MINUTES OF PROCEEDINGS.

8TH JULY, 1886.

Walter Shellshear, President, in the Chair.

THE MANUFACTURE OF ICE BY THE "BETH PROCESS."

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THE author proposes in this paper to describe the machinery used in the manufacture of ice by the "Beth Process."

He will first take the liberty of quoting from a paper read before the Institution of Civil Engineers in London, by A. C. Kirk, Mem. Inst. C.E., which deals with the subject and describes a small machine to illustrate the principles.

"The manufacture of ice to supply a large demand is of comparatively modern development.

To the use of ice and cooling chambers we are indebted for the production of our finest candles, for the better production of much of the beer we drink, for the better curing of pork and bacon, and for the better condition of the butcher's meat which we daily consume.

The artificial production of ice has long been a matter of scientific curiosity in Europe.

Older scientific treatises devoted much space to the composition of freezing mixtures, and to descriptions of methods adopted in India for producing thin ice on favourable nights, by exposing water to the combined action of radiation and evaporation, &c.

These processes did not meet the demand, and they do not come within the scope of this paper."

"Of the liquid employed in the manufacture of ice, ether and volatile hydro-carbons are highly efficient when the difference of temperature required is not too great.

With ammonia a very wide range of temperature is practicable, but this liquid possesses a peculiar property by which mechanical compression and exhaustion can be dispensed with, chemical compression (if we may use such a phrase), being substituted. A machine on this principle was proposed by Mr. Careé in 1859. It is based on an experiment of Faraday's.

While experimenting on the liquification of gases under the combined influence of pressure and cold, he placed in one of the branches of a strong U tube of glass a body which, under the influence of heat, gave off a quantity of the gas he wished to liquefy. The other branch he placed in a freezing mixture.

Heat being applied to the end containing a dry chloride of silver, which had absorbed a quantity of ammoniacal gas, while the empty end was kept cool, he found after a little time in that end a liquid which was liquid ammonia.

He then observed that as the tube cooled the ammonia evaporated, and the gas was re-absorbed by the chloride of silver.

Here was a refrigerating machine, for during its evaporation the ammonia must absorb heat.

Ammonia behaves in the same way with chloride of calcium, with charcoal and with water. The two former however are no use for a practicable refrigerating machine, owing to their almost total absence of heat conducting power and their sluggish action, Mr. Carré, by using water, which from the mobility of its particles, and the rapidity with which it could be heated and cooled, produced a practicable machine.

In its simplest form Carré's machine is intermittent in its action, and consists of two strong reservoirs, connected by a pipe, in fact Faraday's U tube enlarged at each end. The larger end is a vessel about three-quarters filled with a strong concentrated solution of ammonia in cold water. When this is heated and the smaller vessel placed in cold water, the ammoniacal vapour is expelled from the water, and, under the influence of cold and pressure is condensed into a liquid in the smaller vessel. The hot water or rather the hot weak ammoniacal solution left in the larger vessel, being now cooled by the application of cold water to the outside, or otherwise, powerfully re-absorbs the ammoniacal vapour as fast as it is generated. Thus the pressure being continually removed by absorption, the liquid ammonia boils in the smaller vessel, and this goes on as rapidly as we can cool the contents of the larger. Water, under the influence of heat and cold, performs the same function as the piston in a machine, promoting the evaporation of the gas, by creating a vacuum, and also compressing and condensing the gas without the use of any mechanical arrangement. Although no engine in the ordinary sense is employed, energy, in the form of heat, is of necessity consumed, and heat is absorbed at a low temperature and rejected at a higher, as in all other refrigerating machines."

Ammonia gas has a most remarkable property, viz., that water will absorb or dissolve it, for as soon as ever it is brought into contact with water it disappears because the water absorbs it so readily. It is transparent and colourless, and has also a very pungent suffocating smell. Some accurate data on the absorbing power which water has for ammonia gas have been given by Bunson He has shown that one pint of water at 0 °c or the temperature of melting ice will absorb 1180 pints of ammonia gas. This absorbing power, however, is greatly diminished as we increase the temperature. At 20 °c it will only absorb 680 pints, whilst at 40 °c only 444 pints of ammonia gas.

For a very long time no one knew that spirits of salt and spirits of hartshorn were solutions of gases. The celebrated Henry Cavendish when experimenting on hydrogen, attempted to make the gas by acting on spirits of salts with copper. He obtained a gas which seemed to disappear as soon as it came in contact with water. Priestly repeated the experiment and ascertained that copper played no part whatever in the phenomenon, and that a gas might be readily obtained by heating the spirits of salts alone in a flask and catching the gas over mercury. The gas he obtained he called marine acid air. We now name it hydrochloric acid. It seemed to Priestly that spirits of salts was nothing more or less than a solution of this gas in water, and the experiment suggested a new line of inquiry. Might there not be many liquids deriving their peculiar properties from some gas held in solution in this manner? Following out this idea, in one of his experiments he took spirits of hartshorn, treated it, and arranged matters so that if any gas came off it would be caught over mercury. His expectations were realized, and he obtained a gas which he named alkaline air, and this is what we now call ammonia.

"The range of temperature available is great, much greater than in the case of ether, for at the atmospheric pressure, the boiling temperature of ammonia is 40 deg. Fahrenheit. Usually the pressure required to liquefy the gas is 150 lbs. per square inch. This is the simplest refrigerating machine made, but its intermittent action limits its use.

It, however, is easily transformed into a machine of continuous action, the operation being the same.

But, whereas in the intermittent machine there were two parts, each performing two functions alternately, at a high temperature and at a low one, we must now adopt four parts, each performing one function and kept at one temperature

Messrs. Mignon and Rouart's Paris Machine, Fig. 1.

As made by Messrs. Mignon and Rovart, of Paris, the parts consist of a boiler (A, Fig. 1) in which the ammoniacal gas is distilled from its solution, a condenser (B) to liquefy the gas, a volatiliser or boiler (C) in which the liquid ammonia boils and absorbs heat, and an absorber (D) into which the vapour as it is generated in (C), passes and is absorbed by cold water.

These different parts are connected by: 1st, a pipe "aa" taken from the top of the boiler A to the liquefier B. 2nd, a feed pipe "bb" from the bottom of the liquefier B to the top of the volatiliser C. 3rd, a pipe "cc" taken from the top of the volatiliser C to the absorber D. 4th, a pipe "dd" taken from the bottom of the boiler A to the top of the absorber D. 5th, a tube "ff" taken from the bottom of the absorber D to the top of the boiler A. This apparatus is completed by a pump F in the circuit of the pipe ff from the absorber D to the boiler A, a cock G on the pipe dd, and lastly a cock H in the pipe bb. The operations carrried on in this apparatus are as follows:—

The ammoniacal gas is distilled from its solution in water in the boiler A, under a pressure in ordinary circumstances of about ten atmospheres.

The volatised ammonia passes by the pipe "a a" to the liquefier or condenser B, which is kept cool by a supply of water.

The ammoniacal gas being condensed in the liquefier B, passes by the pipe "b b" to the volatiliser C, in which it boils and abstracts heat.

As the liquefier or condenser B is ordinarily at a pressure of about 10 atmospheres while the volatiliser or boiler is at a pressure of about $1\frac{1}{2}$ atmospheres, the liquefied ammonia would rush at once through the feed pipe "b b" were it not regulated by the cock H so as to maintain at all times some liquefied ammonia in the condenser B.

The ammoniacal gas, as fast as it is formed, passes from the volatiliser C to the absorber D, in which cold water absorbs it, compressing it in fact, and liquefying it, forming a solution of a convenient degree of saturation. This ammoniacal solution is returned to the boiler A and the process is repeated, But in the course of distillation in the boiler, which must be performed quietly and without agitation, the solution of ammonia is found at the bottom to be comparatively poor; and while the strong solution from the absorber D is returned in the boiler A by the pump F, a corresponding amount of weak solution is drawn from the bottom of the boiler and returned to the absorber. The flow of this water is regulated by the stop cock G. In order to prevent the great waste of heat, which was unavoidable in the intermittent machine, in cooling down the spent, ammoniacal solution to enable it to act as an absorber, an interchanger is introduced, by which the heat of the spent solution, as it escapes from the bottom of the boiler A on its way to the absorber D, is given up to the strong solution on its way from the absorber D to the boiler A.

Having thus described the principles on which ice is made by the circulation of ammonia in a small experimental machine, the author will now describe how those principles are applied to manufacture ice for the market, by a large machine capable of making twenty tons of ice in twenty-four hours.

The works which the author will describe have been erected by the Sydney Ice Co., Limited, and are situated in Harris-street, Pyrmont.

Beth Process.

The process used is known by the name of the "Beth" process, and the principles of the patent consist in the circulation of ammonia through upright coils of pipes which are placed in parallel rows in a freezing chamber.

This ammonia is deprived of its lateut heat under pressure, and on being released into these coils, it absorbs the heat from the water which is constantly being sprinkled over them by a row of revolving sprinklers interspersed between each row of pipes.

This water gradually freezes, and expanding into the space between the pipes, forms a solid mass of ice 45 ft. long, 2′6″ thick, and 16 ft. high, resting on its base on a concrete floor.

The Works.

The works under consideration in this paper stand on an area of 8000 square ft., and consist of three floors, viz,, a basement, a ground floor, and an upper floor or roof, Fig. 2 and 3.

Basement.

In the basement are the furnaces for the retorts or ammonia boiler.

Ground Floor.

On the ground floor are the engine and pumps, the ammonia retorts, and steam boiler for driving the engine, with the offices and weighbridge while at the back of the building are the stables and van houses.

Upper Floor or Roof.

On the upper floor, which also acts as the roof of the building, are the absorbing coil, condensing coil, and dryer or interchanger. This floor is surrounded by a brick parapet 2ft. 6in. high, with a brick on edge coping and cement weathering. It is formed of 2½in. x 1in. boards, tongued and grooved and well tarred. Over this is placed a layer of felt well tarred, then another floor of 2½in. x 1in. boards tongued and grooved, the whole is then covered with a thick coating of pitch to insure its being watertight.

Well in Floor.

A well is formed in the centre of this floor 2ft. 6in. square. This floor has a fall of about 1 in 50 from the sides to the centre into which all the water from the large sprinkler runs, whose use, will be explained later on.

The walls all through the building are 18in. thick.

Freezing Room.

The freezing room is at the back of the building, and in height equals the basement and the ground floors. It is lighted in the day-time by six airtight skylights in the roof.

Wooden Lining.

A wooden lining extends all around this room, 15in. from the walls, and this space is filled with sawdust, it measures 55ft. wide by 50ft. long. The floor is of concrete, and has a sump hole formed in it for the purpose of collecting all waste water, from whence it is pumped into a tank which is fixed along the party wall that separates the freezing-room from the engine-room. This water is of course perfectly pure, coming straight from the city main, and is simply that which has not been converted into ice.

Landing Platform in Freezing Room.

Here also is the landing platform some 12 feet above the floor, covered with sheet iron, on which is fixed a circular saw bench having four saws, which cut the ice up into whatever sized blocks are required for the market. Access is gained to this room by a door in the basement at the back of the furnace, and a door from the landing platform inside, into a landing platform outside (as per sketch) which is also used to deliver the ice into the waggons. These waggons are backed through the main entrance, which is big enough to admit the largest of them, on to one of Fairbank's weigh tables, capable of weighing 10 tons, up against the delivery platform where they are filled with ice.

The Machinery.

The machinery consists of an inverted vertical single cylinder 6 h.p. engine with an 8 h.p. multitubular boiler.

Two water pumps, which supply the long tank in the freezing room above mentioned, as well as the large sprinkler on the roof.

Two double acting ammonia pumps to lift the ammonia back into the retorts, and a frame containing four circular saws for cutting the ice into any required size.

The author thinks he has now said enough to clearly describe the buildings and machinery, and will now describe the process by which the ice is made. For this purpose he thinks it will be best to trace the course of the ammonia from the time it is put into the retorts until it returns to them.

The Retorts.

It will be necessary first to describe the retorts, which we will suppose are filled with ammonia liquor, and the furnace fires lighted.

On reference to figs. 8 and 9, you will see they are built over three furnaces of fire brick in which coke is burnt, and are arranged in a horizontal coil of six, so that the heat from the furnaces passes under the bottom of each layer of tubes or retorts, on the top of which is laid one course of fire brick set in fire clay.

The retort frame is 15 ft. long by 11 ft. 6 in. wide. At the four corners are placed one cast iron standard, to which are bolted channel iron girders on which the ends of each layer of retorts rest.

The bottom layer of retorts directly over the furnaces are six in number, of 14 in. diameter wrought iron tubes, with a one inch thick flat welded ends, these ends being the same throughout and are used to screw the connecting pipes and bends into. All the other ayers have 12 tubes of 9 in. diameter.

On the top of each layer is placed one course of fire brick set in fire clay, so that although the retorts are round every space is filled, and an airtight flue is formed of the fire brick, coiling backwards and forwards until it terminates in a wrought iron stack in which is placed an ordinary damper to regulate the draught.

The retorts are connected with each other by a piece of pipe accurately threaded at each end, one end is screwed into the retort and the other into a cast iron bend. The last retort in the row is connected to the one above it, and so the coil is completed.

Manifold.

In the front end of each retort is screwed a piece of $\frac{3}{4}$ in. pipe, connected with a 4 in. cast iron manifold, and this again connected into a 4 in. wrought iron pipe, so that this pipe is fed by 66$\frac{3}{4}$ in. pipes, one coming from each retort. Each connection is made with a cement composed of litharge and glycerine, which is quick setting and resists the action of the ammonia.

Condensing Coil.

The 4in. pipe leads the ammonia gas generated by heat in the retorts through the roof into the dryer, thence into a 4in. manifold on the top of the condensing coil, which is kept cool by water falling on it from a large revolving sprinkler, where it loses its superfluous heat and becomes a very rich gas; then it passes on through a 1$\frac{1}{2}$in. pipe into a coil of $\frac{1}{2}$in. pipe, called the cooling coil (Fig. 12), being now released by a 1$\frac{1}{2}$in. valve placed in the engine-room into the top of the freezing plates, and it is around these plates that the ice is made.

The Plates.

These freezing plates are made in a continuous vertical coil 18ft. high of $\frac{3}{4}$in. pipe, each pipe is 12in. from centre to centre, and each plate is 30in. from centre to centre, 18ft. high and long. The ammonia gas now passes through these plates from the $1\frac{1}{2}$in. releasing valve at the velocity of 2000ft. per minute, freezing the water which is falling round the pipes of the plates and manufacturing the ice. (Figs. 10 and 11.)

Small Sprinklers.

The water is distributed over the pipes of the plates by means of fifteen revolving sprinklers screwed into the top of a pipe 45ft. long, as shown in the drawing Fig. 5. They are placed at the top of the plates at 15in. from each one. The revolving T piece has its two ends turned down and terminates in a nozzle; it is prevented from coming off by a set screw working in a slot in the fixed upright piece. They are fixed at irregular intervals on the pipe, but at 15in. from each plate. These pipes are $1\frac{1}{2}$in. in diameter at the entering, and tapering down to $\frac{3}{4}$in. at the other end. The water passing into these pipes causes the sprinklers to revolve and throw the water in a gentle spray all over the surface of the freezing plates, and it is there converted into ice as it falls down. The water is supplied from the long tank above mentioned fixed on to the engine room wall.

All water which is not converted into ice falls on to a concrete floor and thence into a sump hole, whence it is again pumped into the tank. Thus the water supplied from Botany being used over and over again, becomes colder each time, and a great saving is effected. Besides this the ice is far harder and free from flaws than that made by other processes, for, first, all the air is knocked out, and, secondly, the ice is made from the centre outwards.

In each pipe is fixed a tapering strainer made of the finest perforated iron, and these are changed every six hours.

The gas having done its work by making ice on the freezing plates, now passes into a coil called the cooling coil through an arrangement of valves and pipes shown in Figs. 10, 11 and 12, from thence it passes into a 4in. pipe, which leads it up into a flat circular casting fixed on the roof, 2ft. 6in diameter x 4in. deep, containing 84 holes, Fig. 6 and 7. In this works a flat circular plate covered with small spikes, and it is driven round at about 30 revolutions per minute, by a vertical shaft and bevel gearing worked from the engine-room below; this arrangement is called the agitator, and its use will be next explained, see Fig. 6.

The casing of the agitator has holes in its sides into which are accurately fitted $\frac{3}{4}$in. pipes, which radiate away from it in all directions, like the ribs of an umbrella, and it is called the spider. This spider, which is practically a circular manifold, conducts the gas into the absorbing coil. On one side of it, as shown in the figure, is fitted a 4in. pipe, which brings the gas, as already mentioned, from the freezing-room, conducting it up into the agitator, out of which it passes into the $\frac{3}{4}$in. pipes. A $\frac{3}{4}$in. pipe will also be seen on the top

The use of the agitator is this :—

The gas coming from the freezing-room is still very rich, whilst that in the retorts is comparatively poor, so we therefore bring the poor liquor from them by the $\frac{3}{4}$in. pipe, and this falling on to the top of the revolving plate covered with spikes inside the agitator is completely mixed with that coming from the freezing chambers, and the gas is by this means toned down to the required per centage before entering the absorbing coil. The gas and liquor in returning to the retorts, having been thoroughly well mixed by the agitator, passes through the absorbing coil into another cast iron manifold through which all the gas passes into a 3in. pipe down to the ammonia pumps, and from thence it is forced into the interchanger or dryer.

Fig. 4 is a sketch of the dryer. In it are fixed a number of baffle plates; the gas coming from the pumps on its way down is mixed with the hot gas coming from the retorts by the baffle plates as shown, and when it reaches the bottom it passes through a $2\frac{1}{2}$in. pipe back into the retorts, where it is prepared again to circulate through the machinery.

On the top of the interchanger will be noticed a pipe. It goes to the freezing-room and is used to pass hot gas through any plates that are fully charged with ice, to thaw it off and allow it to be readily taken away without damaging the coil.

Large Sprinkler.

On the roof and close to the agitator is fixed the large sprinkler whose object is to throw water onto the condensing and absorbing coil to aid the liquefaction of the gases on which the economical working of the machine depends. It is shown in Fig. 6 and is constructed as follows. A cast iron pipe revolves on a piece of lignum vitæ at the bottom of a base very much like the trunnion of an oscillating engine, except that it is vertical instead of horizontal. A connection is made in one side of it with number 2 water pump. The whole is surmounted by a casting which has two arms screwed into it of 2in. pipe, terminating in 10ft. of 1½in. pipe perforated with holes and stopped at the outer end. On the bottom is keyed a pinion wheel, and on the same shaft which works the agitator is keyed a worm wheel which working with the pinion wheel causes the whole to revolve and sprinkle water all over the abovenamed coils.

The water falls on the roof and runs into the small well whence it is pumped back again.

Thus we see whether with water or ammoniacal liquor there is no waste if we except the evaporation, which in hot weather is very large, and the leakage which is sure to take place when there are such a vast number of joints, for the author may mention in conclusion that there are in the whole manufactory no less than 25 miles of pipes, and all connected at every 15ft. in the condensing and absorbing coils, and 16ft. in the freezing-room. The author will here take the opportunity of thanking Mr. Sprodd, the late engineer in charge, for the valuable assistance he has given him in preparing this paper.

The paper was accompanied by several diagrams, from which plates 17 to 19 have been prepared.