a considerable yield of the oxide of nitrogen yield of the oxide of nitrogen.

Those furnaces now used are each fed with 700 K.W. at an E.M.F. of 5000 volts, and the disk of flame is over two yards in diameter. The utilization of such a large quantity of electricity at a single discharge constitutes the great difference between Birkeland and Eyde's process and those of the earlier experimenters.

The Schonherr process, worked out by Otto Schonherr and the engineer Hessberger, solved the many of the pro-

blems in a surprisingly simple manner, possessing many advantages over the Birkeland and Eyde method.

Schonherr does not use magnets, but produces his ~~arco~~ ~~in~~ arc in a long iron tube of comparatively small diameter, passing the air along the tube with a wirling motion, blowing the arc out to considerable length.

The description of the Schonherr process, which follows, will not be repeated here as it is described more fully elsewhere.

Up to the present time both nitric acid and nitrites have been manufactured from saltpeter by chemical means, nitric acid being produced by heating saltpeter with concentrated sulphuric acid, while nitrites result on heating sodium nitrate with metallic lead, which extracts one atom of oxygen, and is itself converted into lead oxide. Both nitric acid and nitrites are consequently more expensive than saltpeter. Nitrogen in concentrated nitric acid, is two and one-half times, and that in nitrites, is one and one-half times as valuable as nitrate nitrogen.

It would then, be more profitable to make nitric acid and nitrites, provided the consumption of these latter were sufficiently great, but since the demand is limited, the chief aim of every large factory is to convert the supply of nitrogen into the form of salpeter, for which there is an unlimited market.

The so-called acid-absorption process, described at this point is omitted now as it is described elsewhere more in detail.

More recent experiments at the Anilin-u Soda-Fabrik have shown the possibility of effecting the absorption directly with milk of lime and in this case the acid absorption would be dispensed with and the outlay on plant greatly reduced.

Utility of Product.

The calcium nitrate, obtained by means of the operations described can without farther treatment replace Chili Saltpeter for the purposes of agriculture. Even a certain quantity of free lime, say 20% appears to have no deleterious action on vegetable life, and the same remark applies to any calcium nitrite mixed with the nitrate. It is conceivable that calcium nitrite will become the artificial manure of the future especially as its manufacture is so simple and it is richer in nitrogen than calcium nitrate.

Both of these processes require very cheap water power before they can be carried out profitably. The waterfalls in Norway, which, owing to the climate, have a fairly constant supply throughout the year, are particularly suitable. Therefore a number of large Norwegian companies have been exploited in that country for the production of the so-called air saltpeter.

A synopsis of the advantages of air-saltpeter as compared with nitrolime shows that not only is the former much cheaper and richer in nitrogen, but its production, not requiring coal, uses none of nature's resources but the inexhaustible water power.

Part 2.

The Fixation of Atmospheric Nitrogen.

Birkeland & Eyde Process.

Sam Eyde.

Scientific American Supplement. , July 3, 1909 # 1748.

The greatest difference between the Birkeland - Eyde process and previous methods was that the former have applied large quantities of electric energy, and have found the best way of doing it, while it was previously believed that it was small quantities of energy that gave relatively the best results. In this respect, it is probable that future systems will all, to a greater or less degree, employ large quantities of electric energy in the arc.

The formation of the flame occurs through an arc of the electric flame being formed between the points of the electrodes, which were placed close to each other. By this an easily movable and flexible current is established, which, with the arrangements made, will be formed in a highly magnetized field. The arc that is thus formed moves, on account of this magnetic field, with a great velocity perpendicularly to the lines of force, and the electric arc's foot draws back from the points of the electrodes. When the length of the arc increases, the resistance becomes greater, and the tension increases until it becomes so great that a new arc β

springs from the points of the electrodes.

To regulate the current, an inductive resistance is used in series with the flame. With alternating current all of these arcs are formed in opposite directions, and appear to the eye to be circular disks. The flame burns with remarkable steadiness, and appears to be a remarkably powerful technical means for the oxidation of the nitrogen of the air.

An electrode 1.5 cm. thick of copper tubing, through which water is passed for cooling purposes can take up 1,500 horsepower. , producing a flame 1.8 meters in diameter. The chamber in which the flame burns is circular, of only a few centimeters in width, and about two meters in diameter. After the oxide of nitrogen is formed in the furnace, it is converted in the oxidation tank into the dioxide of nitrogen, and in the absorption towers, into nitric acid.

The Birkeland - Eyde process has been developed from a small furnace which one could hold on his hand, with its glass absorption chambers of only a few liters capacity, up through a number of plants, all increasing in size and seeking a greater amount of cheap electrical power, up to the present plant with its capacity for 1,500 horsepower per furnace and absorption towers of 600 cu. m. capacity, each.

The building where the furnaces are located has a floor space of 2,000 sq. meters, and is constructed of masonry and iron. In the basement are tubes for admitting the air and carrying off the gas. Power at the station at Svaelgfos is brought in by eighteen copper wires, each twelve millimeters in diameter. Of the thirtysix furnaces installed, thirty-two receive their power from Svaelgfos, and four from the Tinfos power station.

The flame chamber is formed of fireclay brick; the air enters ~~thru~~ the walls of the chamber, and the gas escapes through a channel in the casting, also lined with fire clay.

They require very ^{little} regulating, burning for weeks at a time, and the necessary repairs are very simple, the electrodes, which are subject to the greatest wear, requiring a change every third or fourth week, and the fireproof masonry every fourth to sixth month.

The temperature of the flame exceeds 3000 or 3500 degrees C.; the temperature of the escaping gas may vary between 800 and 1000° C. These gases pass from the chamber into two fire-proof lined, gas-collecting pipes, about two meters in diameter, which convey the gas to the steam boiler house, where the temperature is reduced by passing them through four steam boilers; the heat given off is used for concentrating the products

and in heating the factory during the winter.

The gas passes on through the steam boilers to a cooling house, thence to the oxidation chambers; these tanks are vertical iron cylinders, lined with acid-proof stone. Their object is to give the cooled gases a sufficient period of repose, in which the oxidation of the oxide of nitrogen may have time to take place, the necessary oxygen being in the air present in sufficient quantity.

From here the gases are lead to the absorption towers, which are filled with broken quartz, that not being effected by the acid. The gas, forced by blowers, enters the base of the first tower, passes up through the quartz packing and out at the top through a large earthen pipe to a second tower; down through the second, up through a third, etc., until, finally, freed of its nitrogen, the air passes out of the last tower

The absorption fluid is distributed by jets at the top, and comes in contact with the gases as it trickles down through the tower, the water being converted into weak nitric acid, and the alkali into Sodium nitrate. The liquid runs out in a continuous stream at the bottom, and is passed through several times before becoming saturated. In this way about 97% of the total gas is absorbed.

The nitric acid so produced, having a strength of 30% by volume, is run into granite vats filled with limestone, forming, with much effervescence of CO₂, Calcium carbonate. This watery solution is then evaporated in vacuum to save heat; concentration is continued until of about 13% nitrogen content. The nitrate is then allowed to settle, ^{and} crystallizing out in solid lumps. These are broken and crushed, and then placed in barrels holding 100 kilos. net weight.

The nitrite solution secured from the alkaline towers is evaporated, crystallized, separated by centrifugal force, dried under a current of hot air, and barreled similarly.

Everything about the plant is run by water power, no coal being used, and the only steam employed being obtained from the heated gases,

Extensive experiments were carried out by eminent scientists of many of the leading countries of Europe, all tending to prove that as a fertilizer nitrate of lime was equal to nitrate of soda, and in soils deficient in lime, it proved to be superior for many crops.

The Svalegfos Power Station, from which much of the power is obtained, is the largest hydro-electric ~~plant~~ plant in the world, at the time of writing, the four turbines yielding from 40,000 to 45,000 turbine horsepower.

Schonerr Process.

Eng. & Min. Jour.

Oct 15, 1909.

This process, worked out in 1905, is said to possess several advantages over the Birkeland and Eyde process.

It dispenses with the electro-magnets and passes air through a tube of comparatively small diameter, in which an electric arc is burned. The iron tube contains an insulated electrode at one end, and can itself serve at the second electrode.

The arc at the moment of its formation springs from the insulated electrode to an adjacent part of the tube, which is only a few millimeters away; but the air, introduced with a tangential motion, immediately carries the end of the arc along the wall of the tube, so that it enters the tube at a considerable distance from the electrode, or on a special electrode placed for the purpose, say at the other end of the tube.

The arc emits a bright white light and is quite stable. The air in passing through the tube comes in contact with the arc and becomes partly converted into nitric oxide, and is rapidly cooled down by contact with outside layers of air, and consequently a decomposition back into N and O is avoided. The tube is further cooled by a water jacket.

The gases leaving the tube contain about 2% NO., from $1\frac{1}{2}$ times to nearly twice the concentration of the Birkeland & Eyde process. The experimental furnaces at

Christiansand are fed with about 600 H.P. at 4200 volts; arcs are produced nearly eight yards long. Altho in this process there is very little loss of electrical energy in producing the arc, only a few per. cent serves to bring about chemical change.

30 % is employed in producing hot water.

40 % heats the boilers.

10 % removed by cooling.

17 % lost by radiation.

On cooling the gases, as soon as the temperature reaches a certain point, about 600 C., the nitric Oxide begins to combine with the excess of O, forming nitrogen tetroxide, N_2O_4 .

As a market, the compumtion is not sufficient to warrent the manufacture of nitric and nitrous acids to any great extent, but there is an unlimited demand for potassium nitrate, or saltpeter.

Before the N_2O_4 , contained in the furnace gases after cooling is capable of yielding HNO_3 it must have an other atom of O added, usually by the action of water. The gases are passed through the absorption tower, where two-thirds of the nitrogen is converted into HNO_3 while one third is regenerated as N.O., forming N_2O_4 , and this goes through the same series of reactions again. An absorption liquid may be used several times, becoming as rich as 40%.

Nitrates can be obtained direct from the furnace gases by employing sodium or calcium carbonate as the absorbing agent at the same time keeping the temperature and other conditions such that during absorption the gases contain equal quantities of N_2O_4 and unaltered N_2O_2 .

Another method is by passing gases over quicklime.

After passing the water towers, the gas passes to a tower where it comes into contact with a milk of lime solution. The lime is converted to a mixture of calcium nitrite and calcium nitrate. The $Ca(NO_2)_2$ is useless as a fertilizer; therefore to this is added a portion of nitric acid and distilled giving Calcium nitrate, N_2O_2 and N_2O_4 ; the calcium nitrate is vaporized by the help of steam raised in the boilers by the escaping hot gases.

The calcium nitrate is marketable as:- 1st, in the fused state containing 13.5% N. 2nd., in crystals. 3rd, as a basic salt, a dry power, not absorbing water from the atmosphere,. The cost of the extra calcium is slight, and is of itself of agricultural value.

The Reduction of Atmospheric Nitrogen.

The Schonherr Process.

Scientific American Supplement# 1784. Mar. 12, 1910.

Dr. Schonherr produces an arc which is very long in some cases over 20 ft.

The bottom electrode is of Cu. with a movable Fe. core from which the arc springs the Fe. and not the Cu. being consumed slowly thereby.

The tangential openings maybe partly closed by means of a sliding collar.

Spiral motion of air up the tube keeps AC, arc straight in center of tube.

In the furnaces inside at the Kristianss-and plant the arc has a length of 16 ft. for the 600 horse power furnace, and for the more recent 1000 type it has a length of less than 22 ft.

Working of the arc can be observed by means of eye-pieces.

Water cooling chamber around upper end of tube.

Entering air is heated by passing up and back the length of the tube before entering the arc chamber.

The gases leaving the furnace consist of air and about 3% of $N_2 O_2$, such per centage, seemingly low, being in fact one of the highest yet obtained.

The $N_2 O_2$ changes to a reddish brown $N_2 O$ when cooled to from 600 to 140°C.

To prepare the nitrates, the gas is absorbed by soda or lime in suspension. By using lime, there is formed a nitrate of lime which has a greater proportion of nitrogen than usual, and contains 18%, while Chili saltpeter has but 15% and the Nottoden product but 13%.

A diagram and illustrations accompany the article.

Part II.

From the Electrical World.

July 21, 1906.

by

J. B. C. Kershaw.

May Sibley Journal gives the following products for the different processes, and also the efficiencies of several methods,

		%
Raleigh.	49.1 gr per K.W. Hr.	
MacDougall & Howles	33.8	
Kowalski & Moscicki	55	35
Nuttman & Hafer	70	
Crookes	74	
Bradley & Lovejoy	83	
Birkeland & Eyde	110	70

The maximum possible yield is 157 Grams per K.W. Hr.

The principle difficulties are to secure a cheap source of power, and to prevent the reaction from reversing.

In the B. & E. process, an arc is struck between horizontal electrodes, in series with inductance; the poles of an electro-magnet are brought close to the arc at right angles electrodes. In the first units employed 75 to 200 K.W. were employed per pair of electrodes. E, 500. f, 50. The electrodes were of copper or iron.

A larger plant was put in in May, 1905, at Notodden. Three generator units and furnaces of 700 H.P. each have been erected. All have a capacity of 75,000 liters of air per minute.

Part II.

The NO is oxidized and absorbed in four stone towers; a fifth tower using milk of lime completes the absorption all owing only 5% to escape.

One half ton of 100% nitric acid is produced per K.W. Yr. at a cost of \$4.00. Each furnace produces an equivalent of 250 tons of 100% nitric acid, equivalents to 325 tons of calcium nitrate, or to 337 tons of sodium nitrate per year. This plant is thus capable of producing 1000 tons of Chile saltpeter per year.

Thomas & Barry Process.

SCI. AM. SUP.

Dec. 21, 1907.

Earlier experimenters wished to expose as much air as possible to the arc, and so blew the flame out to its extreme length and smallest cross section, and fed it with a continuous blast of air --- Later experiments showed this to be wrong. A short length of arc gives nitrous oxide; as the flame is drawn out, more nitric oxide is produced, and when the arc breaks, the discharge which follows produces ozone almost entirely.

The flame is now brought to its most efficient form as quickly as possible, and maintained there while the air passes it. A pressure of 33,000 volts was used, stepped up from 220 volt ~~of~~ a 60 cycle supply. By thus reaching the condition of greatest effectiveness, it is found that under identical conditions, the steady arc produces FOUR times as much HNO_3 at the older forms.

Having investigated the flame, the investigators turned their attention to the air supply. A volume of air is kept in the chamber containing the flame, being held by an arrangement of valves. An advantage is that the rise in temperature nearly increases the pressure of the air instead of rarefying it.

Diagram. The valve circuit is broken just before the flames are put out, and the gases under the heat pressure escape to the combining vessel. When the flames are

extinguished the temperature falls and fresh air rushes in through the inlet. The expansion of the gases as they leave their chamber absorbs nearly all the excess heat, and they reach the combining vessel only a few degrees hotter than the air. They are O., N., & NO

Norwegian Hydroelectric Developments.

Electrical World,

June 8, 1911.

At the May meeting of the Faraday Society Mr. Scott-Hansen, C.E., of Christiania, Norway, read a paper on "Hydroelectric Plants in Norway, and Their application to Electrochemical Industry," showing Norway to be an ideal country for the production of air-saltpeter,

The total water-power in Norway has been estimated at from 5,000,000 to 7,000,000. The power stations can supply power at from \$ 5.50 to \$ 11.00 per annual electrical horsepower, and as the quantities available are as high as from 50,000 to 100,000 horsepower from a single fall, the conditions are ideal for the development of electrochemical and electrometallurgical industries. Nearly 180,000 horsepower will be utilized this year in the manufacture of nitrates of lime, soda and ammonia from the air by the Birkeland Eyde process and the Badische Anilin und Sodafabrik Company's process.

(see. Electrical World, April 27, 1911.)

Construction of the Chamber.

In attempting the experimental work in connection with this subject, the first and most important consideration was the general system to be followed; considerable reading and briefing had been done and the various systems were then considered as follows:-

The Lovejoy process, at Niagra Falls was quite complicated, and as it had proved a commercial failure, further consideration was abandoned. The Birkenland - Eyde process, while commercially successful, was also somewhat complicated. The Schönherr process was for a time considered, as being comparatively simple and efficient. There remained also the Paulding and the Thomas and Berry process. Considering the efficiency claimed for these processes, it was decided to select the method which has shown itself to be the most efficient.

These and other considerations finally lead to the selection of a type of furnace similar to that used in the Thomas and Berry process. Casting about for a vessel of such shape and material as would be most conveniently and easily constructed, and at the same time fire-proof and of a shape which would admit of

its being readily emptied of air, a large five gallon earthen jug was finally ordered as appearing to be the most suitable.

Before going further with the description of the furnace as designed, it might be well to review briefly the operation of a furnace of this type. A gravity intake valve is placed in an upright position at the bottom of the furnace, and a solenoid valve is placed at the top. The spark gap is after the pattern of a horn lightning arrester, being comparatively close at the base and arcing out to probably three times this distance at the top. The arc has a tendency to form at the base of the gap and then run up along the metal of the horn gap until its length becomes so great that it blows itself out. A new arc is then immediately formed and the same operation is repeated.

The operation of the furnace is as follows;

Current is allowed to flow through the solenoid, closing the outlet valve, and the arc is started. The increase of temperature produces an increase in pressure which tends to hold the lower or intake valve closed and force the outlet valve open ^{against} ~~under~~ the action of the solenoid. After the arc has been operating a specified length of time, the solenoid valve is

opened, allowing the gases to escape directly into absorption towers; the sudden expansion due to releasing the gases under pressure cools them sufficiently to prevent the disintegrating of the oxide of nitrogen that might be produced.

After the outlet valve has been left open long enough to allow the pressure to be equalized, the arc is extinguished and the outlet valve closed. The subsequent cooling and contraction of the gases cause a new supply of air to be drawn in from the outside atmosphere, and the cycle is repeated.

In the construction of a chamber of this type, three holes were punched through the bottom of the jug before mentioned, through which were to pass the terminals of the spark gap and the intake valve.

A series of experiments were attempted to find out the best distance for the base of the spark gap and also to note the behavior of the spark. For producing the spark, a large 800 to 1 transformer was used; with about forty volts on the primary and a current of thirty amperes flowing, a very satisfactory distance for the gap was found to be about three inches. But it was further found to depend so much on the voltage of the supplied power, that a six inch spark gap would

operate just as satisfactorily with a little increase in the voltage; it was determined, then, that since the supply power was under control, to set the spark at the most convenient distance to correspond with the size of the jug, and regulate the supply to give the most satisfactory results.

The sparking terminals, as well as valves, were made of brass. For the valves, one inch brass shafting was trued up in the lathe and bored out with a half inch hole. One end was then threaded for a distance of about an inch and a half, and then the half inch of threads nearest the end were cut out in order to make a smooth tip. The valve seat was then cut in at this end at an angle of forty five degrees.

The piece was then reversed in the chuck and a three quarters inch hole was bored to within about half an inch of the valve seat. This left a large passage for the air, contracted at this point in order to provide a long valve seat.

One and one-half inch brass shafting was then bored ~~out~~ out and threaded for an inch of its length on the inside to take the outside threads of the first piece. The other end of this piece was cut down in order to receive a delivery tube.

Both of the valve seats were made in the same manner, the outlet valve being provided with a longer stem in order to accommodate the solenoid.

The valve cap of the intake valve was cut from brass and hollowed out to a thin shell in order to make it as thin as possible. For the outlet valve an iron plunger was turned out slightly smaller than the large part of the stem, and a neck was provided small enough to protrude through the contracted part and be screwed firmly to the valve cap. V shaped grooves were then cut along the length of the iron core in order to allow the air to pass more freely.

The brass parts adjacent to the screws were milled that they might be more readily grasped for tightening or loosening the screws.

All the brass parts were covered with a laquer to prevent tarnishing.

Conclusion.

It is regretted that experiments could not be made to determine the performance of the apparatus. However enough work has been done in the way of collecting material and the construction of the Valves and furnace to provide a excellent basis for future investigation, should anyone desire to take the subject up, and a number of instructive tests may be recommended, among which are the following:-

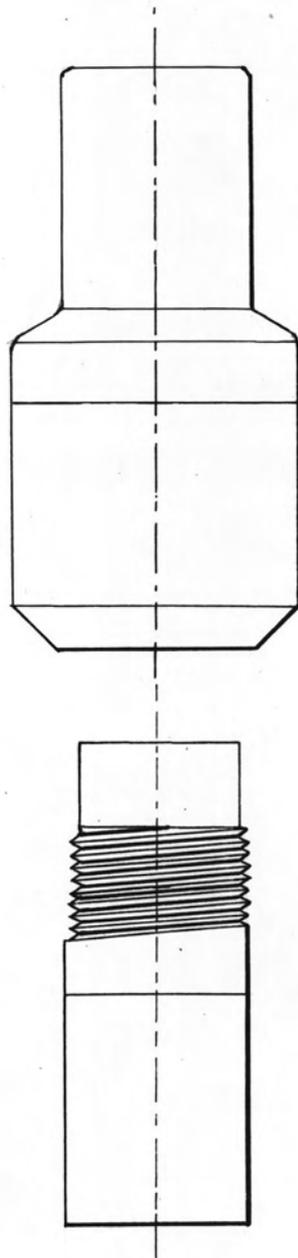
Tests for the most satisfactory combination of spark gap and power supply.

Measurement of the temperature attained in the chamber under various conditions.

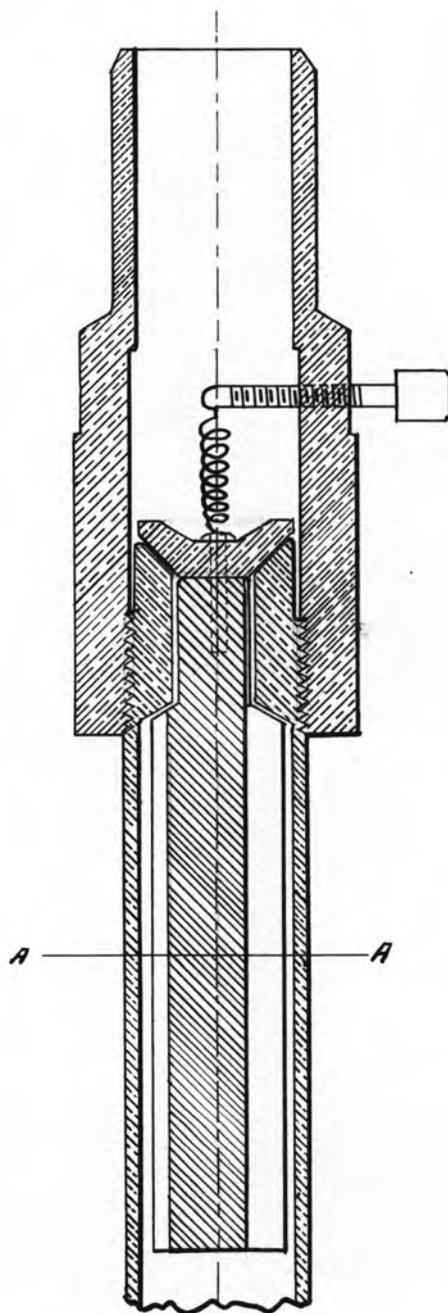
Experiments to obtain the conditions of maximum efficiency.

Comparison of the results obtained with those of other methods.

This is a new and untried field, but one which promises of considerable development. Tests of this nature would, at least in this part of the country, be rather in the original research than hackneyed experimenting, and it is felt that one will be well repaid for the time put in in studying this subject.



Intake Valve.



OUTLET VALVE.



Section A-A.

Full Size.