SESSION 1913-1914

President: THOMAS L. DEVITT, ESQ.

Lecture on Refrigeration.

BY MR. ROBT. BALFOUR.

DELIVERED AT THE MASONIC HALL, GRIMSBY, BEFORE THE GRIMSBY INSTITUTION OF ENGINEERS AND SHIPBUILDERS

On Apri, 25*th*, 1913.

CHAIRMAN: MR. J. MEIN.

THE purpose of this lecture is to lay before the Institution a brief description of the Refrigerating Systems in use on vessels engaged in the carriage of refrigerated cargoes and the stores on land where these cargoes are preserved until they are required for use.

The main objects of refrigeration both on sea and on land are the preservation of perishable articles of food and the making of ice, but other useful purposes are served by it on land in many industries, such as in dairying, brewing, blast furnacing, chemical manufactures, and in horticulture.

It has brought within the reach of the poorer classes not only large quantities of excellent meat, butter, cheese, etc., at reasonable prices, but also many articles which not long ago were considered to be luxuries even to the rich in certain seasons of the year. This specially applies to fruit such as apples and bananas, English markets for which are now almost independent of the seasons.

By the process adopted for transport and storage it is not desired to obtain an excessively low temperature, although this is done in the laboratory for research purposes.

Many foodstuffs such as chilled beef, fruit and cheese, would be seriously damaged if kept too cold. And the difference between success and failure in dealing with such commodities frequently depends upon the maintenance of a temperature not varying one degree Fahr. for long periods of time.

A refrigerating machine therefore should be capable not only of producing the low temperature desired but should permit of complete and precise regulation of the cooling action, in order that the temperature may be maintained practically constant. Modern refrigerating machinery and appliances enable both these requirements to be accomplished, and have thus rendered possible the safe transport of some perishable foods from the most distant parts of the globe. When we consider that many of the vessels engaged in this industry have a carrying capacity of over 3,000 tons of meat, we get an idea of the enormous responsibility resting upon the engineer in charge of the plant. Given the most perfect machinery and insulation, it still requires incessant care and continual attention combined with a knowledge of all the principles involved to ensure the successful carriage of such valuable cargoes.

It is not within the scope of this paper to deal with the theory or history of refrigeration. The thermodynamic theory involved is well known to scientists and was most ably dealt with by Mr. G. James Wells in a paper read before the Institute of Marine Engineers, London, in February last.

"Cold," which is considered by scientists an erroneous term, is merely the absence of heat; it is not absolute except that perhaps the absolute zero of heat may be termed perfect cold. Theoretical conclusions show that the absolute zero of heat would be –461° Fahr. on the air thermometer; this, however, has never been attained, although it has been closely approached in laboratory experiments. In actual practice on board ship –80° Fahr. in one stage is about the lowest temperature obtained.

There are three systems of refrigerating machinery in general use on board ship, these are known respectively as the dry air, carbonic anhydride (CO_2) and anhydrous ammonia (NH_3) compression processes. The principle involved in the production of cold in these three processes may be classed under two general heads.

A. Machinery employing a permanent gas which having been compressed is cooled under compression, then further cooled by doing work in expanding behind a piston, after which the cooled gas is utilized for the extraction of heat.

B. Machinery employing a volatile liquid, during the evaporation of which a considerable amount of heat becomes latent, its behaviour being analagous to that of water when changed into steam.

Take Class A. Air is practically the only gas employed; the principle on which a machine of this class works is that its capacity for performing work depends entirely upon the temperature, increase of pressure merely placing the air in such a condition relative to some other pressure as to enable advantage to be taken of its intrinsic energy by expansion.

If a quantity of air at atmospheric pressure and say at 60° Fahr. is compressed in a cylinder to 60 lb. per square inch, the work expended to do this will appear as heat in the compressed gas, the temperature of which will now be about 340° Fahr. If the gas be then expanded back to its original pressure performing work on the piston, it will give up as much work as was necessary to compress it except frictional losses, and would resume its original temperature, 60° Fahr.

But if the compressed air is cooled down by external means to its original temperature, 60° Fahr., whilst retaining its pressure its volume would be less. Then if it were allowed to expand, doing work upon a piston, when finally expanded to a little above atmospheric pressure, its temperature would fall and would be theoretically about –120° Fahr. and about –80° Fahr. in practice, according to the temperature of the cooling water.

The great difference between the theoretical temperature and that actually obtained after expansion is due partly to friction and the heating action of the cylinder wall, but chiefly to the presence of aqueous vapour in the compressed air, as this vapour not only parts with its sensible heat during the expansion, but also gives up the whole of its latent heat both of evaporation and liquefaction when forming into snow or ice in the expansion cylinder and passages. This difficulty, however, is partially overcome in the more modern machines, special appliances to be afterwards referred to being employed for condensing and removing some of the vapour before the air is expanded.

Several types of machines working on the "air expansion" system are in use. In all of them the motive power is an ordinary horizontal steam engine of the compound type, having its own surface condenser, air-circulating and feed-water pumps. The separate air, compression and air-expansion cylinders are set on the bed-plate tandem to the steam cylinders. The air is drawn from the cargo chamber into the compression cylinder, and on the return stroke it is compressed to about 50 lb. per square inch, and it becomes heated by this compression. The cylinder is water jacketed so that a certain amount of the heat generated in the compression is extracted from the air; the more heat that can be so extracted the better for the efficiency of the machine. The heated compressed air is then passed through coolers which are situated in the bed of the machine, a certain proportion of the moisture in the air will deposit here, and can be blown out through drain cocks periodically. These coolers are similar in construction to the steam surface condenser, and are kept cool by the circulation of sea water, which also passes through the compression cylinder jacket, and thence through the steam surface condenser before being discharged overboard. The compressed air is further cooled and dried by passing it through a nest of tubes forming an apparatus termed a "drier."

This is so placed that the cool air from the cargo chambers circulates around these tubes before it enters the compression cylinder. A large proportion of the moisture still remaining in the compressed air is condensed in these tubes and is blown out through the drain cocks from time to time. The air still under compression, is then led to the expansion cylinder, its distribution in this cylinder being regulated by main and cut-off slide valves, similar to those used in an ordinary steam engine, and like the steam in a steam engine the compressed air does work on the piston and its temperature falls. An early cut off is necessary to obtain an exhaust pressure slightly above the atmospheric pressure. Any moisture that is still in the air by reason of the great fall in temperature is turned into ice or snow; the former may be deposited on the exhaust edges of the valve, and tend to lift the valve off the face. To obviate this the machine is stopped occasionally and the valve casing allowed to warm up. In some cases special appliances are fitted for occasionally thawing off by means of hot air, or steam passed through a coil. The very cold exhaust air is passed through a snow box, where the ice and snow are deposited. It is then led by suitable wooden trunks to the chambers containing the refrigerated cargo. The trunkways are usually fitted on each side of the chambers and are large enough to allow the passage of an attendant to regulate the slides or shutters which govern the circulation of the air amongst the cargo. These compressed air machines, although still in use in vessels of one of the largest steamship companies, are being rapidly supplanted by machines using chemical refrigerating substances. The chief reasons for the change is the fact that the low specific heat of air necessitates the compression of an enormous quantity in a given time to produce the required refrigeration. Greater power is therefore required and the coal consumption is correspondingly higher, being about four times that necessary with the best machines working on chemical systems. Another point which has to be considered is that this type of machine cannot be used while loading or discharging cargo ; also the air being circulated over and over again through the machine and amongst the cargo continually comes in contact with the inside of the air cylinders and valves, and meeting with the lubricants there, is apt to get contaminated, and thus to taint the cargo.

To set off against these disadvantages, the process is harmless, rapidly produces low temperature, while the working substance air costs nothing and is everywhere obtainable.

The most important mechanical points requiring attention with this type of machine are the clearances between the piston and covers at each end of the compression cylinders, which must be reduced to a minimum, so that little or no re-expansion of the compressed air occurs, and that the suction valves lift immediately the return stroke begins. The compression cylinder covers should be carefully jointed, so as to prevent any leakage between the water-jacket ports and the cylinder.

Air-expansion cylinder pistons and valves, especially the latter, require attention. Also the drain cocks on the air coolers and driers, already mentioned, require to be frequently opened to draw off any water condensed in cooling the compressed air, so as to obviate as much as possible the formation of ice or snow in the exhaust passages of the air-expansion cylinders.

Class B. When any substance changes from a solid to a liquid or from a liquid to a vapour or gas, heat has to be supplied. This heat is not sensible, that is to say, it cannot be measured by the thermometer, and is therefore called "latent heat."

The converse is likewise true, viz., when a gas is changed into a liquid or a liquid into a solid, the latent heat is given up. If we apply heat to a block of ice the temperature does not rise above the freezing point, 32° Fahr., until every particle of ice has become liquid, and similarly when water is heated in an open vessel over a fire to the boiling point the temperature remains at 212° Fahr ; and if heat is still added the water then commences to be converted into steam at atmospheric pressure, but both the steam and the water remain at the same temperature of 212° Fahr. unless the pressure is increased by closing the vessel, although the fire during the boiling process continues to give out its heat as before. This heat is in some way absorbed by the steam, but it is not sensible to the thermometer and is, as already stated, termed "latent heat" Yet it has been absolutely necessary for the conversion of the liquid water into the gaseous steam. When, however, the steam space is confined so that a pressure is generated, it is found that while the water and steam still each retain the same temperature as the other, this temperature is greater according as the pressure becomes increased. The increase of temperature nevertheless is trivial compared with the heat absorbed, and there is still a large quantity of latent heat to be applied to raise the water into steam of high pressure.

If we take a quantity of hot water which has been in contact with steam of say 250 lb. pressure, its temperature will be about 400° Fahr., but to retain it as water it has still to be kept under the same pressure. If the pressure be reduced to that of the atmosphere, its temperature will immediately fall to 212° Fahr., but a portion of the water will evaporate into steam. This portion of water will be such that its latent heat will be equal in amount to heat liberated by the fall of temperature of the whole mass from 400° Fahr. to 212° Fahr.

The same law applies to liquefiable gases such as carbonic anhydride (CO_2) and anhydrous ammonia (NH_3) which are

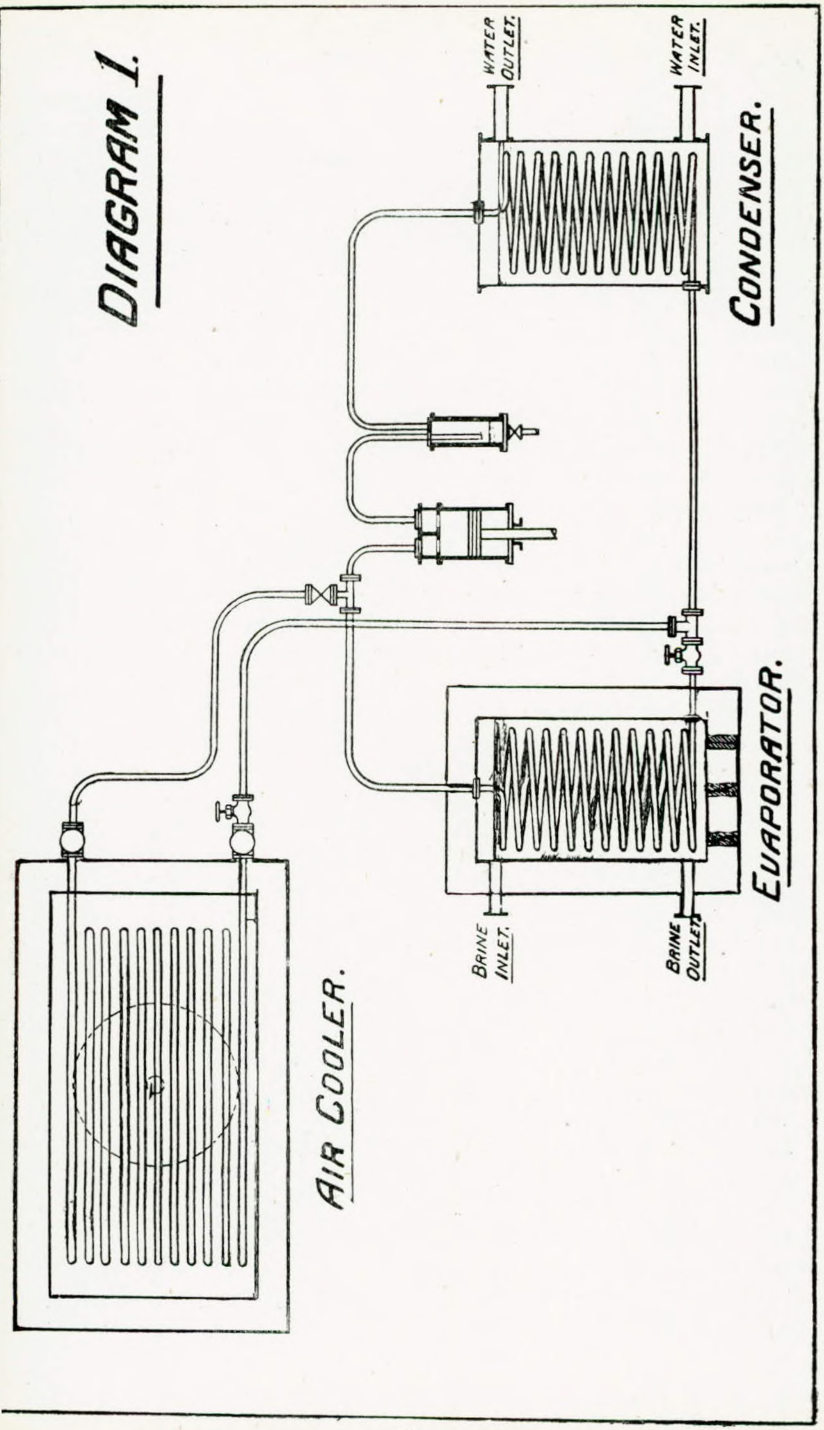


DIAGRAM 1.
CONDENSER.
WATER OUTLET.
WATER INLET.
EVAPORATOR.
BRINE INLET.
BRINE OUTLET.
AIR COOLER.

used in vapour compression machines on board ship. The cycle of operations in these vapour-compression machines in reality is the reverse action of the heat engine as exemplified in the ordinary reciprocating condensing steam engine.

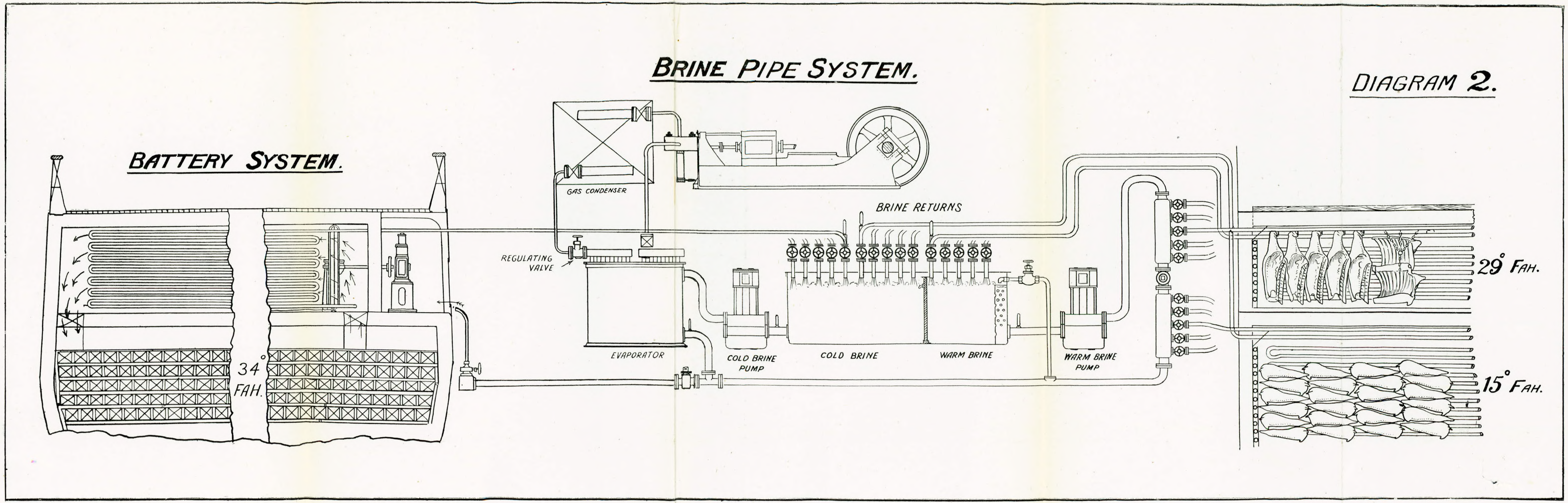
In a vapour-compression machine the medium enters the cylinders as vapour at the lower temperature, and by the expenditure of mechanical work it is raised to a higher temperature and a higher pressure, whilst in a heat engine the medium enters at the higher pressures and temperatures, transforms a certain amount of the heat into mechanical work, and is rejected at a lower temperature and lower pressure. With both these chemical refrigerants, viz. carbonic anhydride and ammonia, the change from liquid to gas is brought about without the aid of fire owing to these liquids having very low boiling points, viz. at atmospheric pressure. Carbonic anhydride (CO_2) boils at a temperature of about -110° Fahr. and anhydrous ammonia (NH_3) at -28° Fahr.; but all the same the change cannot take place without heat being applied, and it is the supplying of this heat from outside the machine which brings about the refrigerating effect.

If we confine either of these liquids, say ammonia, in a coil or coils—see elementary diagram I—and connect the coil to the suction side of the compression cylinder, and so reduce the pressure in the coil, evaporation of the liquid will proceed rapidly and along with it absorption of heat until a gauge pressure of about 10 lb. per square inch and a corresponding gas temperature of -10° Fahr. is reached. These figures are taken from actual practice. The heat which the ammonia absorbs is extracted from the coil and its surroundings, and if the coil is immersed in a tank—Diagram I—containing non-freezable brine (a solution of calcium chloride and fresh water), the temperature of the latter will be reduced to about 0° Fahr.

The refrigerated brine is pumped through a system of wrought-iron pipes suitably arranged, and distributed in sections along the ceilings and walls of the insulated holds. It is then returned to the tank at a temperature of about 8° Fahr. to be again cooled. To obtain this increase of temperature it has had to absorb heat from the cargo chambers, which have thus been correspondingly refrigerated.

This arrangement is known as the "brine-pipe cooling system"—Diagram II.

In an alternative arrangement the coil is placed in an in-


BRINE PIPE SYSTEM.
DIAGRAM 2.
BATTERY SYSTEM.
GAS CONDENSER
BRINE RETURNS
REGULATING VALVE
29° FAH.
34° FAH.
EVAPORATOR
COLD BRINE PUMP
COLD BRINE
WARM BRINE
WARM BRINE PUMP
15° FAH.

sulated chamber—Diagram II. The temperature of the air in this chamber is rapidly reduced by contact with the cold coil to about -4° Fahr. This cold air is then circulated by a fan through wooden trunkways placed along the centre and upper sides of the insulated holds, then through the cargo spaces, and is finally brought back to the coil chamber after abstracting sufficient heat from the hold to raise its temperature to about 12° Fahr.

This alternative arrangement is known as the "direct expansion air-cooling battery system."

We have dealt with the suction or evaporation side and now come to the delivery or compression side of the working cycle of these chemical systems. Here the reverse action takes place. The gas after returning from the coil is compressed in the compression cylinder to say about 95 lb. pressure per square inch and temperature of about 120° Fahr., and it is passed while at this pressure into the condenser coil, around which sea water is being constantly circulated. Here the gas is robbed of its latent heat by the water and it becomes liquid at a temperature of about 60° Fahr. It is then allowed to pass slowly through a regulating valve into the evaporator coil, when it loses its pressure and returns to the gaseous state, its heat becoming latent in the process, thus completing the working cycle of the system.

If CO_2 is the medium employed, the same principle applies, but the pressures and temperatures obtained are different owing to the different natures of the substances.

For every gas, however, there is a temperature above which no amount of pressure will liquefy the gas. This temperature is called the "Critical Point." The critical temperature of carbonic acid is only 88° Fahr., at which temperature it takes a pressure of 1,050 lb. per square inch to liquefy it, and above which it cannot be liquefied. The critical temperature of ammonia is 266° Fahr., and the corresponding pressure is 1,624 lb. per square inch. It is mainly due to the fact that the critical temperature of CO_2 is so low that it is considered to be a less useful refrigerant than ammonia under tropical conditions, when the available cooling water may be as high as 86° Fahr., at which temperature ammonia will readily liquefy at a pressure of about 170 lb. per square inch.

The latent heat of vaporization of carbonic acid varies considerably with its pressure and sensible temperature. The higher the temperature the lower the latent heat, varying from about 122 B.T.U. at a temperature of $-10°$ Fahr. to about 27 B.T.U. at 86° Fahr. The latent heat of ammonia varies from about 580 B.T.U. at $-10°$ Fahr. to 492 B.T.U. at 86° Fahr.

Comparing these two substances, whilst liquid carbonic acid has a much lower latent heat of varporization, a far greater weight of refrigerant is present in a given volume, and this outweighs the inferiority in latent heat. A cubic foot of carbonic acid gas at a temperature of $-10°$ Fahr. weighs about 2·75 lb. as against 0·1107lb. in the case of ammonia at the same temperature. And this admits of a much smaller compressor being used with the carbonic acid. The relative volume for equal refrigeration being about $\frac{3}{23}$, that is an ammonia compressor must have about seven times the volume required for a carbonic acid machine of the same refrigerating power.

In the carbonic acid compression process there is practically only one type of machine employed in the larger installations.

The very high pressure of the gas, as before alluded to, requires the machinery to be unusually strong. This particularly applies to the compressors, which are bored out of a solid forged ingot of steel. The piston is of special design and in most cases is packed with two cup leathers, in others metallic rings are used. The piston rod is also packed with cup leathers, a lantern bush forming a space between the leathers, into which special lubricating oil is continuously forced by means of an automatic pump fitted with a differential piston, on the smaller side of which is the lubricant while the larger side is exposed to the full pressure of the gas. This arrangement maintains a pressure in the stuffing-box greater than that of the gas in the compressor, so that no leakage of gas past the gland is possible.

The high pressures required in the carbonic anhydride compression process render a safety valve desirable; this is fitted on the delivery side of the compressor to provide against the possible starting of the machine with the delivery shut-down valves closed. It consists of a conical valve held on its seat by a strong spring. In addition a thin copper disc is fitted at the base of the valve; this is designed to burst when subjected to an excessive pressure considerably below that to which the machines are tested, and then allows the safety valve to come into action.

In this way a serious loss of gas in ordinary working conditions is avoided, in case of any slight continuous leakage from the safety valve.

The machines are usually constructed of the "duplex type." A pair of double-acting compressors are set horizontally, each in tandem with one of the cylinders of a compound steam engine.

The whole is fitted on a cast-iron base, which contains the steam surface condenser, and in some cases the gas condenser also. The air-circulating and feed pumps are worked off the crank shaft. Each compressor has its own strainer and separator, fitted respectively on the suction and delivery sides. The former intercepts any dirt which may be carried over from the system, and the latter intercepts the oil which in small quantities is continually being carried in from the stuffing-box, which, if allowed to pass into the coils of the condenser and evaporator, would, by coating the inside of the coils, reduce the cooling efficiency considerably.

Each compressor has also its own separate condenser and evaporator, these being interchangeable.

The condenser consists of a number of coils of copper pipes of heavy gauge, usually mounted in a rectangular cast-iron casing; the ends of each coil are connected top and bottom to headers, which are made of forged steel.

The evaporator consists of a number of coils of wrought-iron pipes, mounted in an insulated circular steel casing, wherein "brine" at a density of $12\frac{1}{2}$ lb. per gallon is circulated. This is reduced to a very low temperature by the expansion of the carbonic anhydride in the evaporators. The brine is then circulated by special duplex pumps through a system of pipes, which are fixed to the under sides of the deck, and partly down the sides and bulkheads of the chambers, in which are carried either frozen or chilled cargoes.

The problem of the circulation of the brine at the precise temperature required for the successful carriage of chilled meat, has introduced into the vessels engaged in this trade a number of new arrangements of refrigerating plant, designed to ensure the greatest practicable measure of success.

The brine supply to the chilled chambers must be capable of easy and accurate adjustment, not only in quantity but more particularly in temperature.

The cooling surfaces must be very large and well distributed in each chamber to ensure an even temperature. The quantity of brine circulated must be such that a very small difference in temperature between the outgoing and returning brine is registered.

Two main systems are now in use. These differ in detail and are known respectively as the "open" and the "closed" cycles.

In both systems the brine when it comes back from the cargo chambers has a small quantity of very cold brine direct from the evaporator added to it, so as to bring the temperature of the mixture to the precise point required, an equal volume of the circulating brine being automatically taken out of the circuit by an overflow and added to that which passes through the coolers.

In the "open" cycle—Diagram II—the returns from each separate circuit are visible. It can be seen whether the full quantity of brine is flowing in each section, and the temperatures can be determined promptly, so that some idea is obtained in the brine return tank room as to the state of affairs in the cargo chambers.

A well-known firm has adopted in their "closed" cycle plant a patent system of attemperating brine distribution.

The main feature of the system is the attemporator valve, by means of which the whole brine supply to the chill chambers is under control, and its temperature may be raised or lowered at will by the turning of a hand wheel—see Diagram III.

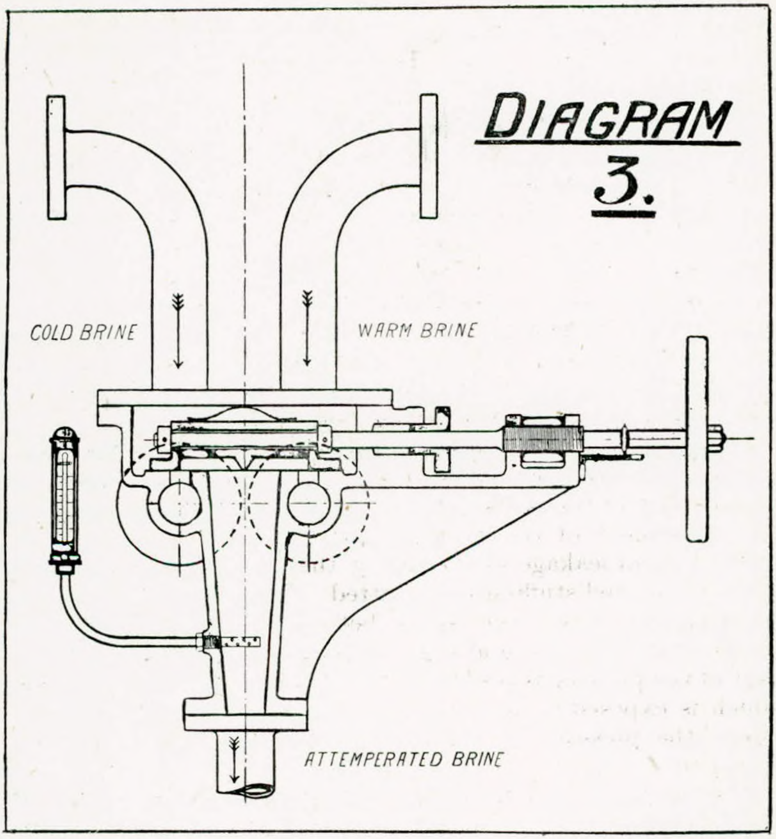
In the "closed" cycle the return brine is not visible, but appliances are fitted in some vessels to determine, by means of the brine pressures, whether the full or a sufficient quantity is passing through the various sections to regulate the temperature of the different parts of the chambers.

In addition to these methods, however, in some vessels carrying fruit, special appliances are fitted for dealing with such compartments as contain cargoes requiring only moderate temperatures. These consist of a number of coils of wrought-iron pipes stacked in an insulated chamber.

The air is circulated by a fan over coils which are cooled by brine circulated through the coils, instead of by direct expansion of the gas into the coils as has already been referred to.

The carbonic anhydride compression process has its advantages and disadvantages.

1. The machine can be placed in the main engine-room, or at any distance from the insulated cargo chambers.



2. The escape of gas in the engine-room is unaccompanied by any dangerous results, unless the escape is of abnormal magnitude.

3. The brine system being only employed, the brine controlling valves for regulating the temperatures in the chambers can be fitted close to the machine, and are therefore under the immediate supervision of the engineer in charge.

4. Any damage sustained to cargo in one chamber does not affect that in the others.

5. The gas being chemically inert towards all ordinary metals, copper or any of its alloys can be used for any parts of the machinery acted upon by the gas.

The chief disadvantages are—

1. The gas being inodorous, leakages are not easily detected.

2. Brine leakages in the chambers are inaccessible when full of cargo.

3. A quantity of snow or frost is desposited on the brine pipes, and when thawed off after discharging cargo, is apt to damage the insulation unless great care is taken.

4. Excessively high pressures are required for its liquefaction, and the critical temperature of the gas being about 88° Fahr. its efficiency is affected when used in the tropics.

There are several types of machines working on the anhydrous ammonia compression process, the chief difference between them being in the design of the compressor. In large installations some are of the single-acting compound type and others of the double-acting non-compound type.

In both types the covers and valves at the ends of the compressors are arranged so as to have a minimum of clearance at each end of the stroke of the piston; this necessitates careful adjustment of the working parts.

To prevent leakage of the gas at the piston-rod end, a specially constructed stuffing-box is fitted. The packing is divided by a lantern bush, the space between being connected to the suction side, hence any gas which leaks through the inner part of the packing is prevented from passing the outer packing, which is exposed to no more pressure than the difference between the pressure on the suction side and that of the atmosphere.

The motive power is usually a horizontal steam engine of the compound type; in some large installations a triple expansion engine is employed, each cylinder having a horizontal double-acting compressor set in tandem to it, the whole being fitted upon a cast-iron or wrought-steel base, which contains the gas condenser iron coils. In some cases, however, separate condensers are used. The ends of the coils are connected top and bottom to headers. These, together with the evaporators and their connexions, are similar in every respect to those already described as being fitted to the carbonic anhydride machines, using brine as the cooling medium.

As in the case of the latter machines an oil separator is fitted between the compressors and the condensers; this is one of the most important parts in the working cycle of the system requiring continuous attention. The separator is fitted with an arrangement whereby the intercepted oil can be passed into another vessel called a rectifier, from which it must be drawn from time to time, and it can then be filtered for further use.

For transmitting the cold produced by the ammonia machines employed on the vessels engaged in the Colonial trade the direct expansion system is mostly employed, which has already been described.

The following may be considered some of the advantages and disadvantages of the ammonia compression process :—

1. The gas is a powerful refrigerant and is easily liquefied at moderate pressures even under tropical conditions of the cooling water.

2. Leakages are easily discovered where the parts are exposed.

3. This process can be used either for the direct expansion or brine-cooling systems.

On the other hand :—

1. Ammonia is extremely poisonous, a slight leakage being sufficient to prevent any one remaining in the engine-room.

2. If any leakage occurred in the air-cooling room, the cargo would be tainted.

3. Ammonia having great affinity for copper, no such material, nor any of its alloys can be employed in parts of these machines acted upon by the gas.

4. The advantages and disadvantages of the brine-pipe system apply to the ammonia, as well as to the carbonic anhydride compression processes.

Reverting to the mechanism of both types of these vapour compression machines, it is to be observed that before the carbonic acid machines are constructed and leave the makers' works, every part which is subject to the pressure of the gas, is first tested for strength to 3,000 lb. per square inch by hydraulic pressure, and then again tested when submerged in a tank of water at 90° Fahr. under compressed air at about 1,500 lb. per square inch pressure, when any porosity would be indicated by bubbles.

In the case of the ammonia machines, the compressors and their connexions, which are made of cast-iron, are tested to 700 lb., and the condenser and evaporator coils, which are made of wrought-iron, to 2,000 lb. per square inch by hydraulic pressure.

The coils are again tested when submerged in a tank of water under compressed air at about 600 lb. pressure per square inch.

Taking all the factors into consideration the choice between these vapour compression machines is a difficult problem, especially in connexion with marine installations.

Refrigerating machines are rated by the number of tons of ice per day of twenty-four hours they are capable of producing, but as this factor depends very much on the arrangement of the ice-producing apparatus, initial temperature of the water to be frozen, the thickness of ice required, proportion of losses through conduction, etc., it is more correct and more convenient to make the unit of their refrigerating capacity equal to the thermal units absorbed in the *melting* of one ton of ice from and at 32° Fahr., the latent heat of ice being 142 B.T.Us. the equivalent of one ton of ice melted will be 318,000 B.T.Us. This is the basis on which machines are rated, and is called their refrigerating capacity. It is, however, a common and fairly approximate rule to estimate the ice-*making* capacity in tons per day as half the ice-melting or refrigerating capacity.

It is not thought to be necessary to refer to the manner of working any of the machines referred to in this paper, as instructions are issued by the various makers for the guidance of those in charge.

At the same time it may be repeated that it is imperative in order to obtain a high degree of efficiency, that the systems be kept as far as practicable, clean and free from foreign matter, and special qualifications are required of the engineers attending them. They must not only be careful and skilful in order to keep the mechanism in good working condition, but they must be thoroughly conversant with the principles involved in the refrigeration process, observant to promptly recognize any slight defect or falling off in the performance of the machinery, skilful to trace it to its cause, and above all resourceful to promptly and efficiently remedy any and every defect after diagnosing its cause.

It must be remembered that deterioration of a very valuable cargo commences directly there is any irregularity in the maintenance of the proper temperature.

Time will not permit of many other points connected with the subject of refrigeration to be touched upon.

With regard to insulation this in itself would involve a paper of great length. Briefly, its object is to prevent heat passing from the outside atmosphere into the refrigerated chambers, and the more perfect it is, the less work has to be done by the refrigerating machinery.

On the other hand, if it is defective or originally insufficient in thickness, more refrigerating power is needed to maintain a low temperature of chamber.

A powerful plant with poor insulation may therefore be as efficient as a smaller refrigerator combined with a better insulation, but it will be more costly to work.