ICE-MAKING AND MACHINE REFRIGERATION.

By FREDERIK A. FERNALD.

THE manufacture of ice now bids fair to become a regular industry in temperate as well as in tropical climates. Pioneer work in this field was done more than sixty years ago, but it is only within the last ten years that the groping attempts of the early inventors have developed into processes sufficiently economical to make the artificial production of ice a commercial success. Artificial ice has been made in tropical countries and in our Southern cities for many years, but the industry has been greatly extended in this country by the two successive mild winters of 1888–'89 and 1889–'90. It has now gained a foothold even in our Northern States, while in the South comparatively small towns have their ice factories.

The scientific fact on which the making of artificial ice depends is that when a liquid evaporates it uses up a great deal of heat, which it draws from anything that happens to be around it. If a can of water is at hand, its temperature is reduced, and if the action goes far enough the water will be frozen. This cooling action can be felt by pouring a little ether or alcohol upon the hand. The liquid evaporates rapidly, and the loss of the heat which it takes up cools the hand very perceptibly. If a bottle containing water is kept wet on the outside with ether, the evaporation will chill the water and eventually freeze it. This is essentially the process by which the *carafes frappées* of French restaurants are produced. The decanters filled with fresh water are set in shallow tanks containing brine, which remains liquid below the temperature at which fresh water freezes. In contact with these tanks are receivers, which can be kept charged with newly formed ether vapor. The chilling vapor cools the brine, and this in turn takes heat from the water in the decanters, which soon freezes.

In making ice on the large scale, either ammonia or sulphurous oxide is used instead of ether, because these substances are cheaper and are not inflammable. Ammonia is a gas or vapor at ordinary temperatures. What is commonly called ammonia, or, more properly, ammonia water, is water with several hundred times its volume of this gas dissolved in it. For ice-making, anhydrous ammonia—that is, ammonia perfectly free from water—is used. The first thing to do is to get the ammonia into the liquid form. There are two ways of condensing a vapor to a liquid—by cold and by pressure. Practically it can be done easiest by combining the two. The ammonia gas is subjected to pressure, and forced through a coil of pipe called a condenser, where it is cooled by water from any convenient supply running down over the pipes. By this means the latent heat in the gas is pressed out, and is taken up and carried away by the water. After being liquefied in the condenser the ammonia is forced into pipes larger than the liquid can fill, where it immediately expands into a vapor and exerts its chilling effect.

Two methods of making ice, which differ, however, in only one step of the process, are now in use. In a factory established last year in New York city, which the writer has been permitted to go through, the "compression system" is used, with anhydrous ammonia as the cooling agent. The machinery employed consists of a powerful pump driven by steam, with which is connected the necessary condensers, piping, etc. Liquid ammonia is supplied by the makers of ice machines in strong iron drums. The ammonia is run into a cylindrical iron tank, from which it is allowed to pass through a small orifice into the coils of pipe in the freezing tank. In this factory the freezing tanks are of iron, about twenty by fifty feet in size, and four feet deep. Over them is a floor, which is cut up into rows and lines of rectangular covers. Each of these lifts up, showing a can under it, twenty-two by eleven inches in size, and forty-four inches deep. The tank contains a brine of regulated strength, and the cans when filled with the water to be frozen float in this brine, coming within an inch or two of the bottom of the tank. Back and forth across the

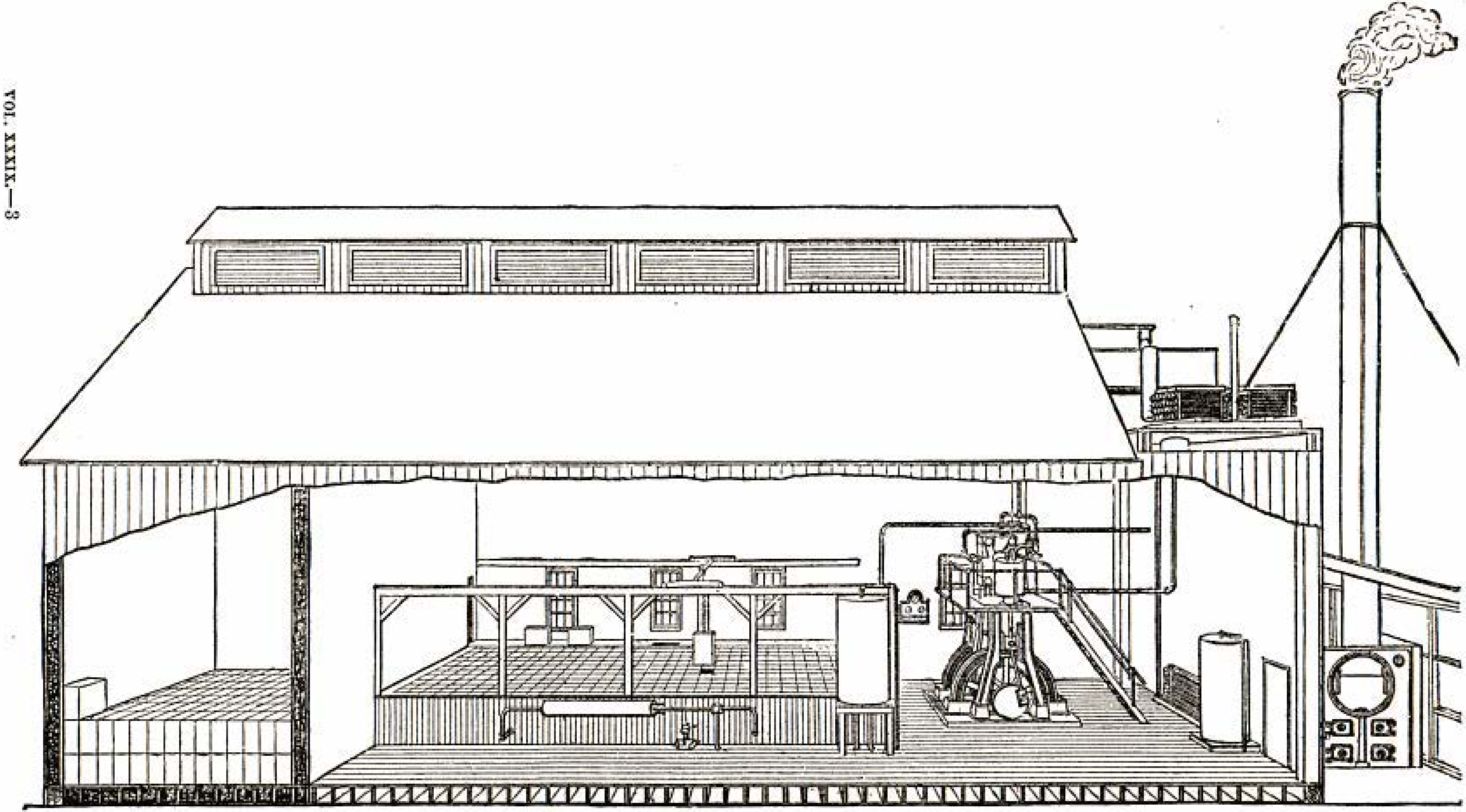

Fig. 1.—Interior of an Ice Factory.

tank, between the rows of cans, run the coils of pipe through which the ammonia passes. The evaporation of the ammonia constantly going on within this system of pipes cools the brine down to 15° or 18° Fahr. In order to equalize the temperature in all parts of the tank the brine is kept in constant circulation by a revolving agitator, which resembles a propeller-screw. Surrounded by this frigid liquid the water in the cans becomes congealed to uniform hard blocks of ice, weighing about three hundred and twenty pounds each. A tank of the dimensions above given contains five hundred cans. About sixty hours are required for the freezing process.

In Fig. 1 the tank, with its flooring, is shown in the middle of the building. To the right of this is the pump, and at the extreme right is the boiler-room. Over the tank is a traveling crane, by which the cans containing the ice are lifted out and conveyed to one end of the room. The crane consists of a beam, with a pair of wheels under each end, which travel on tracks six or seven feet above the floor. By means of the tackle hung from this beam a man raises a can of ice above the floor, and then pushes the crane with its load to the end of the room. Here the can is put into a sort of swinging box and tilted over into a slanting position, mouth downward. Tepid water is then allowed to run over the can from a line of small jets on each side. In two or three minutes the block of ice is melted free from the can and slides through a shute into the ice-house. The box is an automatic contrivance, and, as soon as the ice has left it, it reverses, turning the can upright and shutting off the water. In some factories the can is dipped into a tank of warm water to loosen the ice. In the figure, a can is seen suspended from the crane; at the back, under the middle window, is the small tank of warm water for dipping the cans; and in front of the next window two blocks of ice are lying. The room at the left is the ice-house. It has double walls packed with non-conducting material, and is shown with two layers of blocks in it.

The ammonia gas, after passing through the coils of pipe in the freezing tank, is drawn through a pipe into the great pump, where by the return stroke of the piston it is compressed and forced out through another pipe into the condenser. In Fig. 2 the condenser is shown in an upper room. It consists of several coils of pipe, over which cold water is kept running. The small pipes which run down obliquely from the ends of the coils are to carry away the ammonia as it becomes liquefied into the storage tank, which is the horizontal cylinder on the floor with the condenser. From the storage tank the ammonia, still under pressure, passes down into one of the large vertical cylinders shown in the lower part of the figure, and from this it goes into the expansion coils in the freezing tank, and passes again through the cycle of operations just described. The same ammonia is thus used over indefinitely. The pressure to which the ammonia is subjected in this apparatus ranges from one hundred and twenty-five to one hundred and seventy-five pounds per square inch. The pump, shown in the lower part of Fig. 2, is one of several makes. It has two compression cylinders, seen at the top of the tall A-shaped frame. The piston-rods work vertically beneath these cylinders, and are connected by cranks and connecting-rods to the piston working in the steam-cylinder seen at the right. The use of the ammonia in making ice can be compared to the use of a sponge in baling a boat. As the sponge soaks up water from the bottom of the boat, and after being squeezed over the side is ready to soak up more, so the ammonia soaks up, as it were, heat from the water to be frozen; and, after this has been squeezed out by the compressor, the liquid is ready to take up more heat.

The water from which the ice is made in the New York factory, previously mentioned, is from the city supply (Croton). Before being frozen it is purified by filtering and distillation. It is first filtered, then converted into steam in vertical boilers about twenty feet high; the steam is condensed and again filtered in steam filters filled with coke. The condensation is effected by placing the filters in the open air on the roof of one of the buildings, and circulating around them water pumped from the river, near which the factory is located. After leaving the steam filters and condensers, the water is further cooled by passing through a cooler similar to the condenser used for the ammonia. After leaving the cooler, the water is filtered through charcoal, and is then ready to go into the cans. It is filled into them through a hose, which ends in a long nozzle, containing a patented device that prevents air from being carried down into the water. In order to make clear ice, the formation of air-bubbles in it must be prevented. Water always contains some air, which is driven out by boiling. When boiled water is frozen, the ice contains only what little air is absorbed by the water while it is being cooled down to the freezing-point. The artificial ice, therefore, is clear except a thin layer running lengthwise through the middle of the cake—the part that freezes last. A very attractive exhibit for a market is made by putting meat, fish, fruit, and flowers into cans of water and freezing them into the clear ice. Articles having smooth surfaces, and consequently few crevices in which air-bubbles can cling, give the best results.

It was mentioned early in this article that sulphurous oxide is used as a cooling agent in making ice. This is the choking gas that is formed when sulphur burns. An ice machine employing anhydrous sulphurous oxide is made, which, as it works accord-

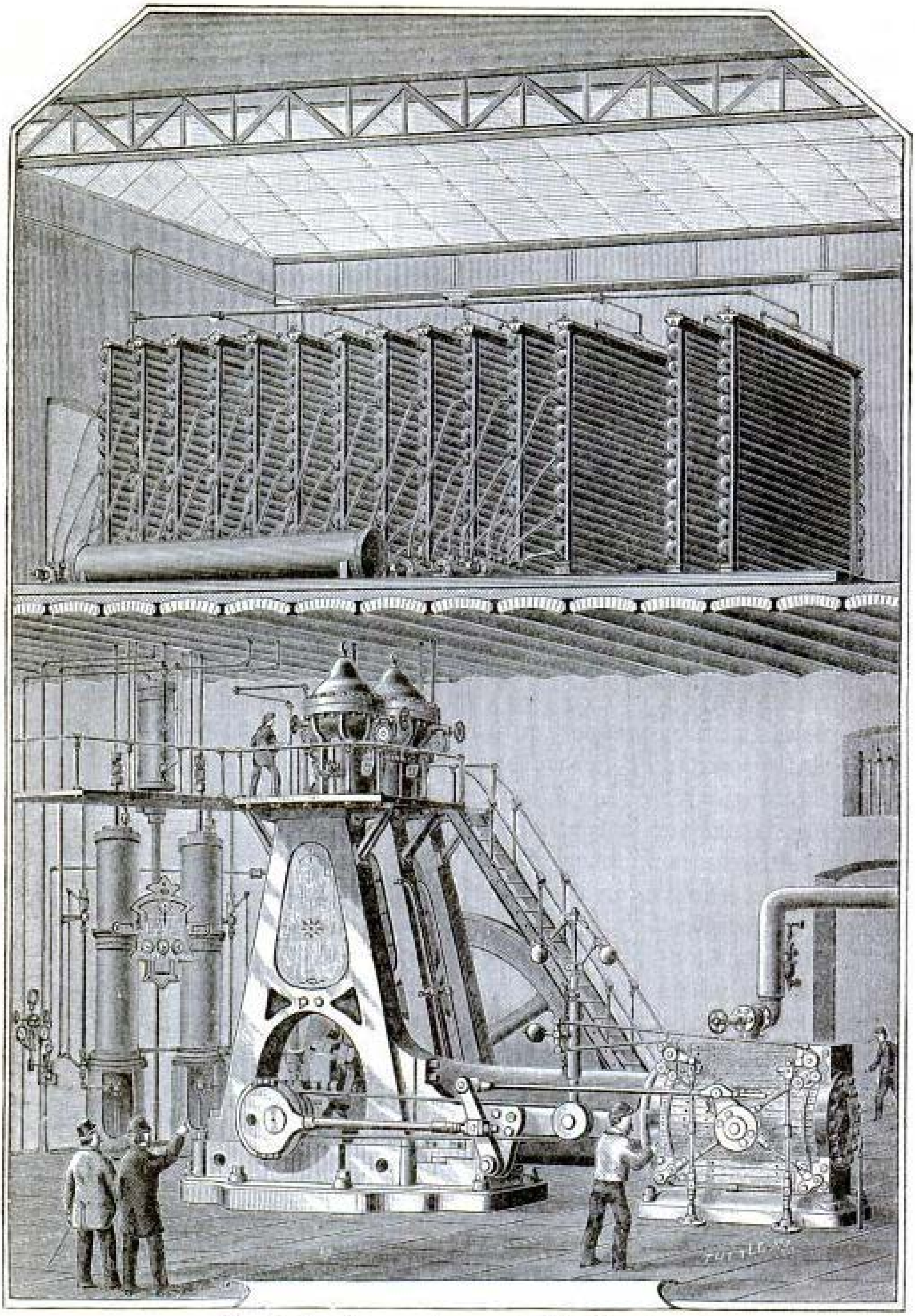

Fig. 2.—An Ammonia-compression Ice Machine.

ing to the "compression system," like the ammonia machine just described, necessarily has the same essential parts, though differing somewhat in form and arrangement. It uses a brine made from magnesium chloride instead of common salt.

There is also a class of ammonia machines, that operate on what is called the "absorption system." In these machines the operation starts with ammonia water instead of anhydrous ammonia. The liquid is heated in a boiler, and a mixture of about nine parts ammonia gas and one part steam is driven off from it. The mixed vapors pass first into a rectifier, where most of the steam is condensed to water, which runs back into the boiler. The temperature in the rectifier is not low enough to condense the ammonia, which passes on, now nearly free from water, into the condenser. Here it is liquefied by the joint action of cold and pressure, only the pressure is not supplied by mechanical means, but by the expansive force of the stream of vapor that is constantly being driven out of the boiler. The liquid ammonia next passes into the expansion coils in the freezing tank, just as in the compression system. After doing its work the gas is led into an "absorber," which is very similar to the condensers already described. Here it is reabsorbed by the water that it was originally driven out of, this water ("poor liquor" it is called) having been forced out of the boiler by the pressure prevailing in it and cooled for the purpose. It is this operation that gives the name to the absorption system. The resulting solution of ammonia is returned to the boiler by a pump and begins again the same round of operations.

In hot climates natural ice is an expensive luxury, as it must be brought long distances, and suffers much loss from melting. In those regions the artificial product has a great advantage in respect to cost. Even where there is usually a cold winter, as in the northern United States, a failure of the ice-crop sometimes occurs in the fields usually depended upon, followed by a more or less necessary increase in price the following summer. Ice machines have now reached such a high degree of efficiency that their product can compete with natural ice in these latitudes. In the summer of 1890 the price of natural ice to families in New York was a dollar a hundred-weight, while artificial ice sold for fifty cents. No doubt further improvements in machinery and methods will be invented, which will make it possible to furnish ice at a still lower price than now, and will lead to a freer and more general use of this commodity. Not only can artificial ice be sold at a lower price than the natural in most markets, but it is more economical, for the reason that it does not melt so fast. This is because it is frozen without the interruptions that allow layers of bubbles to collect under natural ice formed on still water, and it contains no soft snow-ice. It is, therefore, more compact than any but the very best of the natural product.

Another advantage that is claimed for artificial ice is, that when made from distilled water it is free from the impurities that natural ice sometimes contains. Nearly all natural water contains considerable numbers of bacteria, many of which are derived from the sewage discharged into some lakes and rivers from which ice is cut. It is commonly believed that water in

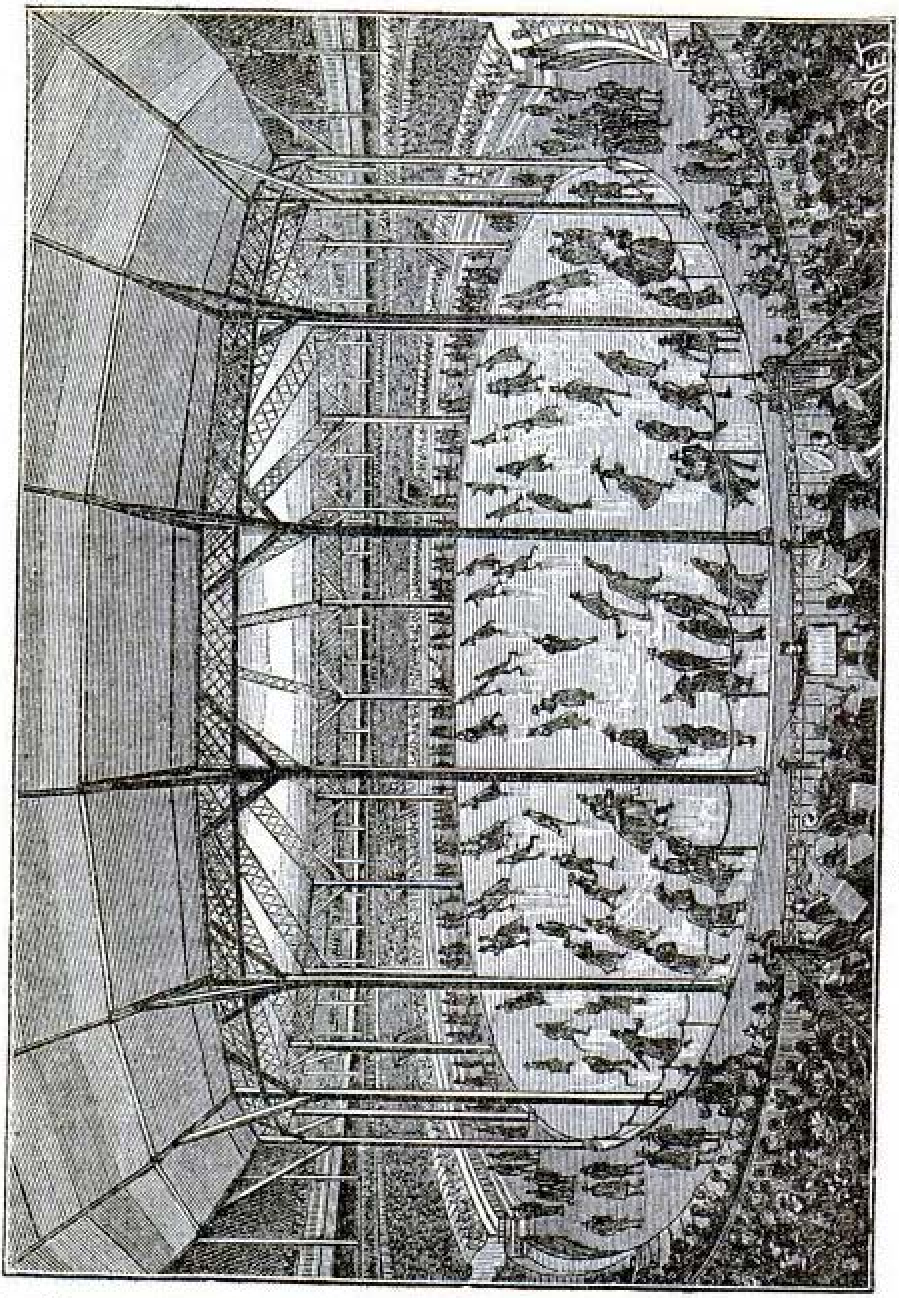

Fig. 3.—Rink of Artificial Ice in Paris.

freezing purifies itself from all kinds of contamination, but Dr. T. M. Prudden has shown in this magazine that the truth is otherwise. In his article on Our Ice-supply and its Dangers (Popular Science Monthly for March, 1888) he says:

A great deal of careful experiment has shown that water in freezing largely expels its coarser visible contaminations, and also that a large proportion of the invisible bacteria which it contains may be destroyed, even as many as ninety per cent. But still large numbers may remain alive, for many species are quite invulnerable to the action of cold. It has been found that in ice formed from water containing many bacteria, such as water with sewage contamination, the snow-ice almost invariably contains many more living bacteria than the more solid, transparent part; so that the snow layer should be especially avoided in ice obtained from questionable sources. Unfortunately, the bacteria which cause typhoid fever are not readily killed by cold, and may remain alive for months, fast frozen in a block of ice.

As the neighborhood of our ice-fields becomes more thickly settled, and the demand for ice also increases, the danger that frozen filth will be served out to consumers of ice will increase likewise. It is fortunate that the artificial process stands ready to shield us from this peril.

Utility has not entirely monopolized the artificial production of ice; it has been made to serve sport as well. About 1875 a Mr. Gamgee, in England, constructed a rink of artificial ice for summer skating, and several others have been made in that country. In 1889 an immense rink of this kind was established in Paris, circular in form and one hundred and seventy feet in diameter. Around the sheet of ice was a promenade over seven yards wide,

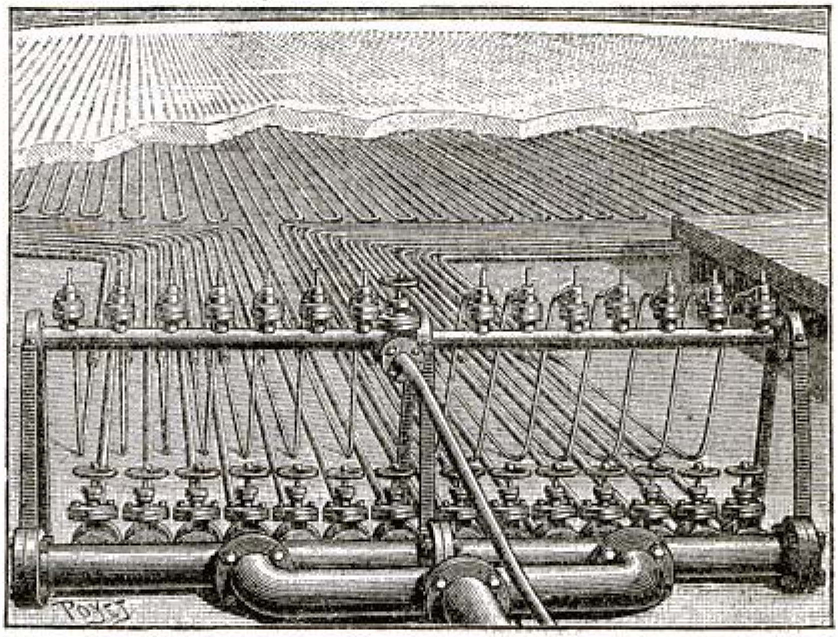

Fig. 4.—Arrangement of the Expansion Coils in a Rink in Paris.

and outside of this were placed seats for spectators, a band-stand, etc., the whole being covered by an arched roof. The arrangement of this rink is shown in Fig. 3. The ice-sheet was formed on a concrete bed, upon which lay an immense coil of iron pipe, as shown in Fig. 4, having a total length of ten miles. The pipe was of an inch and a quarter internal diameter, and the lengths were placed five inches apart. Through this coil the ammonia circulated, the absorption system being used to effect the congelation.

The machines with which ice is made have also another and up to the present time a larger application. This is the production of cold in breweries, abattoirs, markets, and cold storage

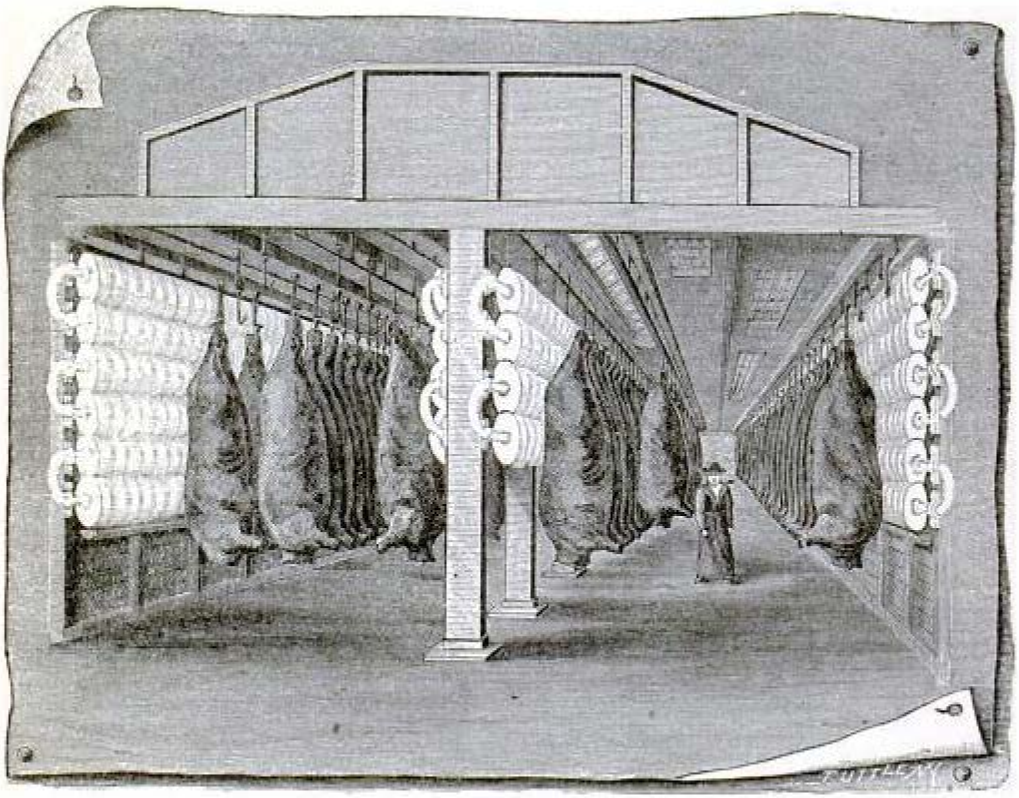

Fig 5.—A Room in a Cold Storage Warehouse.

houses. The fermentation of beer must take place at quite a low temperature, which must be steadily maintained; hence energetic and continuous cooling of the wort has to be provided for. The brewers were formerly among the largest customers of the ice companies, but now nearly every brewery has a refrigerating machine of its own, and more machines are used by them than by all other users put together. No ice is made with these machines, except for packing beer for shipment, as the cooling required can be accomplished more conveniently by circulating cold brine or cold fresh water in pipes where it is needed.

The system of cold storage which has sprung up within the past few years has been made possible by this same process. Immense quantities of meat and other perishable provisions are now kept in great warehouses until wanted, thus insuring a steady supply to the consumers in our large cities. The provisions, when brought into these buildings, have the temperature prevailing outside, and warm the air that comes in contact with them. This air rises into a loft, where it comes in contact with pipes containing cold brine, becomes chilled, and descends through flues to the room below, entering it near the floor. This circulation goes on until the provisions have been cooled down to the temperature of the room. The air may be cooled, also, without the use of brine, by letting it come in contact with the coils in which the ammonia expands. Air has also been used direct for the production of cold by compressing it. Like condensed ammonia, it takes up much heat in expanding to its ordinary volume, but this system is not economical. In Fig. 5 a somewhat different arrangement is represented. Where there is not space for the loft, the expansion coils may be placed in the same room with the provisions. Before refrigerating machines came into use, refrigeration on the large scale had been tried with ice, and had failed. This was owing to the dampness imparted to the air by the melting ice. The brine or ammonia coils not only do not add any moisture to the air, but even withdraw a great deal that it naturally contains. This moisture becomes condensed on the pipes as the air circulates around them, and makes itself visible as a gleaming white coating of hoar-frost. On board steamers, machines are employed both to preserve dressed meat and to prevent live cattle transported through tropical regions from dying of the heat in their confined quarters. Machines of moderate size also find application in hotels—two of the recently built houses in New York have them—in dairies, chocolate factories, and they are used also in making stearin and margarin, in rectifying alcohol, extracting paraffin from petroleum, etc. A machine of the size represented in Fig. 2 will produce a refrigerating effect equal to that obtained by the consumption of two hundred and twenty tons of ice a day, or it will make one hundred and thirty tons of solid ice daily. The company that makes this style of machine is now building one of three hundred tons refrigerating capacity, which will be the largest in the world. But that is soon to be exceeded, as the contract is already made for a five-hundred-ton refrigerating machine.

Artificial refrigeration has also been applied to sinking shafts and driving tunnels through quicksand and loose wet gravel. These materials wash into an excavation as fast as they are removed, and in many cases progress through them is next to impossible by ordinary methods. The difficulty is overcome by freezing the loose soil around or in front of the work. This process was first used by a German mining engineer in 1883. In sinking a shaft, pipes of about eight inches diameter are driven down in a ring around the place of the proposed excavation. A brine, cooled to within a few degrees of 0° (Fahr.), is sent down through an inner pipe and returns through the space between the two pipes. By this means a cylinder of the wet earth is frozen, within which the digging is done and the lining of the shaft put in place. The core of the cylinder which is to be removed will be partly or wholly frozen, according to the degree of refrigeration employed. Frozen quicksand looks like a fine-grained sandstone, and is about as hard to cut through.

Those who are acquainted with the history of invention, will not be surprised to learn that the Asiatics were centuries ahead of us in the making of ice, as in the use of gunpowder, the compass, etc. Ice has long been made in India by the following method: Pits two feet deep and twenty or thirty feet square are dug in a large, open field, and about half filled with straw. After sunset shallow dishes of porous clay are placed on the straw and water is poured into them. The rapid evaporation of part of the water, assisted by the radiation of heat from the straw, chills the water remaining, and, if the night is favorable, thin sheets of ice form in the pans by morning. The operation is most successful when the sky is clear and a gentle dry breeze is blowing. Although we of the Western world have clearly been anticipated in producing ice artificially, we may still claim the superior credit that our process has not remained stagnant for generations, but has achieved many of the possibilities that have been open to it, and become independent of such limitations as the state of the weather, and others that hamper the operations of the "gentle Hindoo." *