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THE LIQUEFACTION OF AIR.*

If Baron Munchausen had recorded that he once came upon a people who were in the habit of changing air into the liquid state and carrying it around in vessels, the statement would have been regarded as a particularly happy effort of that accomplished artist. An assertion so at variance with all human experience would have failed to command belief, even if indorsed by the testimony of less impeachable witnesses than the observant baron.

We are speaking of a bygone age. To-day the public knows better than to deny a statement offhand merely because it contradicts or does not agree with its common experience. The loophole of escape from unexplained phenomena in the days of our forefathers was by assertion of flat disbelief or ascription to witchcraft or the devil. To day, at the first announcement of the wonderful, the public neither believes nor disbelieves; for the incredibly rapid march of science and discovery has taught the world that the marvels and impossibilities of yesterday may easily become the commonplace facts of to-day. But two brief years ago it was whispered from across the ocean that a certain German professor had succeeded in passing light through so-called opaque bodies—wood, leather, the flesh—and the technical press announced the fact with a prefatory "it is said," "a contemporary reports," etc., neither affirming nor caring to deny a statement apparently so preposterous. To-day the fluoroscope is a toy that has lost its charm, and an X-ray equipment is a necessary part of the surgeon's outfit.

The liquefaction of air is another of those feats of experimental science which, having their birth in the laboratory, ultimately graduate into the broader field of the industrial arts, and lose all their wonder as they become useful and familiar to the public. It must not be supposed, however, that because it has only now become possible to produce liquid air in commercial quantities, therefore the principles of its liquefaction are new or only of late discovery. It has long been known that air, like any other gas, was theoretically capable of liquefaction, and that its condensation was merely a question of suitable apparatus. To Prof. Dewar, of Glasgow, belongs the credit of first liquefying air in limited quantities, the necessary reduction of temperature being achieved by a successive series of evaporations. The process, however, was too costly to have any commercial value.

The economical liquefaction of air in large quantities has been recently accomplished by Mr. Charles E. Tripler, of New York, after several years of experimental work. Two and a half gallons of the liquid were recently sent from his laboratory to Prof. Barker, of the University of Pennsylvania, and its properties were exhibited in an extremely interesting series of experiments during a lecture delivered by Prof. Barker to his class and a company of invited guests. This was the first public exhibition of the kind of this article in the United States.

The laws governing the existence of air in the liquid or gaseous state are the same as those for water—to take a substance with which we are most familiar. Above a certain temperature and pressure (212° F. and atmospheric pressure at the sea level) water exists as a vapor; from 212° F. to 32° F. at the same pressure it is a liquid, and below that temperature it is a solid. In its normal condition air, as we know it, is a gas, just as in its normal condition water is a liquid; but if we lower the temperature or increase the pressure, or both, of air to a sufficient degree, we reach a point at which condensation takes place. The liquefaction point of air under normal atmospheric pressure is 311·8° below zero by the Fahrenheit scale.

Mr. Tripler's method of liquefaction is based upon the fact that, if a gas be compressed and allowed suddenly to expand, it absorbs the heat of the surrounding medium, thereby producing intense cold. He compresses air to 2,000 pounds to the square inch, passes it through a coil and permits it to issue from a needle point orifice. There it expands and cools. This cold stream of air circulates around a second coil through which compressed air is flowing, reducing the temperature of the latter. The air issuing from this second coil has its temperature lowered to a point due to its own expansion, plus the cold imparted from the first expansion. The expanded and extremely cold air from the second coil is used similarly to cool a third coil, the air in which is brought down to a temperature of 311·8° F. and below, at which it condenses and flows from the end of the coil in a liquid stream.

In the course of his lecture Prof. Barker made a number of curious experiments with the liquid, illustrating the operation of the laws governing the formation of solids, liquids and gases. When it was poured into a tumbler it boiled until it had absorbed the heat of the glass. The cold gas given off condensed the moisture in the air above the glass, which fell in the form of hoar frost. A piece of tin thrust into the liquid made it boil and the tin was rendered as brittle as glass. Copper and platinum were not so affected, and it is evident that these metals will make suitable receptacles for this new liquid. When it was boiled over a furnace the ebullition was, of course, excessive; but the moment water was poured into the boiling liquid, the former was instantly frozen. Alcohol and mercury were frozen when brought in contact with the new product. The liquefaction point of the two constituents of air is different, that of oxygen for given pressures being several degrees higher than that of nitrogen. Hence, as the temperature of the liquid rises, the nitrogen is the first to escape as a gas. The remaining liquid is proportionately rich in oxygen—a fact which is proved by the bluish tint which a standing vessel of the liquid assumes if exposed to the air. Just what the economic value of this new and extremely interesting product is, time will show; but in experimental work in the laboratory it will be certain to find a ready field of usefulness.

* A series of valuable papers on this subject, by various authors, including Prof. Dewar, has been published in the following numbers of the SCIENTIFIC AMERICAN SUPPLEMENT: 846, 932, 948, 967, 970, 972, 1042.

FALSE ECONOMY.

The reluctance of Congress to push forward the coast fortifications proves that the sound business principles which govern men in the conduct of their private business are too often forgotten or violated in the administration of public affairs.

No one who is entitled to speak intelligently on the subject denies that the wealthy cities on the United States seaboard are at the mercy of an attacking fleet. Our coastline is so extensive and the number of ships in our navy is relatively so limited that every one of our seaports should be in a position to repel, unaided by the fleet, a hostile attack. At present not one of them could do this. Admirable as are the plans of fortification drawn up by the War Department, they still exist, thanks to the indifference of Congress, largely upon paper.

Adequate fortifications are to the protected city what insurance is to a building. No good business man would think of putting up a factory without placing an adequate insurance upon it. No nation in the world but one would dream of allowing its wealthiest cities to lie exposed to the attack of any petty state that can afford to buy a cruiser or two from foreign and competitive nations that are only too ready to furnish them. Looked at from a purely business standpoint, the few million dollars asked for fortifications are to be spent in taking out an insurance upon the thousands of millions of property which are now exposed to possible destruction.

This year's fortifications bill has suffered, as usual, a reduction at the hands of the House Committee, and the knife has been applied so effectively that less is to be conceded than for the two years previous, and the War Department's estimate is cut down two-thirds. Two years ago the appropriation was $7,377,888, and last year $9,517,141. This year a request was made for $13,378,571, whereas the bill as reported provides for only $4,144,912.

The policy of the present Congress may, perhaps, have been influenced by the fact that our foreign relations are less strained than they were when the liberal appropriations of two years ago were made. But it should be remembered that the building of fortifications and guns of the modern costly type is not or should not be emergency work. Activity in this line should never be determined by the aspect of political affairs. To return to our comparison, no one thinks of waiting until his neighbor's house is on fire before taking out an insurance upon his own.

GROWTH IN OUR EXPORTS OF AMERICAN LOCOMOTIVES.

The American locomotive is evidently winning favor in the foreign countries into which it has been introduced. Whether the disastrous strike of the engineers in Great Britain has had anything to do with the large number of orders which have recently been placed in this country or not, it is a fact that the foreign trade has been growing at a steady pace and helped materially to keep our builders busy during the past few months. Japan in particular has shown her satisfaction with the American locomotives which she has already purchased by sending in large orders for more. Her first purchases were made in 1894, when fifteen locomotives were ordered. This was followed by twenty-three in 1895 and another twenty-three in 1896. The figures for the current year will undoubtedly show a considerable increase over its predecessor. Our best customer is Brazil, to which country eighty-four locomotives were shipped in the year ending in June, 1897. Russia comes next with a total of seventy-four, while Mexico purchased twenty-three and Chile twenty-two.

There are many reasons why the American machine should give good satisfaction to these foreign countries. In the first place, it is considerably cheaper (35 to 40 per cent) than the European machine, and the lessened cost is obtained, thanks to our improved machinery and economical shop management, without any sacrifice of quality. It is possible that the American locomotive does not show so much bright work and costly painting as the European engine, but in all points that affect its efficiency it is fully up to the standard.

To this must be added the simplicity and accessibility

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