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Refrigerating Installations, with Special Reference to the Arrangements necessary when Narrow Limits of Temperature are Required.

BY MR. ROBERT BALFOUR (MEMBER).

READ

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CHAIRMAN: MR. F. D. GREEN (MANAGER, ORIENT S.N. CO.).

MR. J. T. MILTON (Chairman of Council): Gentlemen, Sir John Durston has written expressing regret at not being able to be with us to-day, and Mr. Adamson, our Hon. Secretary, has also sent a note regretting his inability to be present. You will be very sorry to hear that the High Commissioner for New Zealand, the Hon. Wm. Hall-Jones, has been prevented from coming to take the Chair at our meeting this afternoon through having received an injury to his knee, but I am pleased to say that Mr. Green, the Manager of the Orient Company, at considerable personal sacrifice, has consented to preside.

MR. F. D. GREEN: It gives me great pleasure to take the Chair here this afternoon. It is said that comparisons are always odious, but I am privileged this afternoon to be comparative without being odious. The Hon. Mr. Hall-Jones, who should have presided here this afternoon, is far more capable of being your Chairman than myself, but I regret to say, as Mr. Milton has already said, he has met with an accident and has thus been prevented from coming ; I understand, however, that nothing short of this would have prevented him from taking the Chair this afternoon. We are met to discuss the important matter of "Refrigerating Installations, with special reference to the arrangements necessary when narrow limits of temperature are required." There is nothing new in the process of refrigeration ; M. Carré in 1860 first used the ammonia method, and in 1862 a Mr. Kirk patented the cold air process. In 1879 the Orient Co., with which I am connected, built a ship to carry frozen meat from Australia, and since then we and others have carried, not only meat, but butter and fruit, all over the world. On one occasion we carried live fish from England to Australia, the fish not suffering in any way, and the same temperature was maintained throughout the voyage, so you will understand that Mr. Balfour, as senior surveyor in the refrigerating department of Lloyd's Register of Shipping, has some data on which to base his conclusions. Mr. Balfour takes a very keen interest indeed in refrigeration, and, as you know without any intimation from me, he has already read two papers on the subject before the Institute of Marine Engineers. This paper, which he is about to read to you, I had the pleasure of reading myself last night, and I may tell you, as a shipowner, it was rather startling to me. I thought we merely had to keep the temperature in our holds down, and there would be no life whatever within them ; but he now says there are certain species of germ life there which enjoy these temperatures. I do not know what the shippers will do, but I am afraid they will be finding out these germs, and say we are cultivating them. I will now ask Mr. Balfour to read his paper.

It is with a certain amount of diffidence that this paper is presented, being, as I am, fully cognizant of the fact that other Members of this Institute have as wide an acquaintance with the subject, and some, doubtless, a far more extensive experience, than I have in the particular branch of refrigeration with which I propose to deal.

Having had, however, for some years past the special privilege of inspecting a majority of the vessels which are engaged in the carriage of refrigerated cargoes trading to this country, I purpose on this occasion to bring under notice a few points in connexion with the carriage of commodities which require to be subjected to the influence of what may be called a moderate rather than a low temperature to ensure their preservation in good condition, and it is hoped that the ventilation of the subject by the subsequent discussion will prove mutually beneficial.

A reference to the Register Book of Lloyd's Register of British and Foreign Shipping will show that there are large numbers of steamers engaged in the carriage of refrigerated cargoes from Australia, New Zealand and South America. It is usual to denote their carrying capacity by the number of carcases of mutton they can bring; some of the individual vessels can carry as many as 150,000 carcases.

Mutton, however, which is always carried in a frozen condition, is not the only commodity these vessels bring to this country, as large quantities of beef, rabbits, butter, etc., are also brought over frozen, and in addition a very considerable and increasing quantity of beef is brought from Argentina under what is known as "chilled" conditions.

Considerable development has undoubtedly taken place during the last eight years in connexion with this special industry, as is shown by the figures quoted below, which give the amount of chilled beef imported into the United Kingdom from the River Plate alone, between the years 1901 and 1908 inclusive.

The following figures are taken from the *Reviews of the Trade*, published by Messrs. Weddel & Co. :—

1901.	Chilled Beef.	24,919	quarters.
1902.	,,	94,498	,,
1903.	,,	142,542	,,
1904.	,,	198,300	,,
1905.	,,	402,195	,,
1906.	,,	454,613	,,
1907.	,,	427,042	,,
1908.	,,	766,284	,,

These figures practically cover the period from the outbreak of foot and mouth disease in the Argentine, and the consequent closing of the English ports to live stock from the River Plate.

Chilled beef had, of course, been imported from the United

States of America for many years previous to 1901, but under entirely different conditions of carriage.

It may be mentioned that up to the present the attempts to carry chilled beef from the Australian and New Zealand Colonies have met with but little success; consequently, the experiment which is now being made to bring a large consignment from Queensland is being anxiously looked forward to. In connexion with this it may be mentioned that a very experienced engineer has been specially selected to take charge of this cargo from the initial stage until its delivery in this country, so that if failure occurs, it will not be owing to lack of skill or to want of attention to the minutiæ of detail necessary for success.

At the present time there is a still further development of this particular industry, arrangements being made for much larger cargoes being carried in individual ships.

It is mainly to the necessary conditions for the successful carriage of "chilled" beef that this paper is devoted, although when dealing with the purely mechanical part of the subject the principles involved in maintaining a practically uniform temperature in large compartments for long periods will be seen to be applicable to the carriage of some fruits, cheese, etc., which also require to be held during the voyage at a definite temperature with no appreciable variation.

Refrigerated cargoes of all kinds are subjected to numerous risks beyond the ordinary perils of the sea. These have been well dealt with by Mr. W. Lund in a paper prepared for the recent International Congrès du Froid. How real some of these risks appertaining to "chilled" beef are, and what is done to meet them, this paper is intended to demonstrate.

Mr. Lund shows that incessant care is required from the moment the live animal leaves its pasturage, through the time when it is conveyed to the abattoir, in the process of slaughtering, preparation and cooling of the carcase, loading into the vessel, transit over seas, unloading from the vessel, during marketing and right up to the time when it arrives at the retailer's shop, and that failure at any one of these numerous stages may have serious consequences which, although not apparent at the time, will show themselves at a later stage.

In order to clearly appreciate why it is that *cold* is preservative of fresh meat we must first determine what it is that leads to the putrefaction or decay of meat under ordinary conditions. There is now no doubt that the changes which take place in lean flesh are due mainly, if not entirely, to two specifically distinct sets of conditions, viz., the action of bacteria or fungi, and that of enzymes. Of these the best known is that of bacteria and moulds or fungi, organisms which under suitable conditions live upon the tissue of the meat, and which develop with extreme rapidity when the surroundings are favourable. "Enzymes" is the name given to certain ferments or active principles which have the power of modifying organic substances, by either breaking them down into more simple substances, or by changing them in some way from their original form.

The gastric juice of the stomach and the pancreatic juice of the spleen are examples of enzymes at work in aiding digestion, etc., in animal bodies, and certain changes which take place in flesh of dead animals when neither bacteria nor moulds are present, are considered to be due to the actions of enzymes, of which there are several distinct sorts.

There is no doubt that for each sort of enzyme and for each variety of mould and bacteria there are certain conditions under which it develops and acts with the greatest activity, and other conditions under which it either acts very slowly, becomes altogether dormant, or even dies. Experience shows that mutton and some other commodities can be held for many months when frozen hard without any appreciable change due either to bacteria moulds or enzymes, and also shows that under certain conditions beef also can be held for several weeks when kept at a temperature of 29½° F. without appreciably losing its freshness, flavour, or other qualities.

Much information upon these matters is contained in the invaluable papers contributed to the Congrès du Froid by Drs. Pennington and Richardson, of the United States of America, by Dr. Rideal and Mr. Tabor, of London, and I shall quote from these authorities matters which ought to be appreciated by all those interested in the question of "chilled" beef.

First as to the effect of cold upon the enzymes found in the meat. Dr. Richardson says: "Beef juice is a liquid containing several salts and other substances in solution. When its temperature is lowered continuously below 32° F.

it is found that a small quantity of ice crystals separate out at 31° F. As the temperature becomes lower more ice separates and the remainder of the juice becomes more concentrated; at a temperature of 16° F. the juice becomes mainly ice crystals mixed with a gummy viscous concentrate. At somewhere about −22° F. this freezes solid. This point, where complete glaciation takes place, is called the cryohydric point." He considers from theoretical grounds that bacterial growth and probably enzyme action both cease at this temperature. Dr. Pennington states that at 14° F. enzymes are still able to function though their action is greatly retarded. Dr. Richardson, however, states that his analyses show that peptonizing enzymes are not active at ordinary freezing temperatures (in his experiments 16° F. to 11° F.). From these statements it would appear that some change may be expected to take place with the lapse of time even when the ordinary refrigerating conditions prevail, and we must attribute to the enzymes the changes, other than dessication, which take place in chilled meat under conditions of complete sterilization when neither bacteria nor moulds are present.

When we come to consider bacteria scientists recognize an immense number of kinds, some harmful, others the reverse, but all necessarily effecting changes in the structure or composition of the pabulum upon which they live. Most of them thrive best at ordinary temperatures, but some of them appear to require low temperatures. Dr. Collingridge, the Medical Officer of Health of the City of London, says in his last report: "Hitherto it has been commonly believed that the freezing of meat properly carried out will ensure its preservation for an indefinite period, disregarding altogether the fact, now well established, that there is a distinct class of bacteria which live and flourish at the low temperatures of the freezing chamber."

Dr. Pennington makes the following statements:—"Organisms have been found in Norwegian glaciers, and they develop rapidly at the freezing point.

"We now recognize a group of organisms which because of their ability to flourish at temperatures that but a short time ago were considered to be prohibitive to life process, have been called 'rhigophile' bacteria. These organisms are found to be widely distributed and of common occurrence in milk, flesh, and spring water.

"These low temperature organisms are found to inhabit slaughterhouses and cooling-rooms and to infect flesh hung in them with a consequent production of flavour in the meat.

"Milk maintained at 29° F., which is sufficiently cold to cause a mass of ice crystals to form, not only fails to kill organisms, but permits a fairly rapid development of bacteria. Even at 2° F. to − 9° F. there has been observed a certain amount of growth in frozen cream.

"If organisms are provided with their natural environment they will multiply when the medium is in a frozen condition."

Dr. Rideal, speaking of the fungus of "brown spot" on chilled beef, says: "It does not grow at blood heat, but grows at ordinary temperatures and as low as 28° F., but at 16° F. there is no growth of this fungus."

Dr. Richardson, however, seems not to hold quite the same opinions as the before-mentioned authorities as regards the growth of bacteria at low temperatures. He says, as before quoted, that "bacterial growth ceases at the cryohydric point of beef juice"; also that "in a solid rigid medium, growth and reproduction of living things become impossible," and that "the fact should be emphasized that it is the solid state of the medium and not any specific temperature which is the limiting condition for growth and reproduction, although retardation of growth ensues with lowering of temperature."

Even if there is some doubt as to the growth of bacteria upon absolutely solidly frozen meat, it will be seen that there is none whatever as to the possibility of both growth and reproduction at the "chilled" temperature at which the beef is not at all frozen; all the authorities being agreed on this point.

It is also important to note that although low temperatures may prevent growth, they do not destroy vitality, and that when the temperature becomes suitable, growth and reproduction again become active. On this point we have the following evidence.

Dr. Rideal states that Pictet and Young cooled some species of bacteria down to −202° F., the entire duration of the test being forty hours, after which growth was recovered on thawing; also that Macfadyen and Rowland subjected a number of varieties of bacteria to −421° F. for six hours without killing them, and subsequently several species to the temperature of liquid air for six hours without impairing their vitality.

Dr. Pennington also quotes Macfadyen, that some bacteria are still capable of reproducing and carrying out a complete life cycle after being maintained for days at temperatures as low as $-310°$ F.; also when speaking of an experiment made after seventeen months' cold storage in a frozen condition, says: "It is a proof of the fact that organisms can survive for long periods at temperatures far below the congealing point, and that growth is prompt and vigorous when a suitable environment is provided." Again: "Though the multiplication of bacteria at low temperature is still in some respects an open question, their vitality for at least four years at 14° F. is a fixed fact."

Mr. Tabor evidently considers that as regards moulds, the sporangia of which are ever present in the air, changes of temperature facilitate their growth. He says: "A rise of temperature, even when the rise has not reached the freezing point, undoubtedly facilitates the growth of mould, and fluctuations well within the limit of 32° F. are generally productive of damage by mould and afterwards most certainly of considerable growth of fungi, even if the temperature be reduced to the former level." And again: "It is useless to talk of the advisability of lowering the temperature of the chambers. These low organisms once started will grow at a temperature even so low as to be fatal to the goods."

In face of this array of evidence of the undoubted risks in holding chilled beef even when the temperature is correctly kept at the proper limits 29½ to 30½° F., it may be wondered at that any cargoes ever get satisfactorily delivered, and the fact that they are so delivered speaks volumes for the care with which all the necessary conditions have been recognized and provided for.

There is another point to which Dr. Collingridge draws attention in the report already quoted, viz., that of the condition or quality of the beef itself. He says, speaking of the chilled beef imported during the year: "Much of the beef has been better made up for slaughter, and it is most interesting to note that if a cargo is out of condition it is generally a poor lot of beef; if a few quarters amongst a lot are out of condition, those are almost invariably the weakest and thinnest; hence it seems fair to argue that if the beef is to arrive in good condition it must be beef not lacking in substance to begin with."

Dr. Pennington's remarks as to the organisms found in slaughterhouses and cooling-rooms point to the imperative necessity of cleanliness in the abattoirs and freezing and storage chambers, even if they do not call for absolute sterilization of these places and of the wrappers with which the meat is covered.

Regarding sterilization Dr. Collingridge says: "Some reference was made last year to the Linley System of preserving beef in sterilized air. Several vessels have been fitted up with the necessary apparatus, and whenever it has been properly selected and well handled it has arrived in a condition which argues that the system has many advantages, but whenever beef of indifferent quality has been shipped it is too much to expect that any method of preservation will make it into desirable meat."

In the Linley System the chilling chambers at the works are sterilized by Formaldehyde vapour as also are the refrigerated holds before loading is commenced, and the air in them is sterilized immediately after loading is completed. Afterwards the air, which is kept circulating by mechanical means, is regularly passed over prepared surfaces to keep it dry and sterile.

Dr. Rideal in his paper mentions another system, that of Messrs. Houlder Bros. & Anderson, in which the chambers are also sterilized before loading. After loading the air is renewed every eight hours by means of an exhaust fan, whilst at the same time fresh air cooled to the proper temperature is supplied. This system required great care in the admission of the fresh air owing to the varying temperature of the outside atmosphere. Although some very successful voyages were made in cases where it was adopted, it is understood that the system has now been abandoned.

This appears to be the proper place to mention that to a large extent the success which has been attained in the Refrigerating industry of the world is largely due to the seagoing engineer. He has been from the commencement, and is to-day, intimately connected with its development at practically every stage, and the most successful engineers now engaged on shore in the industry have obtained their skill and experience on board the vessels which are not only carriers but also immense store houses during the time of their voyages through tropical climates.

In the first place, to ensure success the meat must be properly prepared for shipment, and for this, the works, which necessarily are usually in outlying districts, must not be liable to any stoppage whatever; they should therefore be so equipped with tools and appliances as to render it possible for any breakdown of the refrigerating machinery which may occur to be promptly dealt with by their own staff, which should include, besides a very experienced chief engineer, two or three skilled assistants who ordinarily keep watch and watch about, to all intents and purposes as on board ship. The necessary resourcefulness and experience for dealing promptly with emergencies appears best to be obtained by service at sea.

Most meat works are well equipped, and in some places even the necessary plant has been supplied to enable satisfactory castings to be turned out.

The process of preparing chilled beef is as follows, after the animals are killed and dressed:—

The meat is hung in a cooled space (having been run along overhead rails from the slaughterhouse) for several hours, so as to accumulate a sufficient number of carcases to fill a chilling-room.

When the chilling room is filled the doors are closed and the cooling started, and in order to abstract the animal heat gradually from the carcase, the meat is allowed to remain in the chilling-room for as near as possible twenty-four hours, the air temperature being kept at not less than 31° F. Then follows the cutting of the sides into fore and hind quarters. A selection is then made, the best only being kept for "chilled" meat. Most of the fore quarters and the unselected hinds are then put into a freezing-room and frozen hard. Those selected for chilling are put into a refrigerated store, or deposit, and held with an air temperature about 31° F. until required for shipment. At first, owing to the thickness, there is still some heat left in the heart of the meat, and this is gradually removed in the cooling store without the temperature of any part of the meat being allowed to fall below 30° F.

The beef must never be subjected to frost, i.e. no part of the moisture in it should ever be solidified. Should this occur even to a slight degree, the structure of the meat is burst or broken, and on regaining the thawing temperature the meat juice will not again absorb the now thawed ice, the meat itself will present a flabby appearance, and the moisture will run freely from the cut surfaces, with the result that the meat although perfectly wholesome has much depreciated in value.

As examples of the difficulties in dealing with chilled beef it may be stated that the animals must not be excited or harried immediately preceding slaughter so as to put them in even a slightly feverish condition, or should their joints be sprained or dislocated through slipping whilst being driven into the stockyard, local inflammation is likely to result, and the joint oil or lubricant will in consequence become decomposed. In either case it is found that the keeping qualities of the beef are much restricted, as they are also when the weather conditions existing at the time of slaughter are thundery or sultry, or when the atmosphere is heavily charged with moisture.

From what has been said as to bacteria and moulds it is easily realized that difficulties have to be contended with owing to the atmospheric conditions and surroundings of the meat works where large numbers of animals are collected for slaughter (a stockyard being a place which must under any condition be simply teeming with organic matter).

In addition to this there is to be considered the condition of the men, their clothing, and the implements used, none of which are sterile ; also on the hide being removed whilst the animal heat still remains in the carcase, the warm moist flesh is particularly susceptible to the action of any germs which may settle on it. In short, it would appear that the ideal slaughterhouse should be as regards sterilization on a par with the operating theatre of a modern hospital. This of course is practically impossible, but various systems for sterilizing the surfaces of the meat have been attempted with oxygen, carbonic acid, chloroform, ozone, etc. All these, however, have failed to be a commercial success, notwithstanding the good results attained in what may be termed laboratory experiments. Probably because sterilization is not generally employed where it would be most useful, viz., in the works, and possibly also of the fair measure of success which has been obtained without it, the majority of the Shipping companies engaged in carrying this special commodity are content to adhere to the ordinary methods of cleansing the chambers before receiving the cargoes.

In handling chilled beef critical stages occur during the transit of the meat from the works to the ship, and from the ship to the shore. This is in some cases effected by means of trucks or barges, and whilst the meat is being loaded therein it is often exposed to the warm and moist air for a considerable length of time. It may, however, be mentioned that in the River Plate some of the barges are fitted with refrigerating appliances which minimize the risks involved at this stage.

It sometimes happens that a consignment in itself is not of sufficient quantity to completely fill the insulated space in which it is placed ; this involves the reopening of the chamber to receive another parcel, which may be at a comparatively higher temperature than the first, and also the entry of warm air into the chamber, the moisture in which will be deposited upon the colder surfaces of the first consignment of beef, and mould may then be looked for at a later period.

We will now consider the mechanical side of the question, viz., how the necessary uniformly low temperature is maintained.

In the early stages of carriage of chilled beef from the United States of America the cooling was effected by the use of ice and salt. This frigorific mixture was pumped through galvanized pipes arranged along the sides of the cargo chambers, and after parting with its "cold" was discharged overboard. The insulation and the provision for hanging the meat in the chambers were of the crudest type.

Later another and better method was adopted for keeping the necessary low temperature in the chambers, and special regard was paid to the value of insulation. Ice and salt were also used as in the former case, but instead of the mixture being circulated through pipes, flat tanks were fitted at intervals around the chamber, and these were kept charged with the crushed ice and salt by an attendant during the voyage. The meat was hung on bars supported by coach screws secured to wood grounds bolted to the deck beams. These installations were in some degree successful on short voyages, but the waste of space owing to the necessity of carrying large quantities of salt and ice was very great, and the method was certainly inferior to those now adopted where the cold is produced by refrigerating machinery, and distributed by the brine circulating system, which has permitted the successful carriage of chilled beef from the more distant ports of South America.

The refrigerating appliances mostly in use for this special trade have the machinery constructed either on the Carbonic Anhydride or on the Ammonia Compression system, with the distribution of cold effected by the circulation of brine through numerous grids fixed under the overheading and along the sides of the insulated chambers. As the vessels have to carry either frozen or chilled meat, according to the cargo offering, the appliances have to be arranged suitable for either. Generally when "chilled" meat is being carried in some compartments frozen produce is at the same time being carried in some other parts of the vessel.

In the older vessels this was satisfactorily accomplished by setting apart one or more machines to work exclusively on the chilled chambers, and others working exclusively on the frozen chambers. The control of each set of chambers was therefore independent, and the adjustment of the temperature of the "chilled" compartment was effected by regulating the flow of brine through the system of piping in it. This was found to be difficult. It did not lend itself to a quick and accurate adjustment of the brine temperatures. It was attempted to regulate the cargo compartment temperatures by controlling the quantity of brine flowing through the various grids. The objections were so serious that the present system, to be afterwards described, was introduced, and this is found to leave but little further to be desired.

When the cargo is once properly stowed and the hold cooled uniformly to the desired temperature, all that the refrigerating appliances have to do is to maintain the condition by abstracting the heat which flows into the spaces from the outside and the small quantity of heat which still remains in the thickest part of the meat forming the cargo. Heat under ordinary conditions flows in gradually all over the whole of the surface of the insulation, so that an ideal construction would be for the grids to be uniformly spread all over the insulation, and they should be kept uniformly at a temperature a little below that of the compartment so as to neutralize the heat travelling through the insulation, but they should not be so cold as to appreciably lower the temperature of the air in the hold. These ideal conditions cannot be met, but an approximation to same can be made. The portion of the grid where the brine enters is at the temperature of the incoming brine. At the exit the grid is warmer by the amount of heat extracted by the brine in its circuit. If the quantity of brine circulated is small, the abstraction of a definite amount of heat raises its temperature more than will be the case where the quantity circulated is larger. What is done, therefore, is not that which was attempted in the older installations, viz. :—to regulate the quantity of flow of cold brine to suit the conditions of heat abstraction, but to circulate continuously through all the grids the maximum quantity of brine, and to carefully adjust the temperature of this brine to the precise degree which is found to exactly meet the requirements. The brine inlets and outlets in the chambers should be widely distributed in order to avoid concentration of low and high temperatures.

There are no grids fitted on the bottoms of the chambers, yet some heat enters them from these surfaces. This necessarily warms the air in contact. The warm air, being lighter, rises, the air cooled by the overhead grids is heavier and falls, and thus the difference in temperature between the grids and the bottom insulation produces continuous convection currents which provide the air circulation necessary for keeping the cargo in condition.

Now the expansion of air is only $\frac{1}{492}$ of its bulk for each rise of 1° F. in temperature. It is therefore seen what a small motive power there is to induce these convection currents if the particles of air as they leave the grids are only 1° F. colder than the warmer particles leaving the surface of the insulation. However, where the depth of the compartments is moderate, as it is in most 'tween decks, and where the cargo is so packed as to afford plenty of air spaces round each quarter, experience shows that a sufficient circulation can be obtained. Now that much greater depths of spaces are being utilized, carrying three or four tiers of quarters against the one or two tiers previously carried, it is probable either that more difference of temperatures will have to be made use of, or else mechanical means of air circulation employed.

Further, as it is necessary that the air cooling should not permit of small streams of air cooler than 29½° F. falling on any part of the beef in case of local frost, it will be seen that the grids themselves must not be kept at much lower temperatures than this, and as the cooling effect of any surface increases rapidly with differences of temperature and conversely decreases rapidly as the differences of temperature decrease, it is evident that a much larger cooling surface must be provided for "chilled" than for "frozen" conditions even although less total heat has to be extracted.

With regard to the natural or convection circulation amongst the cargo, too much consideration cannot be given to the methods of stowing the cargo. "Chilled" meat is "hung." Each quarter should have a free air space all round it. Hinds present no difficulty on account of their shape. Each quarter is separately hung from a hook in the hock. Even when they are hung as closely as possible they only touch at the points where they are thickest, and there is plenty of space for air circulation. With fore quarters, however, it is different. They possess a more uniform section, and when they are hung, convex packing into concave, it is quite possible to pack them so closely as to seriously affect the air circulation amongst them. This will be especially important where more than one or two tiers are carried. The saving in space effected by close packing is dearly bought if it involves greater risk in such a valuable cargo as "chilled" beef.

It may be mentioned that the fore quarters are hooked through the ribs. When more than one tier of quarters is carried, the upper tier is hooked directly on to the carrier bars which are bolted to the beams, and the other tiers are hooked with galvanized iron chains which swing from the carrier bars.

The rolling of the vessel in a sea way would set all the quarters swinging and abrading one another unless the packing is so arranged to prevent any but the smallest movement. This is important as it is considered that some mould germs only take root on the dry surfaces of chilled meat when they are rubbed in with considerable mechanical force. Care has also to be taken with the stowage to ensure that the meat is never in direct contact with the brine pipes, stanchions, etc., or with the side insulation, and also to provide for a free flow of air all round it.

Returning to the question of the circulation of the brine at the precise temperature which is required, this is now carried out by what is called a brine-mixing arrangement.

Two systems are in use, differing in detail, called respectively the open and the closed cycles. In both it may be said that the brine circulated is independent of the evaporator or cooler. The return brine as it leaves the 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 brine being automatically taken out of the circuit by an overflow. In the "open" cycle the returns from each separate circuit is visible. It can be seen whether the full quantity is flowing in each section, and the temperature of each can be determined promptly so that some idea is obtained in the brine-tank room as to the state of affairs in the hold. In the "closed" cycle there is practically no aeration of the brine, a point upon which some engineers lay great stress, and when the pipes are once thoroughly filled and absolutely free from air they are kept so, with no fear of their becoming air-locked and of the circulation becoming defective in consequence.

It is important to note that Lloyd's Rules state that brine pipes should not be galvanized on the inside. It has been found that where the brine comes into contact with the zinc of the galvanized surface the zinc becomes oxidized and free hydrogen gas is liberated. With plain iron pipes the same thing occurs, but in a much less degree. The only object of galvanizing is to protect the pipe from oxidation. It is thought by some engineers that the oxidation does not come from the calcium chloride employed for the brine, but from the air itself in the aeration of the brine in passing from the returns into the open tank and through the pumps, mixer, etc., and it is claimed that where the closed cycle is used there is no aeration and therefore no oxidation, besides which if any gas does become generated it cannot escape into the refrigerating room, where it would be a source of danger, but it escapes from a special ventilating pipe provided in connexion with the closed cycles.

Regarding the question of oxidation it is thought by many experienced engineers that calcium chloride brine made with the commercial salt and fresh water does not possess corrosive properties, and that where corrosion is found it can always be traced to an admixture of sea water introduced, possibly, at sea when additions to the brine have been made. A simple test which can be applied to any sample of brine to ascertain whether it is corrosive or not, is to immerse in it a piece of bright iron, which will not show any evidence of corrosion after many days' immersion in good brine made with fresh water.

Where internal galvanized pipes are insisted upon, the system should be efficiently ventilated, and during the first twelve months at least after starting the plant to work, it should be made a rule to circulate the brine throughout all the pipes at least once every two days. This will prevent the accumulation in the pipes of any large quantities of gas.

It is a matter of great importance that the means of ascertaining the temperatures in the chambers should be simple and correct.

In dealing with frozen meat, which can be carried quite safely at a temperature of anything below 15° F., the necessity of being able to ascertain the actual temperature in the chambers to within half a degree does not arise. With chilled meat, however, it is quite another matter. Here the range of temperature permissible is extremely limited, and it is of the utmost importance that the accurate degree of cold in the chambers should be known. The means, therefore, of being able to read such temperatures must of necessity be very exact.

It is known that with some thermometers the indications rise very quickly the moment the thermometer is drawn from the chamber, and the spirit or mercury can be seen moving up immediately the thermometer is drawn. To obviate this it has been found necessary to use a heavy wood casing round the thermometer bulb and stem. This resists the entry of heat, and enables the thermometer to be read before the outside temperature has commenced to affect it.

Numbers of designs of thermometers have been tried, but it has been found that a stout wooden casing enables the thermometer to retain the temperature of the chamber very much better than metal casings. Thermometers should be occasionally carefully compared with a Kew Standard, and only such thermometers as are correct should be used.

It should be remembered that all new thermometers slowly alter, and, therefore, until they are at least two years old the verification with the standard should receive periodical attention. They should be graded on the stem, as well as on the wood case, in $\frac{1}{2}$ degrees within a range of, say, from 20° F. to 50° F. This gives slow registration and ample time for reading. Care should also be taken to keep these thermometers, when not in use, in a place at a temperature which will not affect them. Thermometers should be placed in the positions where the extremes of temperature may be looked for, viz., near the overheading and low down in the compartments. There should be also a sufficiency of locations for them in proportion to the size of the compartments, and the engineers should realize the importance of absolute precision in the records they make not only of the temperatures maintained at each station of the refrigerated spaces, but also of the brine flow and return of each circuit and the sea-water and atmospheric temperatures, such records of actual data being extremely valuable in locating faults and also in furnishing information for guidance in future installations.

On this point it will be well to quote Mr. F. W. J. Moore in a paper on "Fruit in Cold Storage," read at the Congrès du Froid. He says: "Self-registering thermometers in ships' holds would not only be a check upon carelessness and neglect, but if the figures were available to all who take an interest in them the results of comparisons would be of great assistance." He also quotes from a report made by the Hon. W. Fawcett to the Governor of Jamaica upon the carriage of fruit: "I consider it important for a thorough investigation of the subject to have daily records of temperature and humidity in the holds and insulated chambers all through the year, and also a report on the condition of the fruit in each place as it is taken out at the port of arrival."

It should, of course, be mentioned that frequently self-recording thermometric instruments are fixed in the hold in duplicate, in places where they cannot be tampered with during the voyage. One instrument is controlled by the shippers and the other by the shipowners, who compare the records made. It must be said, however, that absolute confidence is not felt by all engineers in these records. It is said that the vibration of the ship affects the instrument, making a wavy line where a straight line would be drawn by the same instrument if fixed on shore, also that the record shows a step which would be thought to indicate a change of temperature every time the vessel is struck by a heavy sea. In other words, the instrument is both too delicate for use on shipboard and not sufficiently sensitive for use where changes of temperature of a fraction of a degree are desired to be recorded.

Another matter of much importance which ought not to be lost sight of is the question of dryness or humidity of the air in the chambers. A dry atmosphere is of undoubted advantage in the prevention of bacterial growth on the meat. With the brine pipe system of cooling the chambers in which chilled beef is carried on shipboard there is, however, unfortunately, practically no control with regard to the humidity of the air, assuming that the insulation is thoroughly efficient as these chambers are sealed and inaccessible after loading.

Hygrometers, etc., are largely used in cold storage on shore where the attendant has access to the instruments, but when used on board ship, even if special tubes were fitted through the decks to the chambers to enable them to be lifted for examination, the results would be very unreliable owing to the very sensitive nature of these instruments.

A certain amount of moisture coming partly from the atmosphere when the holds are first cooled down, and to some extent from the dessication of the cargo, is deposited on the brine pipes with chilled beef cargoes, and as the temperature is below 32° F. such deposits take the form of frost and remain on the pipes.

After the discharge of the cargo this has to be thawed off, and special care has to be taken that the resulting water does not injure the insulation.

In cases where the hold temperature has to be maintained above the freezing point, say when carrying fruit, it is usual to employ only part of the grids for cooling, so that the brine in them can be kept below 32° F. The deposition of moisture on them will then be in the form of frost. If more grids are employed and the brine consequently used above 32° F., the moisture would be deposited as dew, and trouble both with the cargo and the insulation would result from drip. Even when only sufficient cooling surface is employed to enable it to be kept below 32° F., it has been found that the fastenings of the grids have become warmer than 32° F., dew has deposited on them, and trouble has arisen from the drippings from these fastenings.

Prior to loading and after discharging the cargo and thawing off the brine pipes, suitable means of ventilating the meat chambers by forced circulation should be provided, so that foul or stale air can be abstracted and replaced with fresh air. It is hoped that a more thorough appreciation of the importance of ventilation of meat chambers will be given in the future ; and that no trouble will be spared in carrying this out, as it is especially important, not only for the purification of the chambers, but as also tending to the preservation of the insulation and in such manner helping to retard dry rot in the wood.

I have endeavoured in this paper to touch upon what I have considered to be the main points which should be taken into account in dealing with the carriage of produce within small limits of temperature. I feel sure that the subject is one which will appeal with special interest to many here, and it is hoped that the discussion, which is to follow, will be of service in determining the best methods to be adopted to ensure the greatest success, and so lead towards the evolution of a perfect system.

CHAIRMAN : I would like, on your behalf, to thank Mr. Balfour very much for this very interesting paper, and also to give some of you gentlemen an opportunity of stating your views on this important subject of refrigeration. I understand that, though there will be a short discussion this afternoon, the main discussion is to take place in your own home, the Institute of Marine Engineers, some time in October. I will ask Mr. Hal Williams if he will kindly open the discussion.

Mr. HAL WILLIAMS : I should like, before making any remarks on the paper, to second the vote of thanks to Mr. Balfour for the very able and interesting paper which he has just read to us. He has collected together an enormous amount of information which is constantly being required for reference, and it will be of the very greatest convenience to myself, and I am certain to other people also, to have this information in such a concise form. I think it is a most excellent idea that the prolonged discussion on this paper should be deferred till a later date, for two reasons ; first, because it will give us time to digest it, and secondly, for once in a way, it is a charming day, and I understand a large number of our members are extremely anxious to go and see the Exhibition. I think, then, sir, that if you will allow me, I will defer making any further remarks until we have the pleasure of meeting on some future occasion.

Mr. J. Thom : I would have preferred some one else speaking before me on this excellent paper, but now I am up I would like to make a few remarks on it. I have only had it an hour or two, and have not been able to digest it thoroughly; but I think Mr. Balfour has been working on quite the correct lines when he says that to be able to carry chilled meat and other kinds of food at a high temperature it is necessary to get a minimum rate of variation. The suitable temperature may be very much higher for one thing than for another, and, as far as we know up to the present, the highest safe temperature foods can be carried, the less deterioration there will be; but of course there is a limit to this. It is possible to keep chilled meat at a lower temperature for a certain time; but it is also possible to keep it longer than that, although the temperature may not be so low, as long as the air is properly treated and circulated. For instance, beef that has been killed in good condition, well fed but not too fat, may be kept with the ordinary air circulation process at, say, 33 to 34 degrees, for from five to six weeks, possibly more than that; in fact, I have known of two sides of beef being kept fresh and good at a temperature of $33\frac{1}{2}°$ F. for fifty-three days. It was a bullock that had been carried from America and killed at Deptford. It was well looked after till put in the cold store, and when it was put there a steady temperature was maintained. I hold that this same beef, if it had been kept at $29\frac{1}{2}°$, would not have lasted in as good condition so long. To take another instance, there are temperatures at which milk can be kept for two or three weeks, that is, if the bacteria does not increase radically. With regard to cream, the author speaks about keeping it at frozen temperatures. I think if any one dealing in cream sent it to be frozen, he could not know very much about the article he was dealing in. Cream must not be frozen under any circumstances. I should say the temperature most suitable would be about 34°, and it would keep at that temperature very much longer than at any other. If it is frozen it loses its quality and is not fit for sale as cream. Of course it could be manufactured into butter; but that might have been done at the start, and the butter preserved instead of the cream.

Mr. Balfour : I might point out that the remark in reference to cream being frozen was simply in connexion with experimental research.

Mr. Thom: With regard to frozen goods and the temperature limits at which they should be kept, we may say that anything below 15° is good for storing beef or mutton—I should say that is probably even too low for mutton if kept at a steady temperature under good conditions. The idea that some people have, if anything goes wrong, is that the temperatures are not kept low enough. That is not always the case; very often the reverse is true; but it certainly is necessary to keep a steady temperature. If goods are kept at a lower temperature than 15°, it means very often that the proportion of loss of that commodity will be greater. In keeping sheep for a month there will be a loss of a certain percentage; if for three months, the percentage will be greater, but for the first few weeks we may reckon on 6 per cent. loss. If, however, there is a very low temperature, the loss may be reckoned at a good deal more than that. The author states that it is necessary to adjust the temperature of the brine to create circulation of air in the holds; the temperature of the brine pipes, he says, must be colder than the room the goods are stored in so that it may take up all the heat that comes into that room. He states that the convection currents thus set up provide the necessary air circulation for keeping the goods in condition. I do not think that sufficient. The very small variation he mentions, one degree, and that is about the limit, is too little to give sufficient circulation to keep the meat in good condition, and I think there is no question, if you want to carry chilled beef of any description, it is absolutely necessary that the air to do that duty should be delivered into that hold at within a fraction of a degree of the temperature that you require the goods to be kept at. If the temperature of the hold rises, increase the velocity of the air, but let it be at the same temperature and it will come back within a degree of that temperature and the results will be perfect; but to expect that the pipes at the top of the room will keep it at an absolutely steady temperature is unreasonable. Consider a ship under the usual conditions at sea; the sun is shining half the day on one side of the ship, with the result that one side is cool, while the other is twenty or thirty degrees warmer. The convection circulation will certainly not preserve a steady temperature under those conditions. The system should be one in which the air is cooled in a separate compartment and delivered round the hold in such a way that you can get any circulation you like as you wish, either on one side of the hold or the other just as the heat is more in evidence at one side than the other. The difficulty in keeping frozen goods fresh is not only in the matter of temperatures, but, as Mr. Balfour says, it is very often due to the animals, when killed, not being in a fit state. If a chicken is fed on a certain kind of food and then killed, it will keep for three months hard frozen, while if fed in another way, on being killed it will not keep half that time without getting mouldy or discoloured. That is a sure proof that the feeding before killing is a great point to take notice of. Chickens or fowls may be kept twelve months in good condition without going below 15°, and on the other hand they may be kept half that time, and they would be quite black internally. There is another point to notice in handling the air that you are going to move about in the way I was speaking of. I said that the best way was to cool the air and pass it around the articles in the hold at a good speed, not by convection. I think the air also should be treated in some of the various ways of sterilizing—say the Linley process or any other similar; at any rate the air has to be washed. As regards changing the air twice or four times a day, it is not to be thought of. If you change it, you are going to get four times the amount of moisture to get rid of in cooling to 30° temperature. For fruit it is often necessary to change the air, and you must treat that extra air to get out the moisture before using it, but in this system that goes on automatically along with the cooling.

I have had much pleasure in listening to Mr. Balfour's excellent paper and shall be pleased to hear the remarks of other speakers on the subject.

Chairman: We have to thank Mr. Thom very much for the interesting points he has raised. Mr. Balfour will not reply to-day, but will reserve what he has to say until the adjourned discussion. However, there may be some gentlemen here this afternoon who may not be able to attend at the adjourned meeting, and perhaps they would like to speak. If so, we shall be pleased to hear them.

Mr. W. Dibb: I am always pleased to listen to Mr. Balfour and to hear anything he has to say on this subject; but although he has had a great deal of experience and has a great many opportunities of seeing different systems of refrigeration, there are some things that he has not an opportunity of knowing much about. I have just returned from the River Plate, and I may say there are things that take place at that end which considerably affect the condition of the meat. Owners spend large sums on the installation of apparatus to do the work of refrigeration, the best machines and insulation are put in, the holds are properly tested, cleaned and examined out there and the meat brought on board; but what we find sometimes when we arrive in port is that one quarter of beef is in perfect condition, while the one next to it has gone bad. They are both subjected to the same treatment, and yet there is this great difference. The reason is that the Argentine Republic has just had a very dry six months, and therefore the cattle must suffer from the want of water. Although they seem to be all right when brought down to be killed, they cannot be in the plump condition they would be in if they had not suffered from thirst. Thousands of cattle have died from want of water, and it is scarcely to be expected that cattle that have been kept short of water and then brought down to the refrigerating works and given good food and water for a short time, can really be in good condition for chilled beef. If it had been frozen it would have turned out all right. Sometimes the engineers on board ship have been blamed for the meat going wrong under conditions such as this, when it is not their fault at all. I would like to say a word on their behalf now and again, because they have enough troubles in carrying the meat without having additional stresses laid on them which are quite beyond their control.

Mr. J. A. Linley: I should like to join in thanking Mr. Balfour for the very able paper he has read to us to-day. It is a very instructive one, and contains an immense amount of information. Mr. Balfour, on page 6, quotes Dr. Richardson as saying that "in a solid rigid medium growth and reproduction of living things become impossible," and that "the fact should be emphasized that it is the solid state of the medium and not any specific temperature which is the limiting condition for growth and reproduction, although retardation of growth ensues with lowering of temperature." Mr. Balfour goes on to say, "Even if there is some doubt as to the growth of bacteria upon absolutely solidly frozen meat, it will be seen there is none whatever as to the possibility of both growth and reproduction at the "chilled" temperature at which the beef is not at all frozen; all the authorities being agreed on this point." This is, in my opinion, absolutely the crux of the whole situation in bringing home chilled beef from long distances. According to this, if there is a hard surface the growth of bacteria does not go on to any great extent, whereas on a soft surface—that is, chilled beef—the growth of bacteria is going on continually. I think Mr. Balfour has seized upon the most important question in quoting the opinion of Dr. Richardson on that point. I have for some years been experimenting on soft surfaces; in fact, some thirteen years ago I sent home from North Queensland sixty hind-quarters which were sold at Smithfield on the ninety-sixth day absolutely soft and in good condition, but it was not a commercial success. For the last year or so I have been working on chilled beef, following the lines Dr. Richardson speaks of, and up to to-day I have had 120,000 quarters of beef into London and other United Kingdom ports, keeping away the mould etc. by sterilizing in the manner as quoted by Mr. Balfour. Mr. Balfour has spoken of the marine engineer as being the most important factor in the success of refrigeration. For the last twenty years I have been more or less in touch with the marine engineer both in Australia, the Argentine, and on board ship, and I say that the marine engineer is one of the most important men to-day in the successful handling and carriage of refrigerated cargoes, and if I had my hat on I would take it off as a tribute to the skill of the marine engineer.

CHAIRMAN: It has been proposed and seconded, and I take it that you wish to pass a vote of thanks to Mr. Balfour for his very able paper.

The motion was carried with acclamation.

Mr. J. T. MILTON: On behalf of the Council of the Institute of Marine Engineers, I am quite sure I can promise that if the members of the Ice and Cold Storage Association will express a wish to take part in the discussion, and if it is more convenient, we will arrange that the discussion shall be in London instead of at the Institute's own premises, and we shall be exceedingly glad to welcome at the meeting any one connected with the industry.

The meeting concluded with a vote of thanks to the Chairman.

The following were elected at the meeting of Council held August 12, 1909.

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T. J. Roberts, Ilford.

Transferred from Associate Member to Member.

John H. Ferguson, Penrith.

INSTITUTE OF MARINE ENGINEERS

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SESSION 1909-1910

Vol. XXI.

PAPER OF TRANSACTIONS NO. CLVII.

THE EXTENDED USES OF ELECTRICITY ON BOARD SHIP

By Mr. JOHN McLAREN (Member of Council),

Read Saturday, September 4, 1909, *in the Congress Hall,*

IMPERIAL INTERNATIONAL EXHIBITION, SHEPHERD'S BUSH, W.

Chairman: Sir FORTESCUE FLANNERY, Bart. (Past President).

Adjourned Discussion to take place at the Institute,
Monday, October 18, 1909, at 8 p.m.

PAPER OF TRANSACTIONS NO. CLVIII.

THE TREATMENT OF MARINE BOILERS ON LONG VOYAGES

By Mr. H. RUCK-KEENE (Member),

Read Saturday, September 4, 1909, *in the Congress Hall,*

IMPERIAL INTERNATIONAL EXHIBITION, SHEPHERD'S BUSH, W.

Chairman: Sir FORTESCUE FLANNERY, Bart. (Past President).

Adjourned Discussion to take place at the Institute,
Monday, January 10, 1910.

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