be used as a substitute for gunpowder. Soon afterward Bottger and Otto independently discovered gun-cotton. The method of manufacture was not made public until 1847, when Knop, also Kamarsch and Heeren, prepared gun-cotton by means of a mixture of nitric and sulphuric acids. About the same time, Milon and Gaudin employed a mixture of sulphuric acid and nitrate of potash and soda, which they found to have the same effect. Gun-cotton at once became an object of great scientific and practical interest, and its manufacture was undertaken in England, France, and Russia. Unfortunately, several explosions occurred, which temporarily caused its manufacture to be entirely abandoned in this country and in France. In Austria, Gen. von Lenk still continued to carry out experiments, and succeeded in improving its manufacture to such an extent that in 1853 a factory was erected under his supervision at Hirtenberg, near Vienna. This factory was officially closed in 1865, owing to the explosion of two magazines. The success of Lenk's process, however, attracted the notice of English scientists, and formed the basis of Sir Frederick Abel's address at the annual meeting of the British Association at Newcastle, in 1863, with the result that Mr. Prentice, of Stowmarket, in collaboration with Sir F. Abel, erected a factory. Gun-cotton made according to Lenk's process was chiefly manufactured from long staple cotton in the form of yarn dipped in a mixture of nitric and sulphuric acids, and afterward put into cages or wire baskets, placed in a stream of running water, and allowed to remain several weeks, until sufficiently purified from free acids, so as to be comparatively stable. If required for mining purposes, the yarn was afterward twisted, and made into ropes of various sizes, chiefly from $\frac{1}{2}$ -inch to $1\frac{1}{4}$ -inch diameter, according to the size of the bore hole in which it was to be used. It was afterward cut into lengths of from 4 inches to 5 inches, and dried, each length forming a charge for blasting purposes. During the next few years a large trade was done in the above form of charge, more particularly with the slate quarries in Wales. At the same time many experiments were car-

FIG. 1.—EXPANSION WITH EXTERNAL WORK AND LIQUEFACTION UNDER PRESSURE.

ried out, with a view to taming gun-cotton sufficiently for use in shot guns, rifles, and cannon.

The form chiefly used was a braided tube like certain lamp wicks, or a braided rope or coil, similar to engine packing, the idea being that the sportsman having several yards in this form in his possession would cut off an inch or more and charge his gun or cartridge cases as occasion required.

For rifles, the gun-cotton yarn was sometimes tightly pressed into paper or wood tubes which were afterward covered with gun-cotton braid so as to occupy the same space in the chamber of the rifle as a charge of black gunpowder. Charges for cannon were also made upon the same principle, but the results in gun, rifle, and cannon were very erratic and unreliable. Sometimes the charge exploded with great violence. At other times it was scarcely powerful enough to send the shot out of the gun.

About the year 1865, the whole process of manufacture was revolutionized by Abel's patent, which, by a system of pulping and purifying, enabled the inventor to obtain a density and purity hitherto unattainable. It also enabled him to use a super white or comparatively cheap cotton waste instead of the expensive long staple cotton formerly employed.

THE COMMERCIAL PRODUCTION OF OXYGEN BY THE LIQUID AIR PROCESS.*

By GEORGES CLAUDE.

THE industrial importance of oxygen is increasing very rapidly. Its applications to projection, the lighting of automobiles, the manufacture of artificial rubies, and, most important of all, to the welding and cutting of sheet iron, are only the first stages of a development which is destined to do away with blast furnaces, revolutionize chemical industry, and profoundly modify methods of lighting.

I have contributed in some small degree to this evolution, which I advocated as long ago as 1897.

Recently a new agent, liquid air, has furnished me with the means, long sought, of obtaining oxygen easily and cheaply from the atmosphere.†

It has long been known that in the evaporation of liquid air most of the nitrogen passes off first, leaving a mixture richer in oxygen. Parkinson clearly pointed out in 1892 the possibility of separating the two gases by this method economically by recovering the energy expended in evaporation, but liquid air was so costly, so difficult to obtain, that this property remained unused until the production of oxygen in large quantities

was made possible by the invention of Linde's apparatus.

In 1899 I began experimenting with a view to improving the process of making liquid air. Instead of seeking to reduce the temperature to a point at which air is liquefied by its mere escape from a pressure of 200 atmospheres (expansion without external work) I succeeded in effecting the expansion in compressed-air motors working at the temperature of liquid air (expansion with external work) though many experimenters declared this result impossible. In gasoline I found a lubricant which remains liquid even at this low temperature. By this method, with the aid of liquefaction under pressure (Fig. 1) and using pres-

FIG. 2.—SEPARATOR WITH REGENERATOR AND RETURN PIPE.

F. Condensing pipes. P. Return pipe. R. Regenerator.

ures of only 30 or 40 atmospheres, I secured a much better effect than had been obtained with 200 atmospheres and expansion without external work.*

In the application of liquid air to the production of oxygen, also, I adopted a course opposed to that of my predecessors. An inexact experiment by Dewar had led to the belief that in the liquefaction of air its two components liquefy simultaneously. In accordance with this view, in order to utilize the absorption of heat by the evaporating liquid air, air at 3 or 4 atmospheres pressure was forced through pipes (F, Fig. 2) immersed in the liquid, the compressed air having been previously cooled by pressing through a small pipe surrounded by a larger one through which flowed the products of evaporation of the liquid air which bathed the pipes F. As the compressed air liquefied it caused the evaporation of an equal quantity of the surrounding liquid air. The gas thus evolved could be separated into two portions, respectively poor and rich in oxygen, and the regenerating pipes (Fig. 2, above) reduced the loss of energy to a minimum. But though the selective evaporation was utilized, the selective condensation was ignored. The compressed air was completely liquefied so that the resultant liquid, which was subjected in turn to selective evaporation in the next operation of the apparatus, contained only the normal proportion of oxygen, 21 per cent.

I have pointed out Dewar's error. The phenomena of condensation of air are, as logically they should be, the exact opposites of the phenomena of evaporation. As nitrogen is more volatile than oxygen, it is also less easily condensed. Consequently, when a mass of air is gradually liquefied, the portion of the liquid which first condenses is richest in oxygen. (I was anticipated in this correction, as I have since learned, by the Canadian physicist Lesueur.)

In order to utilize this property I added the return pipe connecting the two liquid air chambers (Fig. 2), which enables me to convert all of the oxygen and part of the nitrogen of the compressed air into a liquid con-

FIG. 3.—LEVY'S OXYGEN GENERATOR.

F. Condensing pipes. A. Air inlet. O. Oxygen outlet. N. (Impure) nitrogen outlet.

taining 48 per cent of oxygen, leaving a gaseous residue of pure nitrogen, amounting to more than half the volume of the original air, which need not be liquefied.† This method of operation offers two great advantages: All the oxygen is secured by the condensation of a comparatively small quantity of liquid, the yield of oxygen per horse-power hour being thus increased by about 50 per cent, and pure nitrogen, which is destined to become of great industrial importance, is obtained as a by-product.

But these processes based on the progressive evaporation of liquid air and the simultaneous liquefaction of air under a pressure of three atmospheres yield more or less highly oxygenated air, rather than pure oxygen. The latter may be obtained by a supplementary process

FIG. 4.—APPARATUS FOR COMPLETE SEPARATION OF OXYGEN AND NITROGEN. F, F'. Condensing pipes. A. Air inlet. O. Oxygen outlet. N. Nitrogen outlet.

precisely similar to the rectification of distilled liquors, which was proposed by Dr. Linde in 1902.

Fig. 3 represents the remarkably simple apparatus employed by my collaborator, R. Lévy. The liquid which surrounds the pipes F, in which air at three or four atmospheres is liquefied, consists, in this case, of pure oxygen. As the oxygen evaporates part of it is drawn off for use through the pipe O, while the remainder ascends through a rectifying cylinder of the usual type. The liquid air (containing 21 per cent of oxygen) which is formed in the pipes F flows, through the small pipe on the left, to the top of the cylinder whence it trickles down, from plate to plate, through the ascending column of gas. By reason of its low temperature (−193 deg. C. or −315 deg. F.) it energetically condenses the ascending oxygen, the liquefying point of which is −180.5 deg. C. (−293 deg. F.), releasing a corresponding quantity of the more volatile nitrogen. Thus the liquid becomes continually richer in oxygen as it descends. It is very nearly pure oxygen when it reaches the bottom of the cylinder and joins the liquid oxygen already surrounding the pipes F. In this way about two-thirds of the oxygen of the air treated are obtained in the form of pure oxygen, the gas which escapes at N containing only 7 per cent of oxygen.

I have prevented this loss and separated the air en-

FIG. 5.—GENERATOR 13 FEET HIGH WHICH PRODUCES 36,000 FEET OF OXYGEN PER DAY.

tirely into pure oxygen and pure nitrogen very simply by combining the return pipe with the principle of rectification (Fig. 4). The compressed air, entering at A, rises through the inner pipes F, where it is partially liquefied, yielding a liquid containing 48 per cent of oxygen, and a gaseous residue of practically pure nitrogen, which becomes liquefied during its passage downward through the outer ring of pipes F', both sets of pipes being surrounded by liquid oxygen. The highly oxygenated liquid air formed in the inner pipes F rises, in virtue of its pressure, through the small pipe on the right to the middle part of the rectifying cylinder, while the liquid nitrogen condensed in the outer

* From La Science au XXme Siècle.

† See L. Air Liquide, by Georges Claude, published by Dunod & Pinot, Paris.

* Comptes Rendus, September, 1900; June, 1902; November, 1905.

† For details see Bulletin de la Société des Ingénieurs Civils, January, 1906.

pipes *F'* flows, through the small pipe on the left, to the top of the cylinder.

The operation is as follows: In the lower part of the cylinder the highly oxygenated liquid which flows downward from the small pipe on the right gives up all of its nitrogen to the ascending gas, absorbs from this a corresponding quantity of oxygen, and reaches the bottom of the cylinder as practically pure liquid oxygen. In this process the ascending gas is converted from pure oxygen into a mixture of the constitution of common air, containing 21 per cent of oxygen. As this air continues to ascend through the liquid nitrogen dripping from above it gives up all of its oxygen to the latter and arrives at the top of cylinder as nitrogen. In short, the compressed air which enters the apparatus at the bottom, *A*, is separated into practically pure nitrogen which escapes at *N* at the top, and equally pure oxygen which flows out at *O*, at the bottom of the rectifying cylinder.

Two generators constructed on these principles are used by the Liquid Air Company, of Boulogne-sur-Seine. One produces daily 700 cubic meters (25,000 cubic feet), the other 1,000 cubic meters (36,000 cubic feet) of oxygen containing from 2 to 4 per cent of impurities. Fig. 5 gives a general view of the larger generator. At the right is an apparatus for producing liquid air to charge the generator and to supply loss, in the middle of a tower containing the regenerator (the horizontal pipes of Fig. 2), and at the left a similar tower containing the separating and rectifying apparatus just described, and shown in Fig. 4.

The towers are only 13 feet high, yet the output far exceeds the aggregate production of all other oxygen generators in France. The ultimate aim of the new process is the production of one cubic meter (36 cubic feet), or more, of oxygen per horse-power hour—an efficiency twenty or thirty times as great as that of the usual process based on electrolysis of water.

[Continued from SUPPLEMENT No. 1587, page 25426.]

RESERVOIR, FOUNTAIN, AND STYLOGRAPHIC PENS.—IX.*

By JAMES P. MAGINNIS, A.M.Inst.C.E., M.Inst.Mech.E.
FOUNTAIN PENS.

THE "Autofiller," shown in Fig. 206, is, as its name implies, a self-filling pen, whose ink container, like that of the "Automatic," consists of a soft rubber tube, *I*, the rear end of which is closed by a plug, prolonged in spindle form, which spindle, *S*, projects through the end of the barrel, *B*, when the small cap, *C*, is removed. The other end of the container, *I*, clasps the "feed," *F*. The spindle, *S*, may be revolved by the finger and thumb, and the act of doing so causes the rubber container to twist, as the lower end is held fast, thus driving the air out of the container. Placing the point in the ink, and allowing the container to straighten out slowly from its twisted form, the ink quickly rises and fills the container. The disadvantage of these pens lies in the flexible container, which quickly perishes, but a new tube may be had at a very trifling cost, and may be readily substituted for the old one, when the pen will have a new lease of life. The "Autofiller" is very similar to the Conklin pen, the chief difference being the method of manipulating the flexible ink reservoir, by twisting instead of by pressure.

The "Post" pen, illustrated in Fig. 207, and already described, is a pen constructed on the syringe principle. A piston, *P*, fits the barrel, *B*, and is operated by the piston rod, *R*. The idea is to fill the pen by means of the piston arrangement, just as a syringe may be filled. There is nothing special about the feed arrangement, but an ingenious method is adopted of elongating the piston rod. This rod is hollow, and an extension rod, *E*, is provided, which, when not required for use, slides into the hollow rod, lying snugly out of the way. It may be withdrawn a short distance, and then a couple of turns screws it into the rod, *R*, thus making it a more convenient length to use. Before replacing the cap which covers the piston rod, when the pen is in use, the rod, *E*, is unscrewed and slid back into *R*, thus maintaining the length of the pen as normal. A small cap is provided to protect the nib when out of use. The "Post" pen is very well made; it is an excellent form of self-filling pen, but the ink-holding capacity is small. It may be of interest to state that the Salvation Army is responsible for its introduction into this country.

Fig. 208 shows a section of the fountain pen of the Eagle Pencil Company, a firm well known for its ingenious automatic pencil holders. It will be seen that the barrel and point section are in one piece, and that a second barrel, screwed into the first at its upper end, reaches downward to the feed bar. This inner barrel may be entirely removed and filled with ink in the manner generally adopted, and then returned to the position shown in its outer case, thus keeping joints free from ink. The feed bar has a hole drilled right through its center line from end to end, and a branch leading downward for the admission of air, while ink passes along the groove on its upper side to the underside of the nib, which is not shown in the drawing.

In Figs. 209 and 210 appear two excellent sectional views of the "Conklin" pen. The upper one shows clearly the flexible rubber reservoir fully distended, and ready for use. A metal band passes nearly round the casing and through the opening formed in the thumb-piece of the presser bar. In the position shown in the upper view, the presser bar is inoperative, but when the gap in the metal band is brought into the position shown in the lower view, the reservoir may be compressed for filling.

Fig. 211 (H. Siegert, 1892, 4739) shows a fountain pen in which the penholder, *C*, is connected by a flexible rubber tube, *B*, to an ink bottle, *E*, the tube passing through a cork or stopper fixed in the bottle, and reaching down to the bottom. A second tube with a rubber ball, *D*, also passes through the stopper, but

In this drawing, Fig. 212 (R. Galland-Mason, 1900, 6279), the ink vessel, *A*, is connected to a fountain pen by means of a rubber capillary tube, *C*. The ink flow is regulated by a spring clip, *B*, which may be placed in any convenient position. The idea is very similar to the previous one, but differs in this respect: In the

Fig. 206.

The Auto-filler

Fig. 207.

The Post

Fig. 208.

The Eagle Pencil Co.

Fig. 209.

Fig. 210.

Fig. 211.

SIEGERT. 4739 1892

EYRE & SPOTTISWOODE

MYERS & SON

Fig. 215.

Fig. 216.

Fig. 217.

THE SWAN PEN.

THE WATERMAN PEN

M. MYERS & SON

does not reach so far downward as to touch the ink. By squeezing the ball, *D*, the pressure of air is increased and ink is forced into the penholder, *C*. The inventor suggests that several pens may be connected to the same ink bottle, each having its flexible connection.

former case the ink arrives at its destination by a syphonic action, stimulated by the action of the rubber ball, whereas in the latter the ink flows by gravity.

Fig. 213 represents a neat little pen sold by Messrs. Eyre & Spottiswoode at the modest price of threepence. The ink-reservoir is made of brass, as many Bir-

* Journal of the Society of Arts.