Helium in Deep Diving and Caisson Working.[1]

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In diving and in caisson operations where men are subjected to air pressures above ordinary atmospheric pressure, the amount of air dissolved in the blood stream and body tissues increases. The excess oxygen can be disposed of by the ordinary combustion process, but the excess nitrogen tends to separate in the form of bubbles when the pressure is released. As the amount dissolved is approximately proportional to the pressure, there may be enough separating in the blood stream and tissues of a diver or caisson worker coming up rapidly from a considerable depth to produce 'caisson illness.' This is accompanied by severe bodily pains, and, in more severe cases, unconsciousness or even death.

It is therefore necessary to prolong the time of ascent in deep diving or of decompression in caisson working sufficiently to allow the excess nitrogen to escape from the tissues through the lungs. This period of decompression increases rapidly with the depth or pressure to which the worker has been exposed and with the duration of exposure, and becomes almost prohibitive at depths greater than 200 feet, except in emergencies and for very short exposures. According to present-day diving regulations and practice, it requires but 3 to 8 minutes, depending on the individual diver, to descend to a depth of 200 feet, but after a stay of 45 minutes at the bottom, 2 or more hours would be required to bring the diver to the surface in safety. Mechanical troubles, accidents to the diver, unusually cold water, or stormy weather may make it difficult or impossible to allow such a period, and even at best the proportion of the total time available for work at the bottom rapidly becomes too short to be practical as great depths are approached.

Theoretical studies of the general problem of solubility, begun by the senior writer some years ago, made it evident that the least soluble gas, almost regardless of the solvent, should be helium. As he was familiar with the theory of caisson illness, the idea naturally arose of substituting helium for the nitrogen of air for respiration by divers and caisson workers. Eventually a small amount of helium was obtained from the United States Bureau of Mines through the courtesy of R. B. Moore, former Chief Chemist, with whom the problem had been previously discussed.

Progress was slow, in the absence of suitable equipment, and it became evident that to bring the matter to any practical fruition would require large-scale experiments and access to considerable quantities of helium, of which the United States Government was the only producer. Meanwhile, the sinking of a submarine at a depth that rendered access by divers difficult, suggested that any consideration of personal profit should give way to the prompt working out of the practical problems involved. Accordingly, the senior author wrote in January 1924 to S. C. Lind, then Chief Chemist of the Bureau of Mines, suggesting that the Bureau undertake the necessary experimental work. This suggestion was accepted, and the senior writer was associated with the Bureau as consulting chemist. The work was put into the hands of Dr. R. R. Sayers, Chief Surgeon for the Bureau of Mines, and W. P. Yant, Supervising Chemist, Health Laboratory Section.

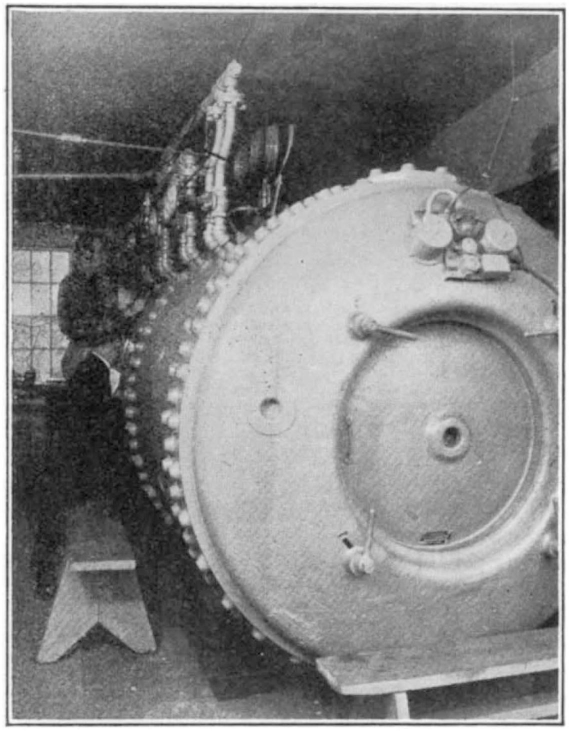

Fig. 1.—Compression chamber used for conducting experiments on men. This was built at the Norfolk Navy Yard and was of 1¾ in. steel and capable of withstanding a working pressure of 600 lb. per sq. in., and a much greater test pressure. Note telephone and electric light connexions above door, and gauges and valves for regulating and indicating pressure. One of the horizontal lines leading from the manifold extends through the reducing valve to the bank of air bottles and the other to a supply of pure oxygen or of helium-oxygen mixture.

As is so often the case, it has since been brought to light that the idea occurred independently to different individuals. On Aug. 15, 1919, an application for a patent was filed, and on Nov. 6, 1923, issued, to C. J. Cooke, of Washington, D.C., for the use of a respirable mixture of oxygen and helium for workers under pressure; and at about the same time Elihu Thomson, it appears, had a similar idea. In a paper, "Helium Production and Uses," by Prof. J. C. McLennan, in Nature of Aug. 19, 1920, is the following statement:

"It has been suggested by Elihu Thomson and

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others that if divers were supplied with a mixture of oxygen and helium, the rate of expulsion of carbon dioxide from the lungs might be increased, and the period of submergence as a consequence be considerably lengthened."

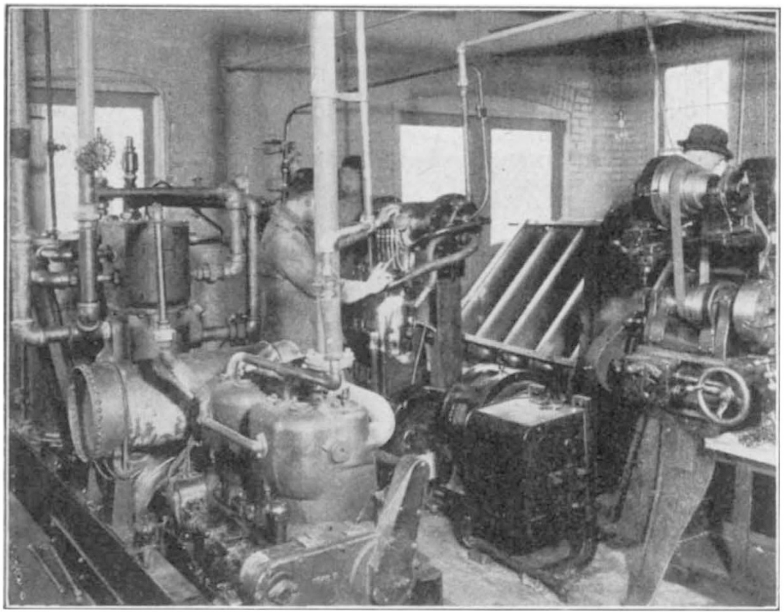

FIG. 2.—Air compressors and apparatus for compressing air into a storage bank consisting of thirty 2-cub. ft. free air capacity cylinders. The air is compressed to approximately 1800 lb. per sq. in., which gives sufficient volume in the bank to fill the large test chamber to a pressure of 100 lb. per sq. in. within two or three minutes. All these cylinders are connected in parallel to a manifold from which the air is released through a reducing valve. One compressor is electrically driven and the other by means of a gasoline engine. This ensures two independent sources of power and an adequate air supply in the event of difficulties being experienced in these experiments, and extended recompression of the men being necessary to allay the occurrence of caisson disease.

As a matter of fact, however, the work at the Bureau of Mines was undertaken and pursued to a considerable fruition before any of those concerned with it became cognizant of the claims of either Mr. Cooke or Dr. Thomson. It may be added also, that if the statement by Prof. McLennan correctly expresses the idea of Dr. Thomson, this was based upon an incorrect assumption, for caisson illness does not depend upon the diffusion of carbon dioxide from the lungs. (For discussion of priority claims see E. Thomson, *Science*, Jan. 14, 1927; J. H. Hildebrand, *Science*, Mar. 15, 1927; and W. P. Yant, *Ind. and Eng. Chem.*, news edition, Mar. 10, 1927.)

The fact remains that the use of helium for deep diving could become practical only after extensive and costly experimentation for the development of a suitable technique. Investigations planned toward this end were initiated by the Bureau of Mines and continued later with the co-operation of the Navy Department. The results of the initial investigations made by the Bureau were published, in part, in its *Reports of Investigations Serial 2670*, February 1925, entitled "Possibilities in the Use of Helium–Oxygen Mixtures as a Mitigation of Caisson Disease," by R. R. Sayers, W. P. Yant, and J. H. Hildebrand. This publication recounts the results of a series of tests with small animals. It was found at the outset that rats could be subjected to a helium-oxygen mixture for 1 hour at a pressure of 20 atmospheres, corresponding to about 600 feet of water, or more than three times the maximum pressure at which extensive diving operations have been conducted; and further, that they could be brought out of this pressure safely in 34 minutes.

It was found important to reduce the proportion of oxygen from 21 per cent. by volume, the proportion in air, to a much smaller proportion, varying from 1·5 to 15 per cent. according to the pressure employed. In most of the studies a pressure of 10 atmospheres was used, with varying periods of exposure, up to 5 hours. It was found that animals could be brought out from the helium–oxygen mixture

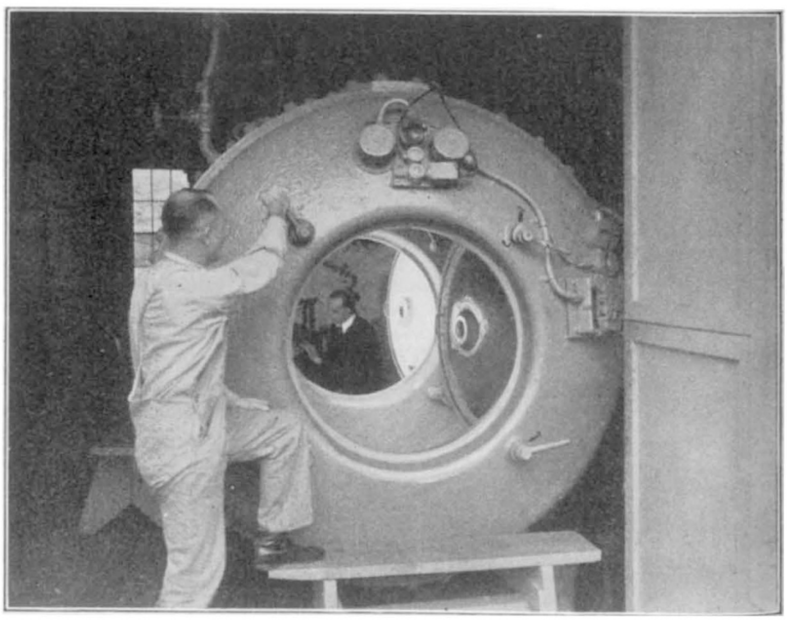

FIG. 3.—Interior of large chamber with men inside.

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safely in so short a time as 4 to 7 minutes, whereas animals brought from a nitrogen–oxygen mixture in 26 minutes or more became paralysed, and many died at once or within a few days. These general conclusions were confirmed in a large number of experiments.

It was interesting to find that the advantage of the helium was considerably greater than was expected on the basis of its smaller solubility. Helium diffuses more rapidly than nitrogen on account of its smaller molecules, which move nearly three times as fast. Hence, not only is less helium dissolved in the blood stream, but also it can escape into the lungs with much greater rapidity during decompression.

Large-scale experiments with men are now in progress under the direction of the Navy Department. The apparatus in use is partly shown in the accompanying illustrations. Considerable time has been spent upon the revision of the decompression tables in order to have an authoritative basis for further work with helium.

On Oct. 4, 1927, United States Patent 1,644,363 was issued to W. P. Yant, R. R. Sayers, and J. H. Hildebrand. Under the terms of this patent, persons under compression are supplied with a mixture for respiration consisting mainly of oxygen and nitrogen and containing a lower percentage of oxygen than air, and while under decompression with a gas comprising mainly oxygen and helium.

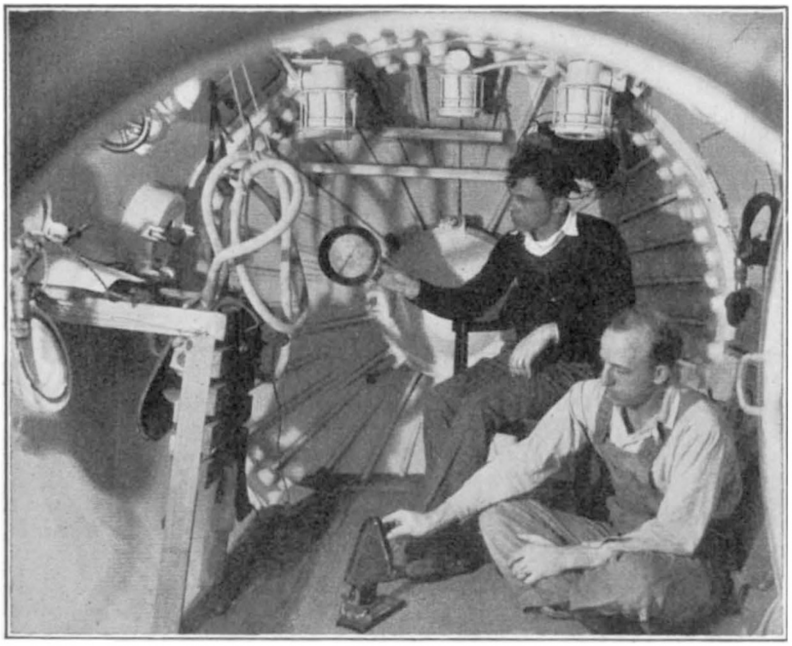

FIG. 4.—Interior of main compartment with test apparatus. Note electric lights, pressure gauge, control valve, hatches for closing windows in event of fracture of windows, and small tending lock at rear. This tending lock is operated similarly to the man lock, and is provided for passing in and out apparatus, food, etc. In connexion with the regulating valves, it should be stated that there are controls inside the chamber as well as outside, but the attendant on the outside can prohibit the use of the inside controls by closing off certain valves. This is done in order to prevent a man whose judgment may be impaired from releasing the pressure at a time or at a rate which is not safe. The oxygen breathing apparatus hanging to the wood support is used for administering helium. This is supplied from an external cylinder through a high pressure line and the man breathes helium from the bag, but at the same time has an air pressure surrounding his body. This obviates the necessity of filling the tank with that gas and conserves the supply of helium.

The Frequency of Rain over the British Isles.

By Dr. JOHN GLASSPOOLE.

THE perennial interest in the chances of good weather in our short English summer is quickened by the advance of spring. While the weather map is the vade-mecum of the forecaster of to-morrow's rain, it cannot help us to arrange our holidays in advance. We can, however, derive a great deal of information from a study of the accumulated statistics of the past.

Rainfall is measured at 9 A.M. at some 4000 stations in the British Isles, the smallest amount recorded being 0·01 inch. A day with 0·01 inch or more is defined as a rain-day. Although the rain-day includes many days with too little rain to be of practical importance, it is only such statistics which are available for any length of time. In considering the frequency of rain over the British Isles, it is necessary, therefore, to consider first of all the distribution of the number of rain-days, and to supplement this information by statistics from the limited number of stations for which more detailed observations are available.

Although a station with a relatively large annual rainfall is usually one with a large number of rain-days, the two quantities do not vary in the same proportion.[1] In the first place, the variations of the number of rain-days over the British Isles are much less than the corresponding variations of rainfall. In other words, both the variations of average monthly and annual values from place to place, and also the variations of average monthly values at one place, are much more uniform in the case of rain-days. The second difference is that, even at stations with the same rainfall, the average number of rain-days increases from the south-east to the north-west of the British Isles. Both these differences can be illustrated from the map reproduced as Fig. 1, which shows the distribution of the average number of rain-days during the six

[1] The question is dealt with in two recent papers : " The Distribution over the British Isles in Time and Space of the Average Number of Days with Rain." " British Rainfall, 1926," pp. 260-279, and " The Distribution over the British Isles of the Average Number of Days with Rain during each Month of the Year," *Q.J.R. Meteor. Soc.*, **54** ; 1928.