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Commercial Production of Oxygen from Liquid Air.

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It is my object in this brief communication to outline some work that has been done quite recently in this country looking toward the commercial utilization of liquid air. I shall not attempt to enter into a theoretical discussion nor to exploit the possibilities in liquid air along many lines; but shall confine myself to that which has actually been accomplished or is really in sight.

Some two years ago the eminent scientist, Raoul Pictet, in collaboration with Moriz Burger, read a paper before this Institute, in which he called attention to the feasibility of separating the constituent gases of the atmosphere after having first reduced them to the liquid state. The liquid-air plant in which Pictet made his experiments was then in New York City; with the substitution of a new liquefier, this plant is now in Washington, D. C., and is under my supervision. The paper referred to put into concrete form the suggestions that had been freely discussed among liquid-air men for some time previous, and constituted one of the few scientific presentations of that period concerning liquid air. To Pictet, probably more than to any one else, is due the credit for crystallizing the thought along this line; but within a few months the apparatus constructed under his supervision for the fractional distillation of liquid air has been dissembled at our plant on account of the mechanical difficulties its operation presented.

The problem of getting cheap oxygen from liquid air, therefore, remained unsolved, so far as this country was concerned. I am aware that considerable work has been done abroad in this line, and some of the published reports of what is estimated as being possible in this direction may seem more glowing than our report of what has been done;

but it is worth noting in this connection that even before publishing results or prospects the Columbia Liquid Air Company, owning the Washington plant referred to, has actually entered the market with oxygen from liquid air, and it is now on sale in many cities.

The liquid-air plant consists of suitable compressors, a pre-cooling device such as an ammonia machine, and a liquefier. The latter comprises coils of pipe so arranged that air at high pressure may be released and expanded, such expansion taking place about the coils which carry the inflowing stream of compressed air. This involves the principle of self-intensification; the absorption of heat by the gases in their change from the compressed to the more rarified state causes a certain percentage of the air to be so reduced in temperature as to condense and collect as a liquid.

We have examined a great many specimens of liquid air freshly made, and find that the percentage of constituent gases is not constant; nor does the liquid air made at the beginning of the run always correspond in constituent proportions with that made several hours after the plant has started. We may, for instance, find the oxygen content varying from 20 to 40 per cent., or even beyond these limits.

It has been demonstrated repeatedly that liquid air on standing for some time becomes rapidly richer in oxygen, and it is this fact that first brought forth the suggestion that oxygen might be accumulated in this manner from the atmosphere, the specially attractive thought being that the raw material is quite inexpensive. The question then arose as to how best to throw out the nitrogen, which is not wanted, and retain the oxygen, which is wanted. The difference in their boiling points, scarcely 12° C., is not so great as to make the problem an easy one; and it is with the question of how best to secure this desired end that we have been working. We cannot here give in detail the method used in thus fractioning the sample; but a clear apprehension of the results achieved may be imparted. More exactly, we have a two-fold problem: (1) how to secure liquid air which is initially rich in oxygen; (2) the choice of

a method of evaporation which will yield a rich product with the least possible loss of weight. Given liquid air with a 30 per cent. content of oxygen, if we could confine the loss by evaporation entirely to nitrogen we should have, with a reduction to one-half bulk, a material holding 60 per cent. oxygen; under like conditions, evaporation to two-fifths bulk would yield 75 per cent. oxygen. In one series of experiments recently we started with 31 per cent. oxygen, and after a loss of 61 per cent. of material (about three-fifths), we had secured 65 per cent. oxygen; this indicated a loss of 6 parts of oxygen coincident with a loss of 55 parts of nitrogen. We have since improved on the method used in that case, with much better results; but if we take our results as given—a 65 per cent. product after evaporating 61 per cent. of the liquid air—we find that they are better than results very recently reported by Linde, who secured only a 50 per cent. product under the same conditions; this is assuming that Linde has been correctly quoted by some very careful journals.

The first suggestion made above, that a part of the problem consists in producing liquid air that is initially rich in oxygen, is full of possibilities. With the completion of a series of determinations we are about to inaugurate, we hope to secure more light upon the causes of the variations in the liquefier; our plans include investigations not reported heretofore either in this country or abroad. A successful outcome of these experiments would enable us to run the liquefier with great uniformity for such a percentage of oxygen as we might wish to turn out, thus requiring no further evaporation.

The question of cost is a pertinent one. It must be remembered that the liquid-air plants constructed in this country have from the first been built with a view to turning out comparatively large quantities of liquid air. Certain departures have been made, therefore, from the beaten paths of European construction; the new liquefier to which I referred is no exception to the general rule which has prevailed, and the present plant, in several important details, is costly in comparison with one which we shall later

construct in the light of experience gained. Yet I propose to show you a remarkable cheapening in cost of oxygen over the chemical method of production, even with the present plant.

The new liquefier of the Columbia Liquid Air Company yields from 12 to 18 gallons of liquid air per hour, with an expenditure of 150 horse-power. For purposes of computation we shall take $12\frac{1}{2}$ gallons, which is close to our minimum and not our average. In a run of ten hours this would therefore yield us 125 gallons of liquid air. If we place the cost of power at 1 cent per horse-power hour, we should have a cost of power of \$15. Estimating, with a very large margin of safety, that this will yield us liquid air containing initially 35 per cent. oxygen, we should secure at least a 70 per cent. product by evaporating to two-fifths bulk, or 50 gallons. This should yield us 5,000 cubic feet of gas, at a cost of three-tenths cent per foot for power and raw material.

In answer to those who will say that this does not compare favorably with other estimates made on this subject, both here and abroad, I beg to say that this is not a theoretical estimate, but the conclusion reached in practical experience when based upon the cost of power suggested. Six months from now we expect to be able to make these figures look very large.

We produce a 70 per cent. material for sale as medicinal oxygen unless a different percentage is specified. It is conceded by many leading physicians that an oxygen approximating 100 per cent. purity would be unsafe for direct administration; and the effort to secure an admixture of air would only result in administering a product of unknown composition. On the other hand, a number of leading makes of medicinal oxygen have been examined, and only two specimens of those tested have gone over 50 per cent. oxygen. The 70 per cent. grade is deemed the best in cases of pneumonia and like conditions, and gives all the stimulation required, and is safe where resuscitation is aimed at. The advantage of definitely knowing what percentage is available is one not to be lightly considered.

The medicinal use of oxygen is one that has grown with remarkable strides within the last few years. The increase in this business alone in the next decade gives promise of being beyond present means of computation. Where a few years ago scarcely a hospital found it necessary to keep a stock of oxygen on hand, now not a modern institution is without it, and hundreds of physicians keep it in their private offices. The advantage of producing an oxygen which cannot by any means become contaminated with chemicals, such as the chlorine of the chemical process, is so apparent as to need no comment.

Large quantities of oxygen are used for the oxy-hydrogen light and in the industries. To what extent its use will be augmented along commercial lines no one can estimate, as the question is simply one of cheapness of production. It will readily be seen that the lower limit of cost is not in sight when made by the liquid-air process, for this process is but in its infancy and is bearing all the burdens of preliminary experimentation.

AMERICAN NITER INDUSTRY.

The recent discovery, in California, of extensive deposits of nitrate of soda of good quality, and the occurrence of that mineral in Nevada and some States on the Pacific Coast, is attracting capital from professional and business men, principally in the East. Much land is being taken up in California, and at least one large company with influential backing intends to undertake systematic development.

The California nitrate deposits are located in the Mohave Desert, extending from the northern portion of San Bernardino County to the southern section of Inyo County, and are 80 or 100 miles from Manvel, on the Santa Fé Railway. Some very high analyses of the mineral are reported, and it is estimated that there are about 22,000,000 tons in sight, though these figures are likely to be revised when active mining is in progress. It is believed, however, that the deposits are richer than the Chilean. At present the American Niter Company, whose president and promoter is W. W. Treat, of Boston, is planning large development. The company was formed in 1901 and controls about 35,000 acres, which have been located by the Baileys, of San Francisco, and others. Dr. Gilbert E. Bailey is the consulting engineer of the company. It will probably take two or three years before the property is in condition to ship to market, and by that time we may expect to hear something of interest concerning the Chilean combination, whose agreement expires in April, 1905. —Charles C. Schnatterbeck, in *Engineering and Mining Journal*.