## PROF. PICTET'S EXPERIMENTS WITH LIQUID AIR.

With the establishment of the Tripler and the Ostergren-Berger plants, atmospheric air has been liquefied in quantities which have surpassed the expectations even of those scientists who for years have made the physics of low temperatures their special field of investigation. As a scientific feat, the liquefaction of air in large volumes is certainly startling, but the practical value of the achievement is still to be demonstrated.

A project for the industrial utilization of liquid air has been formulated by Prof. Raoul Pictet, of Geneva, Switzerland, a physicist who for nearly twenty-five years has been an authority on liquefaction of gases and the chemistry of low temperatures, and who, we are pleased to state, has expressed his intention of becoming an American citizen. His industrial application of liquid air consists in the dissociation of its nitrogen, oxygen, and carbon dioxide, gases which are obtained in such large quantities and at such low cost that they can be profitably used in the arts.

Up to the present time, liquid air has been produced at pressures which vary from 1,250 pounds to the square inch in the Ostergren-Berger system to 2,000 pounds and more in the Tripler and Linde processes. These enormous pressures require the expenditure of so much energy that the rectification of the liquid air is not commercially profitable. The germ of Prof. Pictet's project is found in his discovery that air can be liquefied at the astonishingly low pressure of 15 pounds to the square inch.

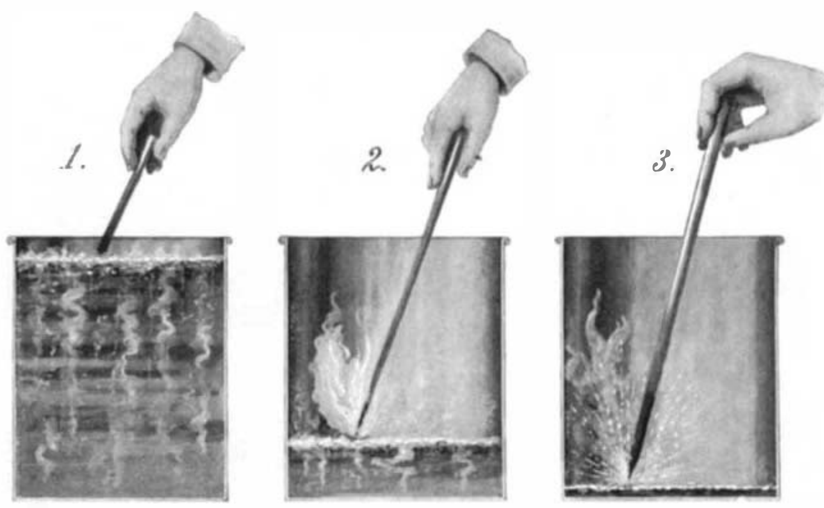
In the Pictet system, air is liquefied by means of liquid air. The principal of the Geneva physicist's discovery can be admirably illustrated by means of the experimental apparatus shown in Figs. 5 and 6. Within a bath of liquid air contained in a Dewar bulb, a coiled tube is plunged, one end of which is connected with a hand-pump and the other end of which is bent to discharge into a vessel. Gages can be provided to indicate the pressure. Atmospheric air pumped into the tube at a pressure of but 15 pounds to the square inch gives up its heat so suddenly that the liquid air in the bulb boils violently and the air within the tube liquefies and flows into the receptacle in an endless stream so long as the pump is in operation. At a lecture recently given by Prof. Pictet at the Engineers' Club in New York, a glass worm was substituted for the coiled metallic tube, shown in our illustration, and an enlarged image of the apparatus was projected by means of a lantern on a screen. The gases could be distinctly seen liquefying within the tube.

One of the most remarkable features of this method of condensing air at low pressures is the means of constantly maintaining the initial supply of liquid air. If the coiled tube is so bent that its mouth discharges into the bulb, the liquid air, it will be found, can be produced in volumes which not only compensate for the loss due to evaporation, to radiation, and to the solidification of carbon dioxide, but a remainder will be left which can be reserved for further use. With the variation of the pressure there will also be a variation in the quantity of liquid air obtained. This maintenance of a constant supply of liquid air within the Dewar bulb or other receptacle, constitutes an important element in the Pictet process of dissociating the constituents of liquid air.

Atmospheric air is composed essentially of nitrogen and oxygen in approximately the proportions of 4 to 1, with traces of carbon dioxide and watery vapor. The nitrogen and oxygen, owing to the exceedingly slight chemical affinity of the nitrogen, are merely diffused and not chemically combined. When air is liquefied the nitrogen and oxygen are condensed almost simultaneously, and the carbon dioxide solidifies. When a jet of liquid air is directed against the side of a vessel, the carbon dioxide solidifies in the form shown in Fig. 4.

Nitrogen boils at a temperature of —194·4° C. (—318° F.) and oxygen at —181·4° C. (—294·5° F.). In a vessel containing liquid air from which the carbon dioxide and moisture have been filtered off, the nitrogen will evaporate first, owing to its lower boiling point, leaving the oxygen behind. The process is akin to that of distilling water and alcohol in producing pure alcohol.

Of a given quantity of liquid air approximately 50 per cent will be pure nitrogen, 30 per cent nitrous oxide, and 20 per cent oxygen, the carbon dioxide having been previously removed. The first nitrogen evaporated will not support combustion. The flame of a match will be immediately extinguished (Fig. 1); and not until the layer of nitrous oxide gas is reached is it possible for combustion to take place (Fig. 2). As the level of the rapidly boiling liquid falls, layers of gas richer in oxygen are reached, until finally, when four-fifths of the original quanty of liquid air have evaporated, oxygen alone remains. As this liquid oxygen boils away its purity increases, until at last a point is reached when its purity is such that steel can be burned, a sufficient proof of its high quality (Fig. 3).



Evaporation of Nitrogen. Evaporation of Nitrous Oxide. Evaporation of Pure Oxygen.

THE SEPARATION OF LIQUID AIR INTO ITS CONSTITUENTS.

With the possibility of liquefying air at low pressures and its separation into its constituents, the collection of the oxygen after the evaporation of the more volatile nitrogen is a matter of no great difficulty. At the lecture before the Engineers' Club, already referred to, a small apparatus was set in operation which proved the feasibility of Prof. Pictet's scheme. The apparatus in question comprises primarily two parts,—a liquefier (Fig. 7), and a gasometer. The liquefier consists of a worm immersed in liquid air poured in through a funnel, the end of the worm being bent so that its mouth is located immediately above the funnel. The gasometer is merely an ordinary water-sealed gas-holder of 600 liters capacity. After the nitrogen had been drawn off, the liquefier and gasometer were connected, and sufficient pure oxygen was obtained to fill the gas-tank in less than one minute at 15 pounds pressure. The oxygen generated was used at the lecture in an oxy-hydrogen jet to produce a limelight.

Fig. 4—SOLIDIFICATION OF CARBON DIOXIDE PRODUCED BY JET OF LIQUID AIR.

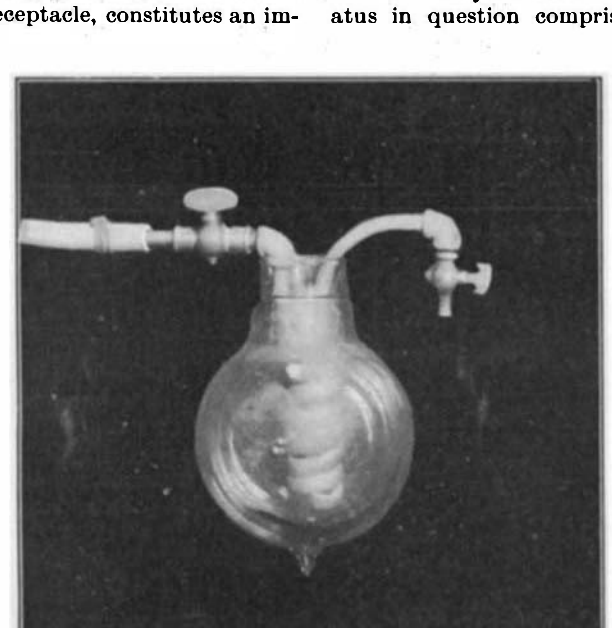


Fig. 5.—PICTET'S EXPERIMENTAL APPARATUS FOR THE LIQUEFACTION OF AIR AT LOW PRESSURES.

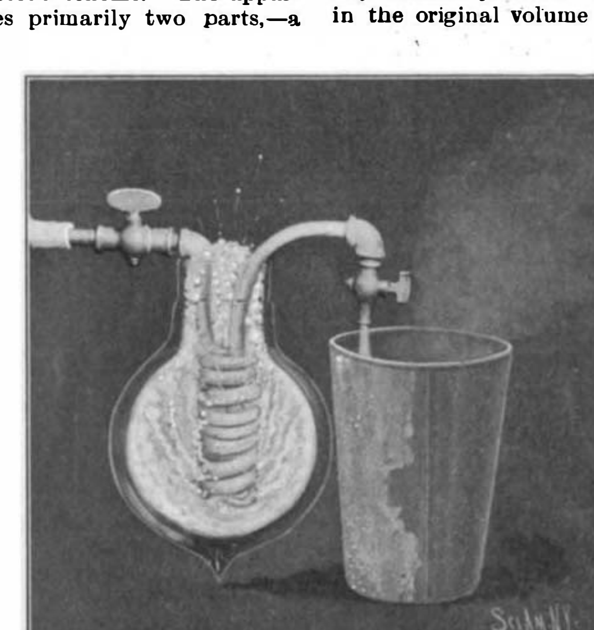


Fig. 6.—METHOD OF PRODUCING LIQUID AIR.

In the industrial application of Prof. Pictet's system (Fig. 8) the atmospheric air at normal pressure enters a supply pipe and passes through a filter, which removes impurities and foreign matter. After having been purified, the air is compressed and forced into a cooler containing a cooling-coil, serving the purpose of reducing the temperature of the air after the compression. From the cooler the compressed air enters a chamber containing pipes through which liquid oxygen is flowing, whereby its temperature is further reduced. It then enters the pipe, *F*, leading to the separator, *G*. Within the separator are a number of superposed trays, containing liquid air, through which is conducted a coiled pipe connected at its upper end with the pipe, *F*, and at its lower end with the pipe, *H*, whereby the air is delivered into a filtering chamber, *I*, at the top of the separator. The cooled air passing through pipe, *F*, enters the coiled pipe lying in the liquid air on the trays, liquefies, as we have seen in the experimental apparatus previously described, and discharges into the filtering chamber, *I*, where the solid carbon dioxide is deposited. Then the liquid air flows into the trays below and compensates any loss in the liquid air on the trays due to evaporation. As the liquid air passes from tray to tray, the more volatile nitrogen separates from the oxygen and enters a pipe, *J*, connected with the top of the separator, and flows into the tubes of a nitrogen chamber, whence it may be led off into gasometers.

When the liquid air reaches the lowermost tray, it nitrogen will have completly evaporated, leaving only pure oxygen, which is collected in the pipes of the oxygen chamber and is then drawn off as desired. The intermediate space contains mixed oxygen and nitrogen, or nitrous oxide, which, like the other gases is drawn off by a pipe, *M*, leading to the collecting pipes of a mixed nitrogen and oxygen compartment. By an ingenious system of gate valves, located at the upper levels of the trays, the liquid air can be cut off at any point in its descent, so as to obtain oxygen of any desired degree of purity. If, for example, it be desired to collect a supply of oxygen containing 50 per cent nitrogen, the gate valve at the proper intermediate tray is closed, thus cutting off all the trays below and leaving only a sufficient number in action to produce the 50 per cent oxygen. If 30 per cent oxygen be desired, the gate at a somewhat higher tray will be closed. Several nitrous oxide compartments will be provided, each receiving liquid oxygen containing more or less nitrogen. For pure oxygen all the trays will be employed.

Before air can be liquefied by means of this apparatus it is evident that the evaporating trays of the separator must contain an initial supply of liquid air. In order to produce this initial supply, atmospheric air will be liquefied, as in the Ostergren and Berger* method, at a pressure of 1,250 pounds, maintained for a period of eight hours. After the necessary amount of liquid air is thus obtained, the compressors will operate at any desired pressure above 15 pounds, the losses in the original volume of liquid air, due to evaporation, solidification of carbon dioxide, and radiation, being compensated for in the manner previously mentioned.

The volumes of the gases separated by the Pictet process are enormous. Prof. Pictet states that a 500 horse power plant after its initial supply of air has been liquefied, will produce in twenty-four hours, 1,000,000 cubic feet of oxygen, 2,000,000 feet of nitrogen at atmospheric pressure, and, as a by-product, 1 short-ton of solid carbon dioxide.

The small cost at which these gases are separated is even more astonishing than the large quantities in which they are produced. The potassium chlorate process now in general use yields oxygen costing from $2 to $3 per cubic yard. By the fractional distillation of oxygen from air liquefied at low pressures, 20 cubic yards, it is said, can be produced for one cent.

Of what industrial value is this solid carbon dioxide,

*See SCIENTIFIC AMERICAN for July 15, 1899.

this liquid oxygen and nitrogen? The carbon dioxide filtered from the liquid air can be sold to brewers and makers of carbonated waters and beverages. It is claimed that the profits of the selling of the carbon dioxide will pay for the cost of operating the plant.

Oxygen, as Prof. Pictet has aptly termed it, is the very bread of industry. It burns the coal beneath the boilers of our locomotives and steamboats. It supports the flame of light and heat giving substances. It is the life-sustaining element in the air we breathe. Oxygen produced in large quantities at a low cost can be employed in well-nigh every art. Every industry is dependent on the calorific force of coal. Supplemented by oxygen not only can the calorific energy be increased, but the amount of fuel used can be reduced. In firing a steam-boiler, by assisting the combustion of the coal with 50 per cent oxygen (oxygen purer in quality would burn out the fire box), a quantity of fuel can be saved equivalent to that usually lost in heating the nitrogen of the air. Moreover, lignite, bituminous coal, and fuels of low calorific value can be employed. With a draft of oxygen of constantly increasing purity Prof. Pictet claims that the temperature of a reducing furnace can be raised 600° to 800° C., with the result that a piece of steel can be heated in half the time usually required, to a temperature even higher than may be necessary, with a saving of 40 per cent of the fuel ordinarily employed. With oxygen produced at low cost, iron, steel, and bronze can be easily welded and soldered. He suggests that framed iron structures and the pieces of metallic vessels can be fused together with the oxygen blow-pipe, thus dispensing with the use of rivets and gaining in strength and rigidity. With the supply of cheap oxygen it would be possible to obtain a more efficient system of street lighting than is at present possible. The cost of manufacturing such chemical products as nitric acid, sulphurous and sulphuric acid, and ozone, in all of which oxygen is an important element, can be very considerably reduced. In hospitals, schools, factories, offices, and theaters, the air could be replenished with oxygen as it became vitiated.

Pure nitrogen is obtained by the Pictet process only in the gaseous state; it is collected in various degrees of purity, and like oxygen, is industrially useful. By chemical synthesis ammonia and its various modifications can be made, as well as nitric acid and its derivatives, and the potassium cyanide so essential in gold mining.

If Prof. Pictet carry out his far-reaching project for the separation of the constituents of liquefied atmospheric air—and, indeed, he has already begun the erection of a plant for this purpose—he will change the methods of industrial processes more extensively than falls to the lot of most physicists. His process, if it prove successful, will affect the metallurgical industries, vastly influence steam and civil engineering, and introduce new methods for the commercial production of the most important chemicals used in the arts.

**Petroleum Deposits on Saghalin Island near Eastern Siberia.**

An Austrian mining engineer, Mr. F. F. Kleye, who for many years was engaged in the oil industry of Galicia, and, later on, in the same industry in Java and Sumatra, made, in 1898 and 1899, extensive investigations on the occurrence of naphtha on the island of Sagdalin, in Eastern Siberia. On his return Mr. Kleye rendered a detailed report of his observations to the Society of Austrian Mining Engineers, from which the following remarks are an abstract:

"In my search for the naphtha deposits on the island of Saghalin. I went from Alexandrowsk, on the west coast of the island, into the interior as far as Derbinsk, on the River Tym, whence I followed the river down to the eastern coast. After much trouble I succeeded in securing the services of some Russian-speaking Orotchons, who make their living in raising reindeer, and are well acquainted with the country. From these people I learned that far up in the north naphtha, called, 'Nephtogen' by the natives, occurred in many districts.

"After a voyage of about a week we arrived at Wal, where the Starost (mayor) informed me that he knew of two large naphtha deposits, of which one, he said, was situated near the River Nutowo and the other at the source of the Boatassin River. The next day we reached a hill called 'Nephtogengora' (naphtha mountain). While advancing over the last few miles, along the river, I noticed that the water of the stream was entirely covered with a coating of oil, and a heavy smell of naphtha announced that we were approaching a great deposit. We then came to the first naphtha sea, situated between two hills, and after having crossed the hills, we reached the second oil lake, which was far larger than the first. What I here saw really surpassed all expectations. I had never in my life seen or heard of, such immense lakes of naphtha.

"The next morning I began my investigations. This liquid naphtha I found to possess a specific weight of 0·925 at 14½° Celsius, and was of a reddish-brown color. Oil taken from another deposit had a greenish red-brown color, and a specific weight of 0·9055 at 14½° Celsius. Later on when I arrived at Alexandrowsk I distilled the oil and found that a quantity of 2½ quarts, heated to 150° C., contained only a few cubic centimeters of benzine, and at a heat of 300° Celsius 27 per cent kerosene. The heat was then developed to 500° when a first-class lubricating oil was obtained.

"From the height of these hills, at the foot of which lies a third large naphtha lake, I noticed a large broad, gleaming surface, and on nearing it, discovered another large lake, 1,435 feet long and 280 feet wide. At the edge of these four lake-like deposits there were numerous smaller oil wells, from which the oil continually exuded under strong pressure. Further up the Nutowo River I also found considerable deposits of naphtha.

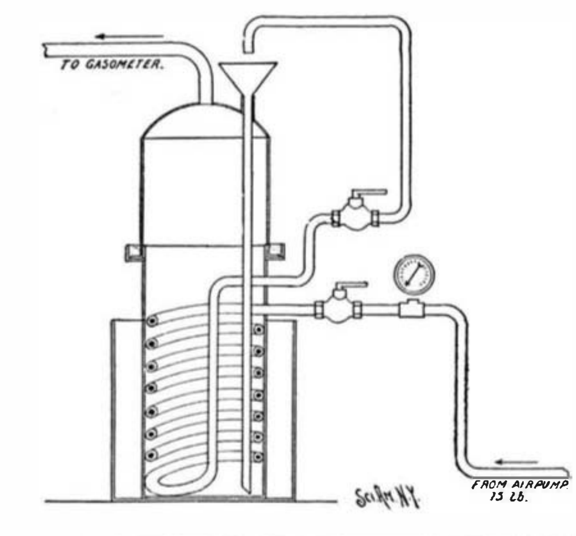



Fig. 7.—PICTET EXPERIMENTAL LIQUEFIER.

"The various hills stretch in the direction of the meridian, which is also the direction taken by the oil streams; voluntary courses I could nowhere find; furthermore, in numerous diggings I could find no beds. At one digging I penetrated first a 10-foot deposit of asphalt, then 10 feet of sand, before reaching the more solid foundation of clay. In spite of all safety measures it was not possible to control, without pumps, the underground water from pressing upward, and the digging had therefore to be abandoned; in spite of all these obstacles, however, the exodus of oil was so great that a considerable supply underneath can assuredly be counted upon.

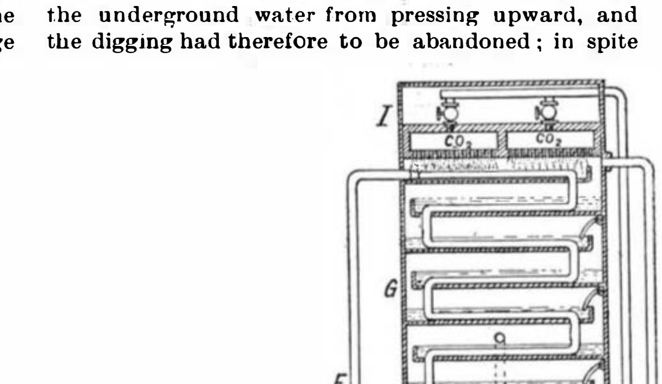



Fig. 8.—PICTET'S INDUSTRIAL LIQUEFIER AND SEPARATOR.

"After four days' work, and after I had minutely taken the location of the most important deposits, we began the return journey, during which I marked the entire way with the compass. On the first morning we reached by boat the mouth of the Hagdusa River. We landed here and continued on land across an almost level plateau. After walking about four versts we came in sight of the outlying hills, and another verst brought us to the naphtha deposits at the source of the Boatassin River.

"The entire outcrop line, forming more or less naphtha deposits, runs along the river to a long line of hills; the direction of these hills was also parallel with the meridian. Although these naphtha deposits were not so immense as those on the Nutowo by far, they are of great importance in view of the fact that they are scarcely twelve versts distant from a good sea-port, possessing accommodation for the largest ships, and also since the country offers practically no obstacles in the way of transporting materials, laying conduits, etc.

"The entire east coast of Saghalin, as far as examined, belongs to the 'tertiary formation.' All naphtha outcrops that I saw extend in the direction of the meridian. The naphtha deposits are embedded, without exception, parallel in the axis of the anticlinal flexure of the strata, and are very rich.

"Furthermore, when the important difference between the specific weight of naphtha of 20 feet depth and of that lying open is considered, it may be accepted that the deposits will supply raw oil sufficiently rich in kerosene. It is certain, however, they will supply a far richer raw oil than the wells of Baku, to which the raw oil of the eastern coast of Saghalin is very similar. It is, therefore, to be expected that not only a second Baku will rise, but that Saghalin 'Baku' will far surpass the present 'Baku.'

"It must be remembered, in prophesying the development of Saghalin, that it is only possible to reckon on a shipping season of from 7 to 8 months; the short stoppage during winter should, however, be outweighed by the extremely favorable shipping facilities, which are not surpassed anywhere in the world. With regard to the working of the naphtha deposits, it would be comparatively easy to transport the oil in tank steamers to a point near Vladivostok, where extensive refineries could be erected."

Since the foregoing was written, an English syndicate with a capital of $500,000 has been formed for the purpose of taking over the three naphtha deposits described above. The syndicate which is composed of three large London firms is called "The Saghalin and Amour Petroleum and Mining Syndicate, Limited," head with offices in London.

Since the English have taken the lead, the attention of the mining world will no doubt speedily be turned to Eastern Siberia with the result that foreign capital will find a way to the development of the rich mineral deposits of that country.

**A Generous Inventor.**

Inventors as a general rule are more or less so carried away with the development of their ideas that they give little thought to the business management necessary to make the invention financially lucrative.

But we have an exception to this statement in Mr. George Eastman, of Rochester, New York, the inventor and promotor of the Kodak camera, now so familiar in all parts of the world, who, trained to business methods in a banking establishment, retired and began the manufacture of the gelatine dry plates some twenty years ago mainly for the use of amateur photographers.

In the development of this new industry his attention was drawn to the need of some substitute for glass, and it was not long after before the roll holder attached to the back of the camera for holding in place a roll of sensitized paper was introduced, by which a large number of negatives could be taken in sequence, thereby dispensing with the heavy weight of glass. This led to the construction of a new special miniature camera, and its introduction, in 1888, by Mr. Eastman, when the phrase attributed to him, "you press the button, we do the rest," became so popular.

It may be considered as a certainty that this popularization of photography, while it seemed repulsive to the majority of amateurs, did more to interest the general public in photography and its kindred industries than any other event since the time of Daguerre. It was a good business stroke and prepared the public for further improvements which Mr. Eastman subsequently inaugurated by substituting for paper a rollable transparent celluloid film. Thus, by exercising excellent judgment in giving the newly created photographic public goods of superior and uniform quality at the same time satisfying the many varied conditions, Mr. Eastman succeeded in building up a business which has many times exceeded his original anticipations. His work resulted in the establishment of many new factories as well the changing of the character of the photographic trade, not only in the United States but abroad.

So it is with pleasure that we chronicle the gift by Mr. Eastman himself, a type of the energetic American, of $200,000 to the Rochester (N. Y.) Mechanics Institute without conditions.

The money is to be expended in enlarging the present building. A year ago he distributed several thousand dollars among employés, according to their terms of service.

Thus the people of his own city are benefited by his generosity, while the public at large derive benefit from the use of his inventions and appliances. He has been most successful as an organizer and leader of large corporations.