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INSTITUTE OF MARINE ENGINEERS AND COLD STORAGE AND ICE ASSOCIATION.

Joint Discussion on Mr. Robert Balfour's Paper on Refrigerating Installations,

with Special Reference to the Arrangements necessary when narrow Limits of Temperature are required.

IN THE HALL OF THE SOCIETY OF ARTS, ADELPHI, W.C.

On Monday, October 4, 1909.

CHAIRMAN: MR. MATTHEW T. BROWN, B.Sc.

CHAIRMAN: We have met to-night to discuss the paper which Mr. Balfour read at a recent joint meeting of the Institute of Marine Engineers and of the Cold Storage and Ice Association at the Imperial International Exhibition. On that occasion it was considered inappropriate to prolong the meeting by discussion of the paper, and it was then decided to hold a meeting early in the autumn for that purpose. This meeting is the result of that suggestion, and I have no doubt that in the interval, those who are interested in this subject have been studying the paper and have come prepared to give their views to the meeting. I am sorry that I have been called upon unexpectedly to take the Chair. If I had anticipated

anything of the kind I would have tried to put together a few remarks with which to open the discussion. I have read this paper with very great interest; not only did I hear Mr. Balfour read it, but I have read it and studied it since, but I will delay any remarks I have to make till the close of the meeting, and now declare the discussion open, and as Mr. Hal Williams suggested that the discussion should be adjourned I think we might call upon him to open.

Mr. HAL WILLIAMS: I had rather you called upon some member of the Institute of Marine Engineers to open the discussion to-night, because it is not quite fair that the Cold Storage and Ice Association should "make the running" so strongly. However, there are some remarks I should like to make, which time did not permit me making when the paper was read. To many people, one of the most interesting portions of the paper, because of its comparative novelty, will be Mr. Balfour's remarks on the action of bacteria and fungi, and of that comparatively little-known ferment, the enzymes of meat. I do not myself think that the enzymes have a very material effect on the meat trade in the way we are considering. No doubt, if meat is stored for prolonged periods, such as was done in the experiments by Dr. Pennington, the enzymes will have a material effect in altering its structure, but, speaking commercially with regard to the preparation and carriage of chilled meat, apart from the quality of the meat itself, I do not think the enzymes come very much into play, and I do not think we have very much to fear from them. The question of fungi is, of course, quite different, especially in relation to the species called *penicillium glaucum*. This is really the thing we have to concern ourselves with, and there is still a considerable difference of opinion as to under what conditions *penicillium glaucum* will grow. It is a matter to which we ought to give a great deal of attention, and I was much struck by the great diversity of opinion as to the habits of this peculiar fungus. The spores of *penicillium glaucum* are present everywhere, in every butcher's shop—the atmosphere we are now breathing reeks with it, and under suitable conditions they will obtain a lodgment and start to grow; but these suitable conditions, in my opinion, are limited, otherwise it would not be possible to keep any food or animal substance at all. If, as some authorities suggest, this fungus does not require special conditions for its

growth, the carriage of meat and perishable produce under present conditions would not be possible. I suppose the man who has studied the habits of the lower fungi better than any one else is Prof. Pfeiffer, the German scientist, and he has carried out a large number of experiments on this fungus. He holds that *penicillium glaucum* will not start to grow below a temperature just above the freezing point—i.e., about 1° C.—and from experiments I have carried out myself in a small way I have found it is a difficult fungus to start, and that it requires moisture as an essential element before it will grow at all. Other fungus, such as *aspagillum glaucum*, which you find on old boots, fruit, jam, bread, and such like, is of a more hardy species and will grow more readily. *Penicillium glaucum* also, once it has started, will grow readily, and becomes apparent two or three days following the inoculation. In this respect I cannot agree with Mr. Tabor, who is quoted as saying that—

"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 by 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."

That sentence, I think, is open to discussion, because as I have already remarked, if these organisms started to grow at any temperature there would be very much more damage from the fungus than we find in practice. In connexion with these matters, although the scientific point of view is extremely interesting, and it is very necessary, in my opinion, that scientific investigation should be carried out, I think it is important that those gentlemen who are engaged in the trade connected with perishable produce and frozen meat should not get an exaggerated idea of the dangers they have to meet—in other words, they should avoid funk. By all means have the slaughter-houses as clean as possible and by all means take all the sanitary precautions possible, but if the danger from fungi and moulds were as great as is suggested we should not be sure of getting any good food at all. The chilled meat trade is a peculiar one as the meat has to be kept at a comparatively high

temperature for long periods. It is, therefore, very much more susceptible to fungi than meat exposed for short periods in, say, the ordinary butcher's shop. This fact is well known and makes the success of the Linley process in sterilizing the air and destroying the action of the spores the more marked.

There is another point arising out of what I have just said, and that is in connexion with Mr. Balfour's remarks as to the effects of abrasion. He says that when two pieces of meat are allowed to rub against each other and become abraded, the surface so abraded is more susceptible to the lodgment of the spores of fungi than the ordinary surface. I do not think, however, that that can be quite sound, unless Mr. Balfour quotes it as a case of actual fact. It does not seem feasible that surfaces in a constant state of friction could form a ground for the generation of bacteria spores, because if you rub any substance covered with fungi, you wipe the spores and fungi off. It seems to me to be more probable that if they start at all, it will be on a surface where they are not disturbed. To turn to another matter which deserves special mention, Mr. Balfour remarks upon the necessity of avoiding the slaughter of animals when they are in a heated condition. That, I venture to think, is where enquiries come in, and has not received such attention in the past as it should. Animals, to my knowledge, have been driven for long distances, and have been slaughtered before they have had time to quiet down or lose their excitement. That is what I think was really at the base of the remarks by Dr. Blitz at the International Congrès du Froid at Paris. As an instance of it we may take the Merino sheep. When caught in New Zealand or Australia and killed straight away, no better mutton can be found; it is perfectly delicious, but if the sheep is driven across country to the slaughter yards and then killed immediately the meat is not worth eating. The Merino sheep is a very excitable animal and suffers very much from fever if fretted.

Another point touched upon by Mr. Balfour is the question of re-opening the chambers. He says :—

" 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."

Again, I venture to think that if that were so it would not be possible to carry on the trade as it is carried on to-day. It is not practicable to entirely fill the chamber at one port ; it has to be opened at intervals for the purpose of receiving more meat. Of course, this meat should be chilled, but even then you must let in a little more air and the carcases must be slightly warmer than those already in the chamber. I do not think that this, under ordinary conditions, can be a fruitful cause of trouble.

Passing from the theoretical to the practical side of the question, there is another matter which interests me very much, and that is the question of the employment of internally galvanized pipes in brine circulating systems. Lloyd's rules say they should be galvanized on the outside only, and I think it is recognized to be bad practice to put in pipes galvanized on the inside. In an installation in which I was interested, some internally galvanized pipes were used and they gave a very great deal of trouble in consequence. Mr. Balfour, I think, has pointed out only one of the dangers. He refers to the danger caused by the formation of hydrogen gas. We know that there have been cases of explosions from hydrogen gas caused by the action of calcium chloride on the zinc, but that is not the only danger. The pipes I referred to, and of which I have brought samples to-night, are smaller than those used in ordinary installations ; they were used for small circuits and got very badly choked. The deposit in the pipes consists of hydrated zinc oxide and oxy-chloride, with a certain proportion of metallic lead. The cause of the deposit was the action of the calcium on the zinc and also the electrolytic action set up by the lead and the iron, which caused the incrustation of hydrated zinc oxide. A great many samples of commercial calcium chloride contain a certain amount of lead. It is the practice in ice-making installations to use for the ice cans iron cans coated with an alloy of lead and tin, and I daresay those who are familiar with ice plants will have noticed that, after some time, the alloy is eaten through and the cans become rusty, making the brine also, of course, very discoloured. This action between the iron and lead in the presence of calcium chloride will cause corrosion of the iron, and as lead is present in the chloride you get the corrosion which is sometimes attributed to other causes.

With regard to the question of thermometers, where thermometers have to be handled and carried to a certain point, or lifted through the thermometer hatch, it is always best to use spirit thermometers because the movement of the spirit is usually slower than the movement of the mercury, and it is possible to put a spirit thermometer into water or water and ice at a temperature of 32° F., pick it up and hold it out of the water for an appreciable time and the reading will not alter, whereas the ordinary mercurial thermometer will alter as soon as it is taken out of the water. The spirit thermometer is thus much more reliable and does not require the heavy coating of wood that is suggested. As to the question of recording thermometers, I am well aware that they are sensitive instruments, but I am told that the Canadian Government makes use of them to a very large extent in connexion with the butter trade between Canada and this country. They have two standard instruments fitted up in the chamber, and at the end of the voyage one record is taken by the representative of the Canadian government in this country and sent to the Department of Agriculture in Canada; the other, after being checked, is retained by the shipping company, and in that way the Canadian government exercises a useful supervision over the refrigerating departments on the vessels subsidized to carry their produce. Recently a new design of automatic electrical thermometer has been introduced which promises well.

Before resuming my seat I should like to add a word to Mr. Balfour's remarks on the marine engineer. I have the very greatest respect for the man who, after having served his apprenticeship, has taken up sea-going engineering as a profession. At sea he is necessarily thrown very much on his own resources, and for that reason is one of the most useful men you could have for positions on shore. Where it falls to my lot to appoint charge engineers to factories and other positions on land I should certainly give the preference, by a very long way, to a man who has graduated at sea.

I desire to thank Mr. Balfour once more for a paper which has been of very great interest.

Mr. F. W. J. Moore: I am very sorry this is the first occasion on which I have had an opportunity to glance at Mr. Balfour's paper. What little I have read seems to me to contain a great deal that is interesting, although it is principally

on meat, and that subject I really cannot say much about. I may say at once that I have had no practical experience of refrigeration, but I have been connected with the trade in a sort of outside way for many years, almost from the first time it was used for the carriage of fruit, and that trade, as every one here will know, has passed through very many vicissitudes. We have thought on two or three occasions that we had got to know everything there was to know on the subject, but every now and again we " ran against a snag " as the saying is and found something wrong somewhere. Only this last season in connexion with the carriage of fruit from Australia to this country we have had a very great amount of loss through the prevalence of a fungoid disease which up to the present has baffled scientific men. It is commonly known as " bitter pit " —I do not remember the scientific name—and during the past season we have had an enormous amount of loss through it. It would be wrong to say that this " bitter pit " is a disease due entirely to cold storage—in point of fact, it would be wrong to say that it is due to cold storage at all—but, strange to say, we have not had one-tenth or one-twentieth of the loss in other years that we have had this year. There are various theories as to its germination. For a long while I have been of opinion that it is due to fruit being overgrown. It has been, so far as my observations extend, principally found in fruit grown on young trees, in fruit full of growth at the time of shipment. Others say it is found chiefly in fruit grown in moist localities ; but it is strange that there should be so much more of it this year, and it has occurred to me that possibly, I do not say probably, it may be accelerated by cold storage, or it may be that the holds require disinfecting before the fruit is put into them. I am not sufficiently well acquainted with the whole of the details of shipping to know positively, but I presume that on the outward voyage the holds of the steamers are used to carry anything and everything, and it may be that something arises through that ; that something is deposited on the walls of the hold which later on finds congenial ground for development. That would not apply to " bitter pit " only, probably not at all, but it may be that a good deal of the damage done to meat arises from such a cause. I noticed some time ago that some one had been suggesting that the pine wood used for lining the holds afforded a considerable lodgment for different germs, and it appeared to be desirable that something better should be

used for that purpose. I myself think that some of the Australian hardwoods, some of the eucalypti, which have a very much closer grain, harder and smoother surfaces, would be much more easily cleansed, and as they are certainly not at all porous they would not provide a "breeding ground," so to speak, for these fungi.

I notice Mr. Balfour drew attention to a paper I had prepared for the Congress at Paris on the subject of self-registering marine thermometers. Our very great difficulty here is to ascertain any correct data—in point of fact, any data at all—upon which to base theories as to the causes of damage. Particularly in connexion with fungoid growths we find there is a certain amount of damage in fruit which we are unable to trace. We cannot get any information from the engineers, and, unfortunately, representations to shipowners do not carry us very far. I have many times been told that I am not an expert in refrigeration. Of course, that is very true and I have to be content with it, but I think if we had these self-registering thermometers, even although they may not be entirely accurate, there are many minds that could be brought to bear upon the matter, and even one like my own might some day hit upon a solution which would have the effect of making for improvement. Some mention has been made of the difficulties which arise through holds being opened. We find that this is particularly damaging to fruit where a hold is opened after some fruit has been put in and the hold has been cooled down. We had one case of a ship loaded at Hobart, the hold was opened for more fruit at Adelaide, and when the ship arrived here there was a considerable amount of snow on the pipes. Nearly one half of the cases in that ship were very wet ; I do not know whether it damaged the fruit, but certainly it discounted the price. Buyers took advantage of the appearance of the cases, which were of eucalyptus and very dark through the sap having run, and in that way we lost considerably.

Mr. J. A. Linley : I was privileged at the White City to make a few remarks with regard to Mr. Balfour's paper on chilled meat, and I prefaced my remarks with a quotation he made from Dr. Richardson. I would refer you to that quotation again, which is as follows :—

"The fact should be emphasized that it is the solid state of the medium and not any specific temperature which is the limit-

ing condition for growth and reproduction, although retardation of growth ensues with lowering of temperature."

I think Mr. Balfour, in quoting this statement, has really hit the nail on the head with regard to the conveyance of chilled meat in a satisfactory condition. As far as my experience and observations go, the difference in temperature for holding between what I may call soft meat and hard surfaced meat, is very small say half a degree; if the meat is soft, the bacteria are gradually growing, whereas if there is a hard surface, according to Dr. Richardson the growth of the bacteria is arrested, certainly to a considerable extent. I think this is the top and bottom of the whole subject, with regard to the question of mould, in the endeavour to bring home beef from long distances, in the form commonly known as chilled meat. I go on to the next point, which also bears on the subject. Mr. Balfour, after treating of the evidence as to whether bacteria grows above temperatures of 29·5° or 30·5° F. goes on to say :—

" 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."

That brings us back again to the question of the soft and hard surfaces. Further on we read :—

" 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 the ordinary slaughter house—I have been in many—the conditions, as far as they can control them are very good. After the day's work the slaughtering floors, etc., are washed down with the hose and appear to be quite clean, but as far as the freedom from bacteria is concerned, they might as well have been blown upon. Then again there is the condition of the men who handle the meat.* The slaughtermen in this country are not particularly

* The Regulations now in force in Britain with regard to slaughter houses are more stringent than formerly was the case, and with the object of overcoming the evil effects referred to by Mr. Linley.—J. A.

nice-looking gentlemen, but when you go to foreign abattoirs where they deal with large numbers of horned cattle, 500 to 1,000 per day, the conditions generally certainly are worse than they are here. It may be said as a fact, that the healthy animal, when it arrives at the meat works properly brought in, that is to say, brought in without being harried and ill-used, and then allowed to stand about twenty-four to thirty-six hours to cool down, dies absolutely clean; the flesh underneath the hide is quite sterile. The first infection it receives is when the knife is used to take the hide off and to open up the carcass and dress it. One must consider the men who are handling the meat; the implements they use have never been sterilized from the time when they were made; their aprons have never been cleaned from the time they were put on new; their boots were obtained at some remote period, and have never been cleaned since; the mere fact of putting their hands on the surface of these animals, killed in a climate with a temperature of about say 75 to 100° F. (when the flesh is particularly receptive to all kinds of bacteria), must of necessity infect them. Mr. Balfour was probably facetious when he said that the conditions under which an animal should be slaughtered should be, "as regards sterilization, on a par with the operating-room of a modern hospital," but Mr. Balfour is absolutely correct, and if those conditions could be brought about it is highly probable that the meat, if carried under clean conditions, could be carried for twenty to twenty-five days (with a soft surface) and arrive in a state in which there would be neither mould, slime, decomposition, black spots, or any other deterioration. But I think Mr. Balfour made that remark simply to show how difficult it is to get the right conditions for the proper preservation of the meat, and we have to take matters as we find them. If we accept the present situation the animal is infected from the time it is killed. In the ordinary way, in dealing with large masses of beasts, they have a rough and ready way of taking the hide off. The beast comes into position, in front of the slaughter men, on overhead rails; it is lowered to the ground, opened up, and then hoisted by the hind legs, in order to get the hide off. In order to effect this purpose, a baulk of rounded timber is used to hammer it down; this piece of timber has been previously lying on the floor in all kinds of filth. In due course, the animal is stripped of its hide, and properly butchered. Boys are then set to work to clean off the blood

To do this, they use a pail of water, and cloths that have been used over and over again in this way. If any part of the surface has not been infected before, they ensure that it is so now, and in many cases, to make doubly sure, they use a hard scrubbing brush, and brush in the infection. The beast is then run into the secadero (holding space), divided into sides. It stands there, surrounded by its fellows, in a temperature possibly 90 degrees in the shade. While the sides are in this hanging space they are again carefully looked over, and finally trimmed up, all blood stains being removed. When a sufficient number of sides have accumulated, they are then run into the chilling room, and chilled down by artificial cold. (In my case, as soon as the chamber is loaded I give them a charge of gas before any cold is put on.) This takes place both in the case of meat which is finally frozen, and what is known as "chilled meat." Chilled meat, which arrives from the Argentine, has frequently a hard surface, and is, consequently, more or less frozen. In this latter condition, when it is thawed out and cut up by the butcher it weeps, and in many cases the meat juices are running out very freely. Frost causes the moisture in the meat cells to expand, and most of them burst; therefore, the aim should be, in order to bring over chilled meat, that this should never be subjected to frost at any time.

When I was in Australia some twelve or thirteen years ago I quite realized that it was necessary to do something to get rid of the non-salubrious effects and surroundings of the slaughterhouse, and it occurred to me, that the simplest thing to do was to use heat in some form or other. I had sent over to me from London a tank, and one and a half tons of highly rectified cotton-seed oil, which was, practically, colourless, odourless, and tasteless. The tank containing the oil was fitted up in the Meat Works, and in this tank I put a coil of pipes, connected with the boiler, and brought the temperature of the oil up to 212° F. I then had about 60 quarters of beef, which had been previously chilled, dipped into this boiling oil, and left them in for periods of 1, 1½, and 2 minutes. After each one was dipped, it was sent back to the chilling room, where the sixty were kept until the arrival of a steamer. I had the provision chamber of this steamer washed out in the ordinary way, and hung the sixty hind quarters of beef in it. The refrigerating engineer had instructions to bring

the meat home at 32° F.; he carried these out, and it arrived in London and was sold on Smithfield Market ninety-six days after killing, quite sound, but uncommercial. There was one thing that I had forgotten, viz., the difference in temperature at which the meat was carried during the voyage and the temperature at which it came into on discharge. As luck would have it, the ship arrived in the docks during mid-summer, with a temperature somewhere about 72°. Of course, what took place was heavy condensation on the surface; the water mixed with the oil which made the meat look very unsightly; however, it was sold at frozen beef prices. As this experiment was not a success, I let the question of dealing with chilled meat drop for several years, but about five years ago I took it up again. My next endeavour was to bring about the desired result by atmospheric sterilization. After a great deal of work, and many experiments, I arrived at what is being done to-day, and up to the present time some 140,000 quarters of beef have come from the Argentine Republic to this country, by this method.

My main difficulty was to find a sterilizing agent which gave the required result, but left no trace. I tried sulphur, chloroform, ozone, etc., all with more or less unsatisfactory results, and finally came to vapourized formaldehyde, which is being used to-day. This agent, if applied in proper quantities, and not applied too frequently (the general practice is twice only) gives a good result.

Having put the butchered meat in the works into the same sterile condition it was in when the animal was alive, I therefore started with a clean slate. The next thing to do was to sterilize all along the line until the meat arrived in England. The cloths in which the meat is enveloped are sterilized separately in the works by the same agent; the trucks, or barges, are also sterilized periodically; the ships' holds are sterilized before stowing the meat on board, and, finally, when the loading is completed and the hatches put on, the meat is given another charge of formaldehyde vapour to endeavour to neutralize the handling by the men in the act of stowing. As it is not possible in practice to ventilate the hold, owing to the varying temperatures of the outside atmosphere, I found it necessary to clean the original air contained in the hold in which the meat is stowed, and for this purpose I devised what is known as the No. 2 system. This consists of two

tanks, one containing sticks of chloride of calcium, the other containing sulphuric acid, in which discs of lead revolve. The atmosphere is then coursed round from the hold through these tanks, and is thereby dried and purified, care being taken only to work this apparatus for about half an hour each day, so as not to remove too much moisture from the air. Both these tanks contain a drying agent, but the main use of the sulphuric acid tank is, to burn out any organic matter that may be in the atmosphere as it passes between the corrugated discs.

I am now awaiting the experiment from Australia.* The s.s. *Marathon* left Brisbane forty-two days ago last Thursday with 1331 quarters of beef, and is due in London on November 1. This meat will have to be on board the ship for sixty days, Brisbane to London, and unless there is an accident it will arrive in London in as good order as the meat that comes from the Argentine. I have received meat from the Argentine which has been killed for considerably longer than sixty days, and it was taken in from barges at a temperature of 95 degrees, and shipped with the cloths absolutely sodden, yet it came home without any slime, mould, or black spots upon it.

When I was in Paris at the Congrés du Froid last year, I found that many persons interested in refrigeration had come to the conclusion that it was necessary to do something more than rely on cold, in order to bring meat with a soft surface long distances, therefore I only anticipated, by sterilization, the general trend by some two or three years.

(Since the Meeting, the s.s. *Marathon* has arrived, and the Market Reports state that the result was excellent. Some of the meat was killed ten days before it was placed on board the steamer ; it had to face sixty-two days on the passage, and then afterwards be marketed. The s.s. *Marathon* leaves for Brisbane again on November 23, and she will then bring home a second lot of meat ; and it may be taken that chilled beef will come regularly from Australia and New Zealand, thereby furnishing another source of supply to the English Market outside of North and South America. These latter countries, hitherto, have supplied the whole of the chilled meat brought from over sea.)

* The *Marathon* arrived in the Royal Albert Dock, November 1, with 1,350 quarters of beef, 100 tons of which was sold at Smithfield Market at 3¼*d.* per lb. for fore-quarters and 4½*d.* for hind-quarters.—J. A.

In reference to Mr. Moore's remarks, the system that I am using for meat, theoretically applies also to fruit. I am not quite so conversant on this subject, but I may state that wherever fungoid growths or bacteria exist, they can be destroyed by the same method ; the great point to be aimed at, is to see that the minimum amount of formaldehyde vapour is used.

With my second system I get over one of the great troubles that exist in relying on refrigeration only, viz. drying the atmosphere. The action of refrigeration naturally dries the air, which, at once, proceeds to extract moisture from the fruit. The effect of this causes the skin to become toughened, and in many cases the fruit becomes crinkled, or corrugated. With my method, after having cleaned the air in which the apples are stowed by the No. 2 system, no doubt I remove a certain amount of moisture during this proceeding, but I can put back, with the No. 1 system, either steam or atomized sterilized water, and bring up this air to any desired point of atmospheric saturation that may be necessary. Moisture in the atmosphere which is absolutely sterile (and the surfaces of the fruit also being sterile) has no harmful effect.

I may state, that during the passage home on the s.s. *Guardiana* with the first lot of chilled meat from the Argentine, I was, on several occasions, in the hold in order to inspect the condition of the meat. There I had placed at opposite sides of the ship two polymeters, and these recorded respectively 98 and 99 degrees of atmospheric saturation. At the time I was horror stricken, as it had always been held that the atmosphere should be dry ; however, I went carefully into the subject, and was convinced by scientific opinion that if absolutely clean moisture is in the atmosphere it does no harm, as above stated.

Mr. W. E. Farenden : I am sorry I have not had much experience with the carriage of chilled beef, but there was one point raised by Mr. Thom at the short discussion held when the paper was read at the Exhibition which I think might be enlarged upon ; that was with regard to the convection currents of the air in the holds. I think Mr. Balfour allows that there is a difference of 1° between the top of the brine pipes and the bottom of the insulation, where the depth of the compartment is moderate, as it is in 'tween decks. Mr. Thom did not think

this was sufficient to get through circulation and he advocated that the air should be cooled in a separate chamber. I should like to ask Mr. Balfour whether he would consider it suitable to shut off the brine pipes in the hold and cool the air by a battery in a separate compartment similar to that used for fruit and deliver it to the holds by fans, or whether the air in that case would be of too searching or too dry a nature. Perhaps Mr. Balfour would also say whether chilled meat is carried to any large extent by the cold air system.

Mr. H. Brier : My work up to the present has been mostly on the mechanical side of the subject, but I have taken great interest in the discussion this evening. Mr. Moore stated that there was great trouble with regard to condensation making the boxes of fruit damp. That has been our greatest trouble from the commencement. We have fitted holds to the proper ratio to obviate condensation and even then have had considerable trouble and have had a slight amount of condensation. In this chilled meat carrying trade again we have come to a state between wind and water, neither one thing nor the other ; the meat must be kept at a constant temperature to do any good, and that temperature is just between the freezing point and the condensing point, and unless the atmosphere is kept in a fairly saturated condition it becomes dry and the meat comes home parched and thirsty. We have had trouble also from the distribution of the cold ; that is to say, one portion of the hold is comparatively hot while the other part is below freezing point and doing damage in hardening the surface. To get over that we adopted a better system of circulation. We circulate more with a current at, as far as possible, the temperature at which it is intended to cool, and distribute the air more evenly. But I think we must look at refrigeration, particularly the chilling department, from a natural point of view. We must accept the fact that we are fighting nature and must use natural means to fight it. We have a tremendous army of bacteria, fungoid growths and enzymes to encounter ; under frozen conditions they are driven into winter quarters ; they are helpless ; but when we come up to moderate temperatures, as for chilled meat, they become lively and interested in what is going on. These bacteria will multiply very quickly unless we call in the aid of some system such as Mr. Linley has recommended, and I think that by chemical means we will get

a more perfect system. I am a refrigerating engineer and, of course, with the Linley process on the market we are told that refrigeration would be no longer used, and that we should not assist it or fall over one another in adopting it; but when we arrive at these niceties of temperature, when the shipowner begins to quarrel if the chamber is not up to the exact temperature, we must have something to prevent deterioration of the meat, whatever it is; we must adopt every possible means to prevent the surface being spoiled, as, although it may be good meat to eat, it is not saleable if it has a poor appearance. I think, therefore, if the refrigerating engineer adopts something of this kind it will be better for everybody concerned. In the case of the *Marathon* we shall, of course, have a good example of long voyage refrigeration on the chilled principle, and I think everybody connected with the industry is looking forward to the arrival of that vessel with interest. On the question of saturation and moisture Mr. Hal Williams spoke of the necessity of opening the holds. I think that, as far as possible, they should be kept closed, because it will be found that wherever a chamber is opened the cold air will find its way out and the fresh air entering will cause a deposit of moisture not only on the pipes but on the first surface it comes in contact with, and you will find it on the meat if it is at all colder than the dew point of the atmosphere. If this air carries spores, they will be deposited on the surface and set up the growth we are all trying to avoid. Mr. Linley is trying, I understand, and I should like to know how far he is successful. In his second process, as he terms it, he uses, I believe, a powder containing sulphuric acid and also calcium chloride for drying the air with the object of keeping up the full saturation. I do not see why calcium chloride should be used, I should think it would be more likely to take the moisture out than add to it.

Mr. Linley: In order to collect the gases and organic matter given off from the meat it is necessary to collect the moisture and deposit it in something, either chloride of calcium or sulphuric acid. I could rely entirely on sulphuric acid to collect and burn it up, but sulphuric acid is not a nice thing to handle on board ship. I prefer to take 80 to 90 per cent. of it out by the chloride of calcium, then the sulphuric acid collects the remainder and burns it. The best results are obtained by using it 20 minutes to 30 minutes every 24 hours. Pipes pass

from the chamber to the tanks, and certainly any smell there may be is deposited in these two tanks.

Mr. HAL WILLIAMS : May I refer to another point ? On page 187, Dr. Richardson is quoted as saying :—

" When the temperature of the meat 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, etc."

On page 191 the author says :—

" The beef must never be subjected to frost ; i.e., no part of the moisture in it should 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."

Mr. Linley also referred just now to the fact that chilled meat, if allowed to get below 31°, could not be cut into steaks by the butchers because of the ice crystals bursting the tissues. I should like to know exactly what authority he has for saying that the ice crystals burst the cells and tissues of the meat. Such meat when examined under the microscope gives no appearance of burst cells or tissues. When meat is frozen the juice concentrates and some of the water in it is separated out as ice crystals. As Dr. Richardson says, some of it separates out at 31°, and this goes on until it reaches its cryohydric condition. If it were the case that the crystals thus formed burst the tissues it would be apparent under the microscope, and I have never found this to be the case. Is there not a much more simple theory ? When frozen meat is taken into the atmosphere the moisture of the atmosphere deposits on the meat, condenses and runs down and makes the meat look flabby. A certain amount of the blood or meat juice on the cut surfaces is washed away by the condensation and the water is of a reddish colour. If the burst tissues theory is correct it means that meat which has been frozen hard, if carefully thawed out, would be distinguishable from freshly-killed meat, and this is not the case. Arguing from what happens with other concentrates it seems to me that the water which separates out of the meat juices when they are taken down below the freezing point, are reabsorbed when the temperature reaches normal.

Mr. LINLEY : In practice I find meat becomes solid at 29°. Of course it is a very difficult thing at any time to keep the temperature as the list of the ship will make a difference of half a degree and that half degree means the difference between hard and soft meat.

Mr. MOORE : I notice in reading through the discussion that Mr. Thom stated that, 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. Our experience is that the less air is changed the better it is for the fruit carried. I remember about two years ago we had a very considerable battle over that and a good deal of money was spent in cabling between Tasmania and London over the fitting of the *Durham*, which carried the largest and in many respects the best cargo of apples ever brought over, amounting in all to 126,000 odd cases. Mr. Balfour most strongly advised that we should not change the air at all. I cannot say that was absolutely carried out, but at any rate it was changed very little, and we find that where the air is changed least, or not at all, the cargo is carried most successfully ; the fruit opens out with all its natural bloom upon it. The " crinkling " Mr. Linley spoke of is due, as far as I know, in one or two cases, either to fruit not being sufficiently ripe when shipped or to the air being changed too frequently, and violently causing a shrivelling draught. Last season two steamers arrived with cargoes of fruit, the skin of which was all crinkled ; in fact, there is one line of steamers which has never been successful in carrying fruit, and, in my opinion, it is due to them changing the air too frequently. What is really needed is a low temperature, say, 36° F., which should never be allowed to range more than two degrees or under any circumstances four degrees, and the change should never be sudden ; but care should be taken that the cold air is gently circulated throughout all parts of the hold. That is how all the cargoes which turn out best are carried.

Mr. J. T. MILTON : I only wish to say a very few words about the paper Mr. Balfour has been good enough to give to the two Institutions. Mr. Balfour is a very skilled engineer who has come in contact with the refrigerating industry a great deal more than the ordinary man because he visits a very large number of ships and sees the conditions under which the various refrigerating installations work on those ships, and when, in

addition to the results of his own experience, he quotes the results of scientific research, I think we may depend upon it that he does not quote anything on the scientific aspect which his practical experience does not show him is worthy of consideration. Mr. Hal Williams, who also has had a very wide experience in refrigeration, seems to throw some doubt on some of the scientific statements which Mr. Balfour quotes, but I am not quite sure that he understands Mr. Balfour's position correctly ; I thought some of his arguments told in favour of certain points Mr. Balfour mentioned. Take, for instance, the question of what he calls *penicillium glaucum*, one of the species of bacteria. Mr. Williams, I gather, said the spores are everywhere and will not start to grow below 1° C. They also require moisture to grow, but he said that, once started, they grow apace. Now I think that is what Mr. Tabor said in his paper quoted by Mr. Balfour.

Mr. WILLIAMS : I took exception to the remark that they would grow below freezing-point.

Mr. MILTON : I understood you to say that once started they grow rapidly.

Mr. WILLIAMS : No, I took exception to the remark of Mr. Tabor ; they will grow apace above freezing-point not below it.

Mr. MILTON : Again, with regard to changing the air, Mr. Hal Williams says these bacteria require moisture for their growth. It is the opening of the holds that brings in moisture, a thing very undesirable, from Mr. Williams' own showing ; the moisture is deposited not only on the brine pipes but on the food itself, therefore, you have one of the conditions favourable to the growth of spores. Then I think he did not altogether grasp what Mr. Balfour meant in regard to the rubbing in of the spores. Of course if the rubbing were continuous the spores would be rubbed off. I read Mr. Balfour's remarks to mean, however, that if the meat is abraded there is a tendency for the spores to be rubbed in, but the abrasion is not continually going on ; it is only when the ship is rolling that the abrasion would take place, and on the other days the spores would seem to have good conditions for germinating. I cannot see how Mr. Williams' views about thawing out not bursting the tissues of the meat can be correct. Surely, it would mean that frozen meat, carefully thawed, would be as valuable as

chilled beef, and I do not think that is the case. As Mr. Linley said, it is the freshly-cut surface, when the butcher cuts up the meat, that is affected. At any rate, I thought the real reason for going to the trouble of chilling meat was because the meat which was chilled was indistinguishable from good freshly killed beef, whereas meat which has been frozen can always be told.

Mr. LINLEY : In nine years the shipments of chilled meat from the Argentine have been raised from 24,000 to 967,000 quarters ; the difference in value between frozen beef and chilled is about £14 per ton.

Mr. MILTON : A question was raised about enzymes. Enzymes are ferments in the juices, not bacteria. We have evidence on the subject from Mr. Thom, who said, when the paper was read, that poultry grown on some farms will keep twelve months, whereas if fed in another way the same kind of poultry will only keep about three months. Mr. Linley and Mr. Williams have both spoken about the meat being damaged when the animal is harried immediately before it is killed. The difference between the flesh of the animal killed when in a fevered condition and the perfectly healthy beef is a question of the enzymes. These enzymes in the flesh of the harried animal are in a different state to those under healthy conditions, and I presume the same thing applies in the case of the poultry under different conditions of feeding. The question of enzymes cannot be dealt with by Mr. Linley's or any other system of sterilization, but only by low temperatures. I think the main result of our discussion here is that, whatever else is done, it is advisable to sterilize both the ship and the cargo. Mr. Moore suggested that we should sterilize the holds before carrying the fruit, and that possibly " bitter pit " might have been due to something carried in the previous cargoes, or at any rate might be accelerated in that way, but it seems to me that if this particular season has been a very bad season, it would appear to be due to climatic conditions and not in any way to the conditions of transport. If it only occurred in one ship there might be reason to think that it was due to the ship. The question he raised with regard to wood linings is one that ought to be considered, and it would have been interesting if the matter had been discussed when we had the paper in our

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The 19th Annual Dinner of the Institute of Marine Engineers,

King's Hall, Holborn Restaurant, London, November 3rd, 1909.

Institute a short while ago by Mr. Dyer upon the decay in the timber used in refrigerating installations. Mr. Moore suggested that harder woods would be more suitable ; it may be there is a bacterial growth in the wood in the hold that sterilization would stop.

I agree with Mr. Moore that it is a very great pity we cannot get really practical data of all the troubles that occur during the voyages for future guidance. The reasons are, no doubt, commercial reasons ; men who know are afraid to tell the truth because it might reflect upon them in some way, but we ought to be able to get reliable data in cases of trouble as it is through mistakes and difficulties that we learn. A point was raised by Mr. Farenden and also by Mr. Brier in reference to the question of air circulation, and that is a point I wish some of the gentlemen who are experienced in ships would have dealt with more. If it is really necessary to have the whole of the air in the chilled meat holds with a variation of only half a degree in temperature, it appears to me that great changes will require to be made and that mechanical means of circulating the air will have to be adopted. Mr. Thom spoke of the difference between the temperature of the hot side and that of the cold side of the vessel on a sunny day ; half a degree is very little, and if it is really necessary to maintain the temperature within that small variation I think there will have to be mechanical circulation.

Mr. W. McLaren : I think we are much indebted to Mr. Balfour for the educative value of this paper, for the high standard he aims at and for the way in which he defends the marine engineer. I do not think the marine engineer is at fault in the majority of cases where the meat goes wrong ; we have heard how, from the very beginning, the way the cattle are driven and housed together before being slaughtered and the conditions under which the slaughtering takes place, everything goes against the meat being kept in good condition. The engineer is very often blamed and the fault is attributed to him for not keeping to within the temperature—in some cases, as we have heard, to within half a degree. I think half a degree is too small a variation to depend upon natural circulation, and it would be better to circulate the air by mechanical means.

Mr. Hal Williams : I think a wrong impression has been taken of my remarks on the opening of the holds and I am

sorry if I did not make my meaning quite clear. My point is that it is not practically possible to carry on the trade without having to open the holds to admit cargo at different ports, and if the opening is carefully done and for short periods I do not think there will be any damage. If the hold is kept open too long, of course, moisture will be deposited and mould formed. Mr. Thom and I fought an interesting action on that very point, but in that case the hold was open for, if I remember correctly, ninety hours continuously and mould did grow.

CHAIRMAN : I am sorry that I have to bring this most interesting discussion to a close, but we must give Mr. Balfour time to deal with all the points raised. I think this discussion has been most instructive and interesting. We all, I am sure, enjoyed the graphic description by Mr. Linley of what happens in foreign *abattoirs*, and after such a description one does wonder, as has been said already, that the meat comes as it does and that no bad effects result from the work of these microbes, bacteria, and enzymes. I said when I took the chair that I would reserve any remarks I had to make till the end. I am glad the discussion has been so vigorous that there is very little time left for any remarks I have to make, because on the question of bacteria I feel I cannot add to the general knowledge. The engineer has certainly to be a " Jack of all trades " nowadays, but it is only the few who can study such a special subject as bacteriology. Medical men specialize in bacteriology, but for engineers to tackle such a question, along with all the other multifarious sciences they have to assimilate, is almost expecting too much. The question of thermometers has been touched upon and I would like to say a word on that. Thermometers can be made either quick reading or slow reading. It simply depends upon the relative capacity of the bulb compared with the calibre of the stem, so that I do not see the need to have wooden or other coverings such as has been described. It is simply necessary to get a bulb and tube of the relative capacities required to make a thermometer slow reading as may be wanted. With regard to recording thermometers, I have not had any experience, but it seems to me that the difficulty referred to by Mr. Balfour, of the variation in steamers making a wavy line upon the recording paper, should not be serious because that vibration would have a regular beat, producing a regular wave line which should be easily distinguish-

able from any fluctuations due to change of temperature. I am interested to hear the old question of the bursting of the meat cells coming up again. I am inclined to think with Mr. Hal Williams that it is the condensation of moisture upon the cold meat when brought out into the warm atmosphere which is the trouble. With regard to the use of formaldehyde, I think a Commission recently reported adversely to the use of it, especially if used to excess.

Mr. LINLEY : I have been in touch with the Department which has to do with this question, and I may say that the point is, how often and how much of formaldehyde is to be used (or rather how little). The Department condemns the use of formaldehyde by the butcher or fishmonger. In fact, there was a company selling safes, the object being to use them for holding food which was on the point of going bad. One purchaser gave a certificate to say that he had used a sterilizing safe on produce that was unfit for food, and after treating it with formaldehyde, he was able to sell the articles.

I previously forgot to mention that the formaldehyde vapour that I use is one of the preservative agents in the smoking of bacon, ham, fish, etc. ; this is produced in the burning of wood and sawdust. I use the finished article, whereas the smokers use formaldehyde in its crudest form.

It will be interesting to the Society to know that one of its members was again to the fore in the *Marathon* shipment. Mr. E. C. Platt, late chief engineer of the s.s. *Guardiana*, left this vessel, and joined the Improved Chilling Co. Ltd. He then proceeded to Brisbane, and fitted up the works there with the " Linley " process, and also superintended the treatment of the cattle in the works. (The s.s. *Marathon* was fitted up with the " Linley " process before she left England for Brisbane.) He further looked after the sterilizing of the vessel, and the shipment of the meat, and came home with her, and thereby has to his credit a very excellent record, viz., being the first man who has prepared and brought home successfully chilled meat from Australia.

CHAIRMAN : Another point raised was that of maintaining the temperature within the limit of 1° variation. I cannot say that I have had any experience of the bringing home of chilled meat in recent years, but in the early days it was utterly im-

possible to maintain anything approaching these narrow limits, the difference between the roof and the floor temperatures always was considerably more than 1°. That was in cases where there was air circulation, and I should think that where there is still air the difficulty of maintaining that narrow limit of variation would be very much greater. I would like if Mr. Balfour could say that really, within his knowledge, that limit can be maintained between the roof and the floor. He makes some interesting references to the early methods with ice and salt, and if there had been time I should have liked to say something about them ; but one point I must take exception to, that is, where he says that in those early days great care was taken with regard to the insulation. I knew those early steamers on the Atlantic as far back as 1879, 1880 and 1881, and there was practically no regard paid to the insulation. It simply consisted of wooden walls with 4″ to 5″ air space between, and so long as the ice and salt method continued that was the sole insulation, and even that was very often disturbed on the outward voyage because emigrants were then carried in those 'tween deck chambers. Some one remarked upon the effect of the outward cargoes, but I often wondered what was the effect of those emigrants, whether they left lodgments of higher organisms than those we have been discussing to-night. I will now call upon Mr. Balfour to reply to the discussion.

Mr. J. THOM : I hope I may be allowed a minute or two before Mr. Balfour gives his reply. In my opinion the crux of the paper lies in what Mr. Balfour refers to with regard to the small range of temperature which should be allowed in all refrigerated spaces, whether chilled goods or frozen goods. I think Mr. Balfour himself says that ; but I do not think we have heard a single word about the temperatures at which the various classes of goods should be carried. After a paper such as this we should have heard something of what is the best temperatures to keep these goods and what the range should be limited to. I ventured to give figures in the short discussion which took place when the paper was read about various points of interest to us all and hoped it would draw further information from those who are occupied with the work of refrigeration every day, because a paper of this kind loses in value if we do not get other person's experience. On the question of fruit one gentleman says moisture is the cause of the trouble, another says some-

thing else is the cause. On the subject of chilled beef Mr. Linley says, "Treat the animals properly and you will get good results," and if you treat them indifferently you will get bad results. We have been given instances where there have been bad results, but we were not told how the work was done that gave the bad results, we were not told the temperature the goods were carried at, the amount of moisture in the air, the extent to which circulation or the changing of air in that chamber was carried on. I think most of us have been speaking from different aspects. Mr. Linley had sufficient time to tell of his way of solving the difficulty; we could not all have time to do that, but there are dozens of different ways of treating various kinds of goods, and if we only localize the issue and keep to one kind of goods we would get on much better. With regard to fruit one gentleman mentioned about it coming home with the skin crinkled. If fruit is kept in a hold with a perfectly dry atmosphere it is bound to crinkle; there is a limit to dryness of air for fruit. I once asked a man who sells apples on the road, "Where do you keep those apples when you have a large stock?" He said, "In the cellar." I then asked, "What sort of a place is it?" and he said, "There is a door at one side and a window at the other a little higher up. I leave the door open about two inches and there is always a stream of cool air passing through and coming over the apples and out at the window." That was his refrigerator and he keeps the apples in that way for four, six and seven months. It is not a refrigerator in reality, it is simply a cool room. These are things one should study carefully and take by degrees, one part of the subject at a time I believe in keeping the goods as clean as possible and in preventing the growth of bacteria and fungi as much as possible, but I do not think we need be too much concerned about their effects. I was once on a steamer where a nasty disease broke out and everybody was put in quarantine. But before the authorities knew of the disease every one had been at liberty, and it took seven or eight days to get those people together, by which time they had contaminated a very large number of others. There was great excitement in the town and the doctors were not very busy, so they made the most of the scare, but nobody died, and although we have been speaking of terrible organisms, and we have to deal with them, I think it is just as well to remember that they are not quite so injurious to health as we are made believe.

Mr. R. BALFOUR : Mr. Thom, who opened the discussion at the White City, is somewhat sceptical as to the results obtained by the brine circulation system, in which the air in the holds or chambers circulates only by convection currents, and he evidently supports the air circulation system by mechanical means. Mr. Thom has had much experience with refrigerating machinery and appliances both on board ship and on shore, but with regard to the carriage of chilled beef since its introduction, the brine distribution system has been universally adopted in preference to that of mechanical air circulation, especially where a precision of temperature is absolutely essential. I must confess that until recently, I was somewhat doubtful regarding the very narrow range of temperature obtained, but am now convinced that with ordinary care and good insulation this is practicable in chambers of limited depth, of (say) 7 to 12 feet. With further reference to air circulation, I think it hardly fair to compare the results of cold storage on land with shipboard practice, the conditions being somewhat different. In a cold store the air distribution can be easily regulated by the attendant who has access to the outside of the air ducts and can adjust the slides at will, whereas on shipboard the air ducts have to be constructed of sufficient size to allow the passage of an attendant to regulate the slides, and unless other means are adopted to obviate this it will be admitted that it is no easy task to perform. Again, air circulation is apt to spread any evil which may be locally deposited ; in connexion with this it may be mentioned that recently in Paris and Brussels investigations were made of the effect of ventilating fans in restaurants and other public places. Some of the fans simply agitated the air, while others were connected to the outside air. The experiments were made by determining the number of bacteria in a cubic metre of air before the fans were started and after they had been running for a time, with the result that the number of bacteria increased by about six times, showing that a lively current of air had stirred up dust containing bacteria.

Mr. THOM : But the air is being kept in motion all the time, it would not be allowed to settle.

Mr. BALFOUR : Mr. Thom referred to the effect of the feeding of chickens ; Dr. Pennington dealt exhaustively with

that in her very interesting paper at the Paris Congress. He (Mr. Thom) considers that there has not been enough discussion on the question of air temperatures in connexion with the treatment of chilled beef. I agree with him to some extent on this point, still it will be admitted that the title of the paper gives a certain amount of licence to those who have somewhat drifted from the main issue.

With regard to the carriage of apples, I have had some experiences with it on a large scale, one of which has been referred to by Mr. Moore. For some time back I have considered the carbonic acid gas theory to be erroneous. Instructions used to be given to the engineers to extract the air at intervals daily from the bottom of the holds containing the fruit, but this was thought by many to have the effect of robbing the fruit of its flavour, and I am glad to say that Mr. Moore, along with others interested in the trade, eventually agreed to reduce this practice next to nil, and at the same time lowered the carrying temperature to 36° Fahrenheit, which has met with much success.

With regard to Mr. Hal Williams' remarks, I do not claim to be a scientist, but fully appreciate the views of the eminent authorities quoted in the paper. Enzymes, one of which is familiarly known as the gastric juice of the stomach, must have an effect on animals—some of them may be suffering from indigestion, and this, together with their treatment before slaughter, must have an injurious effect on the structure and quality of the beef. Mr. Hal Williams referred to the effects of abrasion, i.e. the quarters rubbing against one another ; at one time it was considered advisable to keep the quarters apart to avoid abrasion and to admit of a free circulation of air. The practice nowadays is to hang the quarters as closely together as possible—this has turned out very successfully and with comparatively little abrasion. My authority for referring to the ill effects of abrasion of the surfaces is Dr. Klein of St. Bartholomew's Hospital, one of the most eminent bacteriologists in the country, who in his interesting report and lectures attaches great importance to this matter.

The next point was the question of re-opening the chambers—I am afraid it too often happens that a consignment in itself is not of sufficient quantity to fill the chambers, and probably this is unavoidable ; but the trouble is that the

second consignment may be at a much higher temperature than the first, in which case moisture would be created and the growth of mould encouraged. With regard to brine pipes, most of us, I think, agree that they should not be galvanized internally, owing to the danger caused by the formation of hydrogen gas. Mr. Williams has given us something to think about as a result of his experience with brine pipes and various deposits found therein, and the probable source. He also attributes the action between the iron and lead in the presence of calcium chloride as being one of the causes of corrosion.

The question of thermometers, which was also referred to by the Chairman—these instruments should be of the very best quality and of slow movement, to enable the inquirer to take the temperatures accurately, especially at night or in heavy weather. These are now universally adopted; it depends chiefly upon the size of the bulb, which is practically insulated with wood or other substance.

Mr. Moore, as I have already mentioned, has had a very large experience in the growing and carriage of fruit, and his remarks are very welcome. The advisability of using self-registering thermometers I have referred to fully in the paper, but the main point is their non-reliability, particularly on board ship in heavy weather. Some thermographs have been known to go wrong, and in the event of a case of damaged cargo being taken to a court of law and tried before a non-technical jury, I am afraid if the thermograph diagram of temperatures differed from those entered in the log-book it would go hard against the shipowner, who is, therefore, justified in being somewhat chary in adopting the use of these instruments.

Mr. Linley gave us a very interesting description of his experiences abroad, particularly in connexion with this industry. I have always thought sterilization necessary, especially in holds of vessels where emigrants have been carried, and as regards chilled beef the coverings should be sterilized before use.

Mr. Farenden referred to the effect of convection currents of air. Experience shows that in chambers of from 7 to 12 feet deep there is little or no difficulty in maintaining the necessary temperature, the difference between the top and bottom being only 1°, i.e. with good insulation. As regards

adopting the forced air circulation by the battery and fan system, I am afraid that in long voyages it would have a desiccating effect on the beef, and favour shrinkage. What we have to carefully watch is in cases where chilled beef is carried in 'tween decks above lower holds containing frozen cargo. The temperature of the air in the 'tween decks requires to be kept (say) at 29° F., while that in the hold may be below 10° F.—a difference of 20 degrees—and unless the deck between these chambers is efficiently insulated the very low temperature in the hold will affect that in the lower part of the 'tween deck. This has been known to freeze the lower extremities of the quarters by conduction through the deck beams—these not being properly insulated and the frozen cargo being kept at an unnecessarily low temperature. When this is experienced there is no control of the temperature in the 'tween decks, convection currents being retarded.

Mr. THOM : Could it not be regulated at the battery ?

Mr. BALFOUR : Supposing the ship has a list or her trim is altered, and it was found that the temperature was rising at the far end of the chamber, what would be the result ?

Mr. THOM : But you have told us the temperature does not vary more than a degree.

Mr. BALFOUR : Yes, by the direct brine circulation system.

Mr. THOM : I do not agree. You told us to be so careful about the cold coming up from underneath, that is with an insulated compartment. What about the effect of the sun overhead ? there is no more insulation there than there is down below. You spoke of there being 20 degrees difference between the lower and upper holds, yet why not speak of the 80 or 90 degrees on the top ? Is it not possible there might be a variation of 2 or 3 degrees in the hold ?

Mr. BALFOUR : I think the insulation on the top is a secondary quantity compared with that of the deck between.

Mr. THOM : Admitted, for doing damage to the cargo.

Mr. BALFOUR : To adopt your suggestion would mean to go contrary to the laws of nature.

Mr. THOM : It is against the laws of nature to expect the

coldest air to move from the bottom without mechanical means. The only thing you have told us is to be careful not to forget this cold hold underneath, which if utilized by stirring the air would reduce the work to be done with the pipes.

Mr. BALFOUR : We are considering the different temperatures in the two compartments and their effect.

Mr. THOM : No, no ! in the same compartment.

MR. BALFOUR : The cooling medium is chiefly on the top and can be controlled at any part of the chamber by the arrangement of grids. You refer to the effects of the sun. Supposing the ship's side be exposed to an outside temperature of 100° F., brine pipes are fixed along the sides to overcome that.

Mr. THOM : To get rid of the heat at that point.

Mr. BALFOUR : For example, the air in the lower hold is at 10° and in the 'tween deck at 29½°, and two thermometers are fixed in the 'tween deck, one a foot from the top and the other a foot from the bottom—the top one registers (say) 29½° and the bottom one 28½°—there is practically no circulation of the air in the 'tween decks, the very low temperature of the air in the hold below affects it by the conduction through the deck beams. If the temperature of the lower hold was raised to say 90°, which would be the case with a cargo of grain, I think it would be comparatively easier under these conditions to carry the chilled beef, as there would be more natural circulation of air.

Mr. THOM : I do not see that you have made your position good. The 10° still annoys you, and you cannot carry your chilled beef properly because of the cold temperature underneath. Why not use it for some purpose, why not stir the cold right through the chamber and do away with some of the pipes at the top ? I say circulate it, not necessarily in trunks. The cold you have already is the very thing you want, but move it.

Mr. BALFOUR : I believe mechanical circulation is a good thing for a deep hold. When we take a hold (say) 19 feet deep convection currents cease to a certain extent with the limited

narrow range of temperature, and in that case, as I suggested in the paper, it would be perhaps advisable to adopt some means of forced air circulation. I had had discussions at times on this subject, and on comparing notes find that this is the trouble, and have advised the adoption of fans to assist the air circulation in deep holds. Only the other week in the case of a deep hold where there were four or more tiers of quarters, it was found that they must move the air either by fixing more piping at a lower level or by assisted circulation. I quite agree with the air circulation in these holds, but that is a different matter from that of the temperatures which we have been considering. I am only trying to give engineers some information which they may not already possess. They may find that if the cargo in the lower hold is carried at such a low temperature as that I have mentioned trouble may be looked for in the chilled chamber above. I think it is unnecessary to carry frozen meat at such low temperatures. It could be carried at 18° so as not to affect the temperature in the upper chamber. With regard to the point raised by Mr. Hal Williams as to the difference between frozen and chilled beef, I have at times examined the freshly-cut surface of meat after being thawed, and have always been led to believe that the water ran with the blood, and also that it was due to the frozen moisture in the fibrous tissues breaking up when brought into contact with the higher temperatures. It is a moot point, however, and well worth considering.

Mr. Milton dealt with the scientific part of Mr. Hal Williams' remarks and inquiries regarding "enzymes," and I will not go further into that subject, but I think these enzymes play an important part in the structure of the animal. He also referred to the question of the wood, which is also a very important point. I may say with regard to Mr. Moore's remarks that the thickness of the scantlings of the wood cases carried in the *Durham* was ½ inch. Lately there has been a tendency to reduce this, but as the pressure of the cases against each other, also the weight of the man loading and discharging, presses the thin wood against the apples, this should be seen to in future. I think if we had thicker scantlings we would get better results. Mr. Williams also referred to the impossibility of carrying on trade without opening the holds, and while this is true to some extent, it is very essential for the hold to be filled in as short a time as possible, apart from

the question of moisture altogether, so as to get a fair start with the greater portion of the cargo. The Chairman's remarks about thermometers I entirely agree with. He opposed my remarks with regard to the insulation of the vessels in the old days, but in the case of Swift and Co. I think their representatives did pay, comparatively speaking, more attention to the insulation. I must thank you for the kind interest you have taken in this paper, and am only sorry the questions of brine mixing, circulation, and methods of construction, etc. were not brought forward in the course of the discussion.

A vote of thanks was accorded to Mr. Balfour on the motion of the Chairman, seconded by Mr. Thom, and to the Chairman, on the motion of Mr. Balfour, seconded by Mr. Linley.