Discussion.

Mr. J. Wolfe Barry, C.B., President, was sure that the members would all recognize from the Author's interesting Paper that an important trade had grown up and had become flourishing within a comparatively few years. It was a trade of the greatest interest to everybody in the United Kingdom, as well as to their brethren in the Colonies. It was also of much importance from the point of view of the British producer, who would have to take the facts that were set out in the Paper very seriously into his consideration. He could imagine that the Colonial Secretary might view the work of the Author with the greatest admiration, and that the Minister of Agriculture would look at it with very different feelings. However that might be, the members could all see that the works which had been described were not only of a most extensive nature, but that every detail connected with them appeared to have been carried out with the utmost care, and with much scientific precision. He was certain he was speaking the sentiments of the members in saying that they were very grateful for the Paper, and admired the talent which had produced such interesting buildings, and such carefully-designed machinery. They were also obliged to the Author for the fine set of diagrams which he had prepared to illustrate his Paper. Mr. Wolfe Barry.

Mr. Donaldson desired to state that the work at the Victoria Dock had been commenced by his predecessor Mr. Robert Carr, to whom the credit of the initial stage was largely due, and many of the results of whose labours the present works had embodied. The duty obtained with the automatic lift, a model of which was on the table, showed that it would do about three times as much work in a given time as the ordinary box type of lift, with one-third the number of men. With the ordinary type it was necessary to have trucks, and men to manipulate them, with separate lift-drivers for each lift. At present one man worked the whole from the ground floor. The carcases had not to be touched, except to guide them into separate shoots leading into the chamber. Mr. Donaldson.

Mr. Montague Nelson observed that one of the chief objects of Companies working refrigerating processes had been to place their machinery as near to the flocks of sheep as possible, and as far from the port as the risk of having sheep thawed before they Mr. Nelson.

Mr. Nelson. could be placed on board ship would allow. It was well known that driving sheep long distances produced a state of fever which was very detrimental to the meat; it was therefore desirable that they should be killed as near the pastures as possible. In Australia it was found that refrigerating machinery could be erected 200 miles, or 300 miles, from the port of shipment; and there was no difficulty in carrying frozen bodies by railway that distance in properly insulated trucks. In an insulated air-tight truck, with only 3 inches or 4 inches of insulation, packed full of frozen meat at a temperature of 15° or 20° F., absolutely excluding air and heat, the temperature would not rise for a very long time, and it could be taken with perfect safety 200 miles or 300 miles. That was very important, and had a bearing also on the trade in London. The Colonial Consignment and Distributing Company had refrigerating stores on the Thames, opposite the Temple Gardens, where frozen sheep were taken up the lift at the rate of about one thousand per hour. The lift was not exactly like the one described, but it raised the sheep very rapidly from the lighters to the floor where they entered the chambers, and proved very effective. As to the advisability of bringing sheep from the ships in lighters, say from the Albert or the Tilbury docks, so far up the Thames as between the Blackfriars and Waterloo bridges, when it was remembered that in Australia they were taken 200 miles or 300 miles by rail it would appear that in a properly constructed lighter, with the heat and air excluded, 10 miles, 20 miles, or 30 miles up the Thames was a comparatively trifling consideration. It was, as stated in the Paper, generally considered that the texture of beef was injuriously affected by freezing, but he did not think it was so. In experiments on the subject,[1] Dr. Rideal had been unable to discover that the meat was injured in any way by the process of freezing. In the early days of the frozen-meat trade it had been said that the cells of the meat were burst by the freezing, just as water-pipes were burst by the winter's frost, and that when the meat was thawed the cells were burst and the juice ran out, so that the meat was spoiled. On making careful enquiries and experiments, he had found in the first place there were no cells to burst. Meat consisted of bundles of fibres, with juice between them; but there were no cells. He might be permitted to give the results of a few experiments that he had made in connection with his process for defrosting meat. He believed that the popular error

[1] *The Hospital*, vol. xxi. pp. 265, 283, 314.

Mr. Nelson. on the subject had arisen from the fact that, when frozen beef was brought into the outside atmosphere at a temperature of perhaps 50°, 60°, or 70° F., the condensation of moisture of the atmosphere on it was very great. It became wet, and when it was cut in slices it was colder inside than out; there was condensation on the cut parts, and the water mixed slightly with the juice of the meat and ran away, giving the impression that all the juice was running out of the meat. It was simply the moisture of the atmosphere condensed upon the meat, just as water was condensed on any cold body. It had occurred to him that to remedy the evil the beef should be heated to the temperature of the outside atmosphere without allowing the deposit of moisture upon it, in a warm dry atmosphere. It was easy to obtain the warm atmosphere, but the question was how to get it dry. He had come to the conclusion that the simplest way was to freeze the moisture out of it. He had fitted up a small room with ammonia pipes running along one side and steam-pipes along the floor. The meat was hung in the room, and all the moisture in the atmosphere was immediately frozen as snow on the cold pipes. The room was heated gradually to about 60°, and the result was that the beef was defrosted without any deposit of moisture upon it. In one of his experiments, carried out in a room holding about ten quarters of beef, the temperature was raised to about 60°, but notwithstanding that, and even when it was raised to 90°, the pipes remained with about ½ inch of snow on them, derived from the moisture from the atmosphere. After he had thawed the ten quarters of beef he had weighed the moisture, thawing off the snow, and found that there was 160 lbs. of water on the pipes. Probably that amount of water would have been deposited on the meat by any other process; and that, he believed, was the cause of the disrepute into which frozen beef had fallen. By the application of the defrosting process no one could tell from the appearance of the meat, or its taste, or anything else, that it was not ordinary fresh-killed meat. The first frozen meat had been brought from Australia in 1880. From that time to the end of 1896 37 millions of sheep and lambs had been imported into Great Britain. The number imported in 1880 was only 400, while in 1896 the number was 5¾ millions, besides 250,000 cwt. of beef. That was independent of the chilled meat from the United States and Canada. It was actually frozen meat coming from the Australian Colonies or from Argentina. The possibilities of the trade were enormous. It appeared that the discovery of refrigerators would probably revolutionize the food-supply of the world. He believed

Mr. Nelson there would be refrigerating stores in every town in England. There was in London alone a storage capacity for more than 1,000,000 sheep—a very large number when it was remembered that the total number of sheep in England was not more than about 27,000,000. The process applied not only to meat, but to butter and many other supplies. Within the last few days his Company had sold excellent peaches from South Africa at *4d.* or *5d.* each, leaving a good profit to the South African grower, since the cost of bringing peaches to England from the Cape was not great. Now that fresh meat could be conveyed 12,000 miles, the result had been that the supply had exceeded the demand. Meat was not like most other commodities, and a reduction in price did not necessarily lead to a largely increased consumption. Australian mutton was now to be obtained at *2d.* per lb. Householders would remember how the price of meat increased between 1852 and 1872. In 1870, importations began from the United States, and they now formed 25 per cent. of the whole consumption in England. In 1880 the importations commenced from the Australasian Colonies and from the River Plate, with the result that meat was now cheaper than it was in 1852.

Hon. W. P. Reeves. The Hon. W. P. Reeves had the honour to represent a Colony which was sending yearly to Great Britain between 100 million and 150 million lbs. of frozen mutton. New Zealand did not export beef to any extent to Great Britain. For beef, such a defrosting process as the interesting one described by Mr. Nelson was a necessity; in the case of mutton it was in the nature of a luxury, since any intelligent person having a decently-built house ought to be able to successfully thaw his own mutton without trouble. On behalf of New Zealand he thanked the Author, who had not only studied and mastered the subject, and gained information of great value to himself and to the Dock Companies and owners of stores, but he had had the industry and generosity to make it public for the benefit of others. It was quite in the spirit of the Institution that scientific information should be made public for the benefit of science. Cold storage was now a question affecting not only London and two or three of the principal parts of the country, but every place of any magnitude in the United Kingdom, as well as in most other civilized countries.

Sir Alfred S. Haslam. Sir Alfred Seale Haslam observed that reference had been made in the Paper to an experiment tried at Deptford by his firm. It was more than experiment, for last season the chill-rooms available had been used for chilling eight hundred sides of beef per day of sixteen hours; and, now that the new rooms were finished, two thousand sides could be chilled in the same time. The plant consisted of an ammonia compression machine, combined with the Haslam cold-blast battery. In Fig. 1, Plate 2, the Author had shown a cold-air machine applied to a cold store at Victoria Docks, which Sir A. Haslam had fitted up many years ago. It was, he believed, one of the most successful stores of the kind in the kingdom, and was worked with the dry-air machine on the compressed-air system. It was fixed in a central position very favourable to working, but with a building like that erected at Smithfield by the Author, however good the results might be at the store No. 1 at Victoria Docks described in the Paper, still better results would have been obtained. From the cubical capacity of the store at Victoria Docks, and the surface of the wall and the loss by conduction, there would be found an immense interchange of heat. In the other case, at Smithfield, the interchange was vastly different. In the case of the Victoria Dock store (which he believed had answered fairly well), that was an unfavourable comparison with the Smithfield store. He desired to state a few of the results of the dry-air machines on board ship, and to call attention to a machine he had erected on board one of the first steamers that ever brought a cargo of meat to England. At that time there were three steamers fitted with Haslam machines, carrying 200 tons of meat per cargo. The walls of the chambers were of very large area. The steam-pressure was about 70 lbs. per square inch. It was a comparatively small machine, and it required about 30 cwt. of coal per day in bringing 200 tons of meat from Australia to England. A few days ago he had looked at some records of a recently fitted boat, one of a number of the same kind. They had brought from Australia about 90,000 carcases of sheep and lambs and 200 tons of cheese, with a coal consumption of 4 tons per day. The efficiency of cold-air machines had increased to a very great extent, and ships were now built specially for the trade; the machines could therefore be placed in the most favourable position for obtaining the best results. The cubical capacity of those chambers was very large compared with the surface of insulated walls; they had therefore an immense advantage. More than 2,000 tons of meat and dairy produce could now be brought over with 4 tons of coal. Considering the weight of a cold-air installation and the space it occupied, and remembering that weight and measurement on board ship were the two great things a shipowner had to consider, he maintained that the cold-air machines had an advantage over any economical chemical machine in existence. Moreover, air could be obtained all over the world,

Sir Alfred S. Haslam.

Sir Alfred S. Haslam. and water could be taken from the ocean, so that both articles were cheap. Very little difference would be found in the results on board ship, and the risk of accident to an air-machine was nominal.

Mr. Harris. Mr. H. GRAHAM HARRIS noticed that the Author had given a description of three or four installations he had erected, where the principle of refrigeration was employed for the storage and preservation of food products. Although that was probably one of the main uses of refrigeration in England at present, it was by no means the use which was most common throughout the world. The employment of these machines in America and on the Continent was much more general, and this want of development in England was probably due to the temperate climate, as compared with the extremes of heat and cold of those countries. The uses to which refrigerating machines were being applied were extremely numerous, and he thought that if in years past the possibility of easy reduction of temperature had been known, those uses would by now have been enormously increased, and might have been as numerous as the uses of increases of temperature obtained from fuel and fire. Refrigerating machines were employed for skating-rinks, in chemical works, in the production of gelatine and of photographic films, in ice-making and chocolate-making, in dairies, for food storage and for brewers' purposes—probably brewers were the largest users of refrigerating machines throughout the world. Considering the question generally, there were two objects to be attained; one to produce the low temperature, and this was now an easy matter with almost all the machines available; the other to keep the "cold" when it was obtained, by providing a fairly perfect heat insulator. It was a truism that with a vessel absolutely and perfectly insulated, so that heat could not pass in, when once the temperature was reduced there would be no need to expend power to maintain the low temperature, and no need to reduce it again. The medium in which low temperatures had, as a rule, to be produced, was atmospheric air, which was a fluid, and, like all other fluids when at a low temperature, was denser than when at a higher temperature. He had taken an open-topped vessel, a cube of about 6 feet, then, insulating the sides and bottom as perfectly as possible, he had kept it standing in a mechanic's shop where the temperature ranged between 60° and 70°; the temperature of the air contained in the vessel had been reduced mechanically to 15° or 20°, and so little tendency was there for the hot air in the shop and the cold air in the vessel to mix, that the temperature of the air in the vessel, after being left for hours, had not sensibly increased, and on putting the hand into the vessel, the difference in temperature between the atmosphere of the shop and the atmosphere of the vessel could be readily distinguished, the sensation being that of putting the hand into a tank of cold water. This experiment taught that a storage-chamber, in which to maintain low temperatures, should be without openings in the side, but with openings only in the top. He, with Sir Frederick Bramwell, had erected the great storage warehouse at Nelson's Wharf, which could hold nearly a quarter of a million of sheep, and consisted of a brick box carried down to the gravel some 23 feet below the surface to get a good foundation; in order to obtain sufficient storage capacity, having regard to the area of land at disposal, it was carried up some 23 feet or 24 feet above the surface; and there were no openings in it except in the top floor. The only purpose of the brick box was to contain the insulating box, which consisted of wood. This was constructed at the sides of three thicknesses of match-boarding with brown paper between, then 15 inches of sawdust, and then again match-boarding with brown paper between, the bottom being similarly insulated; this construction was adopted so that heat-infiltration might be prevented. The chamber, having a capacity of about 900,000 cubic feet, was now kept at a temperature of about 15° or 17° below freezing-point, with an expenditure of less than 1 ton of slack coal per day. This was easily accomplished by the refrigerating machine employed, but he did not think the small amount of coal required was entirely due to the efficiency of the machine; it was rather due to the shape of the store and to the efficiency of the insulation. The store had been designed and built in the manner described after a considerable number of experiments had been tried. With such a construction there must be an increase in the cost of handling the meat, as it was obvious that everything had to be lifted 23 feet from the ground and dropped into the store, it might be to a depth of 40 feet to 45 feet, depending on the floor where it had to be dealt with; and when it passed out, it had again to be raised to that height and again be lowered to reach the ground level before being taken away in carts. But this increased cost of handling was more than counterbalanced by the reduced cost of maintaining the low temperature, and most of all by the certainty with which this low temperature could be maintained. After years of experience at Nelson's Wharf, the new store now in course of erection on the bank of the Manchester Ship Canal was being built in an exactly similar manner. He should like to utter one or two words of caution as to the mode in which

Mr. Harris.

Mr. Harris. "insulation," as it was called in the refrigerator business, had hitherto been tested. All the tests of which he had been able to find records had been tried in this way: a given weight of ice was enclosed in a box constructed of wood, or, in some cases, of tin, and round the box was placed a certain thickness of the insulating material to be tested—charcoal, slagwool, silicate cotton, coke, breeze, hard-wood sawdust, soft-wood sawdust, in fact every material that could be suggested had been tried. The ice when put in the box was carefully weighed; the box was then closed, and after a certain time it was opened; the weight of the ice left was taken, and the difference was estimated to represent the value of the material for insulation. Various materials were tried with the same weights of ice, and that which showed the greatest weight of ice unthawed after a given time was assumed to be the best. Now ice that was "hard frozen" would thaw very much less rapidly than ice "soft frozen"; and although the weight might be the same, and although the temperature registered by the thermometer when put in contact with the ice might be the same, yet the number of "cold units" contained in any given weight of ice might vary considerably, and also the rapidity with which different pieces would thaw would vary considerably, depending upon the way in which it was frozen, and upon the position in the original block from which the piece had been taken. The reason was obvious; frozen ice was more or less porous, and the more porous the piece the greater the surface, per unit of weight, exposed to the thawing action. Further, although atmospheric air was one of the best insulators, it was also one of the elements which would most rapidly communicate heat from one body to another, and thus most rapidly destroy the effects of insulation. He had come to the conclusion that the best insulator was a material which, while a non-conductor of heat in itself, divided the air into the smallest possible particles, and was so compact that each particle of the material was in touch with the adjoining particle, thus forming a number of minute air-cells, there being no circulation of air throughout the mass and from one cell to the other. The rapidity with which porous ice—"soft-frozen ice," as it was known in the trade—although its weight might be the same, would thaw, as compared with "hard-frozen ice," was very marked. As the result of many experiments, Sir Frederick Bramwell and he had come to the conclusion that ice was unsatisfactory when used for testing insulation, and that the results obtained might be fallacious. The neglect of these considerations probably accounted for the different results with the same materials recorded by different

Mr. Harris.

experimenters. In his experiments he had taken maximum and minimum thermometers, carefully calibrated before and after use, and suspended by pieces of string from each end from nails driven into an air-tight wooden box, placed inside another circular box, with the material to be tested between the two. The result of a great many experiments, taking into account the two elements of cost and efficiency, showed that hard-wood sawdust, "flour" sawdust, such as was obtained from cutting veneers, and was made in quantity by railway-carriage builders, &c., was the proper material to use. In fact, it had been used at Nelson's Wharf, where, as he had said, whether it was due to the brown paper, which was also used, or to the wood, it was possible to keep a store (containing the large storage capacity stated, and passing in and out every day probably from ten thousand to twenty thousand sheep) for years and through the hottest summer weather at a temperature of from 15° to 16°, with an average expenditure of less than one ton of Durham slack coal per day.

As to the coal efficiency of the various refrigerating machines, he thought it was not an all-important consideration. Refrigeration was almost always an adjunct, and only an adjunct to a trade. In the case of ice-making, which was probably one of the most concrete instances, many makers of machines would say that they could make a ton of ice for a little over 4*s.* That might be so, but it could not be sold to a customer for less than 11*s.*, after bearing the expense of storage, extending probably over many months, with the possibility of no sale to-day and of a large demand to-morrow. A difference of even 25 per cent. in the coal-efficiency of any two machines would make so small a difference upon the total cost of 11*s.*, and there were so many other ways in which it was possible to save the difference of cost between the coal for one machine and the coal for the other, that it was certain the engineer should not take into consideration merely the coal-efficiency, but the easy working of the machine—should obtain a machine which would give but little trouble, and which would not cost much in repair. Those were the points which had been considered at Nelson's Wharf. In addition to the de la Vergne machines by which the work was really performed, a comparatively expensive machine from the point of view of coal-efficiency—the dry cold-air machine—had been employed. The butchers had affirmed that it was absolutely necessary, in a store of that capacity, that there should be a continual circulation of cold air. It was true that the machine had been erected as a stand-by machine, and therefore to that extent it was an "insurance," but it had been adopted, although

Mr. Harris. more expensive, because of the alleged necessity of a continual circulation of cold air where cold meat was to be stored, some of which might come in at times from the ships in a "soft" or semi-thawed condition. The cold-air machine was only worked once a month, the de la Vergne machine being ordinarily used. These latter were ammonia compression machines with two vertical pumps, and, probably, from the point of view of coal-efficiency, were the most satisfactory. He was not sure, however, that the old absorption machine, of which the brewers employed so many, was not as good as any for mere cold production. It was not perhaps scientifically as satisfactory, but it was good enough, and it scarcely ever gave any trouble. Such a machine had been erected at Meux's Brewery twenty years ago, and when his firm had been called upon to test it two years ago, after an expenditure of about £100 in cleaning and overhauling, its efficiency was practically the same as when it was first erected, and as regards coal-consumption it was practically as good as the best compression machine. His opinion was that coal-efficiency was not by any means the principal point to which the engineer should direct his attention; but where used for food storage, his great object should be to maintain the cold by means of good insulation. The use of the machines in America and on the Continent by brewers was far in excess of any use to which the machines were applied in England for all purposes, and it was to the American and to the foreigner, especially the German, that the English engineer had to look for knowledge on the subject.

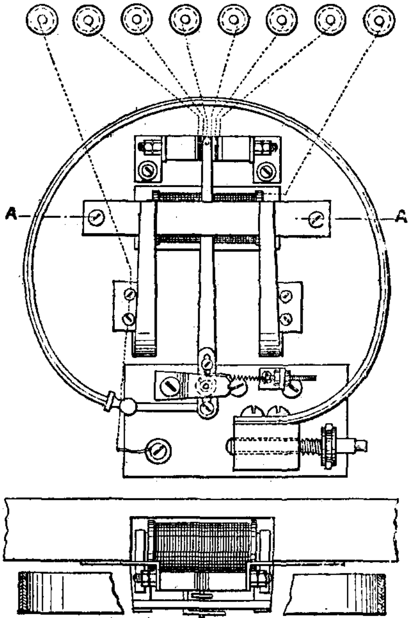
Mr. Marcet. Mr. Alexander Marcet desired to refer to one of the newest machines, of a type introduced by Messrs. J. and E. Hall, of Dartford, about seven years ago, one of the peculiarities of which was that it used what was then an entirely new material for refrigeration purposes—carbonic-acid gas. Particulars were given in the Paper of various materials used for insulating purposes, and the Author stated that he had found silicate cotton more efficient when loosely packed than when tightly packed. Their experiments entirely agreed with that statement. All that was wanted was material which would form as many air-cellules as possible. There was, however, an objection to loosely packed insulating material, particularly on board ship or in any buildings subject to vibration, namely, that it might in time settle, and the place from which it settled would form a duct through which heat could pass; the material should, therefore, be so tightly packed that it would not settle, and, in case it did settle, arrangements should be made round the upper walls of the cold chambers to remove the top board and fill the space left vacant with further insulating material after, say, two years' work. He agreed with what Mr. Harris had said as to sawdust. His firm had made many experiments with different insulating materials, charcoal being previously considered the best. The apparatus used did not depend upon the rate of melting of ice, but consisted of a tin box containing a known weight of warm water at a given temperature surrounded with a certain thickness of insulation. The experiments lasted over twenty-four hours, the temperature outside the insulation being maintained constant, so that the loss of heat from the warm water contained in the tin vessel inside the insulating material could be measured accurately as the water cooled, by carefully recording the fall of the thermometer in the water, and a curve was afterwards drawn showing the fall. With this apparatus experiments with a dozen different materials were made, and a dozen different curves were obtained under exactly the same conditions, so that they could be compared. That material which maintained the water warm in the tin box the longest time was the best insulator. Sawdust was found very good if it was dry, but if it became damp, it lost a good deal of its insulating property. He entirely agreed with the Author that the vertical type of compressor was preferable; it was indispensable when a liquid seal had to be obtained around the gland, as was the case with some of the ammonia compressors. When no liquid seal was desired, it was a matter of importance to have vertical valves, so that the weight of the valve was evenly distributed, and the wear round the valve-seat was uniform. For that purpose they used steel compressors with vertical valves. An important point in all cold-storage installations was the method of applying the cold. With the air-compression machine, the cold air was pumped into the chamber, and nothing further was required beyond regulating the slides—dividing the cold air equally all over the chambers, if there were a number of them. But the newer or chemical types of machines were either utilized to cool brine, or cold was produced by direct expansion—ammonia being allowed to circulate in pipes within the chamber. The direct-expansion method was a good one in that it saved the brine altogether, so that one of the losses of the refrigerating machine was done away with, but it was somewhat risky. There had been occasions in almost every direct-expansion ammonia plant where some joint had been badly made and the ammonia had escaped into the chambers, the results being sometimes serious. A system had therefore been adopted by his firm in which brine was circulated through pipes in the chambers. That system had the advantage, Mr. Marcet.

Mr. Marcet. where there were seventeen chambers, as there were in the Smithfield store, of maintaining any temperature that might be required in any one of the chambers. Each chamber had its own circulation of brine-pipes, and each brine-pipe commenced at the main supply-pipe and terminated at the engine-room, where it was fitted with a thermometer and a regulating-valve. Another system consisted in circulating air by means of a powerful fan over the surfaces wetted by the brine. In that way the desired result might be obtained and air at only a moderately low temperature, as compared with the air-compression machine, could be circulated through the chambers, but it had a disadvantage that the moisture contained in the meat or the goods to be stored passed into the brine, which in the course of time became weakened and had to be reconcentrated. That presented no great difficulty, but it needed care in working the machine and maintaining the brine at a constant density. There was also loss in reconcentrating the brine and making it up to its proper strength. That system involved trunks and slides. When it was required to shut off or add a chamber, some regulation was necessary to distribute the air evenly by setting the slides, which sometimes meant going into the cold chambers. With the brine system the whole regulation could be done from the engine-room, which was considered by many persons to be a point of importance. The carbonic-acid machines, though using a safer material, differed from the ammonia machines in that the pressures required to liquefy the carbonic acid were high—they were hydraulic pressures and under temperate conditions, with condensing water at 70°, the pressure was sixty or sixty-five atmospheres, or about 900 lbs. per square inch. Those pressures would have been deterrent some years ago, but now that marine boilers were worked up to 300 lbs. per square inch with a diameter of 14 feet, he did not think that 900 lbs. pressure per square inch in a pipe of 1 inch diameter and $\frac{1}{4}$ inch thick could be a source of fear to engineers. Their methods of testing were special—every piece which was subject to the pressure of carbonic acid is first tested for strength to 3,000 lbs. per square inch by hydraulic pressure, or three or four times the working pressure, and then again tested when submerged in a tank of water, under compressed air at about 1,500 lbs. per square inch pressure, when any porosity would be indicated by bubbles, and after personal examination under both tests the foreman of that department then stamped the part with his initials; after taking that course leakages of the carbonic acid through the metal were almost unknown. Carbonic acid must be added to the machine from time to time, as with all machines using any material in a closed cycle. But the additions were small, and, moreover, the cost of the material was very small. Another point in connection with the safety of the machines was that, owing to the practically harmless qualities of carbonic-acid gas, it was easy to fit machines with a "weakest part," so that in the event of an attendant overcharging a machine or starting it with his delivery valve screwed down, say, after the examination of the compressor, instead of an accident occurring, the "weakest part"—a small copper disk about as thick as a stout piece of paper—gave way, making a noise like a pistol shot, the result being that the attendant took care on the next occasion to open the valve; no accident, however, could arise, and the carbonic acid might be replaced at a cost of a few shillings. With regard to machines using ammonia, the escape of ammonia was known to be dangerous, and he observed that the Board of Trade had recently taken the matter up with regard to ammonia machines in the main engine-rooms of steamers, where escapes of ammonia had been known to turn everybody out. The question of coal-consumption was a very important one in the trade, but he agreed with Mr. Harris that an unnecessary degree of importance was attributed to it. There were a great many other things besides coal-consumption to be considered; still it was a convenient basis of comparison. It had been said that with the air-compression machine on board ship 2,000 tons of frozen meat had been carried with a consumption of 3 tons of coal per day. He had results from recent logs of steamers fitted with Hall carbonic-acid machines. One steamer running from Buenos Ayres to London (her third trip), fitted two years ago with a carbonic-acid machine, carried 1,460 tons of meat; the refrigerating machine was of 110 I.HP., which at 2 lbs. per I.HP. per hour showed less than 1 ton of coal per day, the machine working on an average 10·4 hours per day. The value of the carbonic-acid gas used on that trip was £6—a not very deterrent element. Another steamer (on her fourth trip) sailed from Sydney to London in sixty days, carrying 1,461 tons of meat. The machines worked 7·8 hours daily, and 2 lbs. per I.HP. consumed 15·6 cwt. of coal per day. The value of the carbonic acid consumed was £8 10*s*. A third ship (on her first trip), fitted last year, carried 1,800 tons of frozen meat from New Zealand to London. That ship was fitted with a duplex machine, one half of which worked 10·7 hours per day, so that the consumption of coal in bringing that cargo and maintaining the holds at about 10° F. was less than $\frac{1}{2}$ ton per day, which he ventured to say was an improvement on previous performances. The value of the carbonic-acid gas in that case was £11 10*s*. Owing to the careful method of testing the various parts

Mr. Marcet.

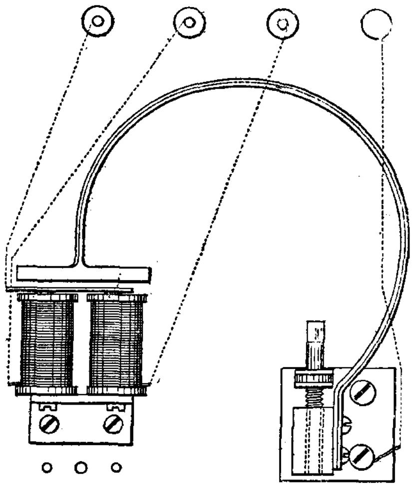
Mr. Marcet.

Figs. 22.



SIX-WIRE LONG-DISTANCE THERMOMETER.

Fig. 23.



THREE-WIRE LONG-DISTANCE THERMOMETER.

and the presence of the safety-valve referred to, no accidents had occurred on account of the pressure of carbonic-acid gas in any of the refrigerating machines built by his firm.

Mr. Vernon.

Mr. C. E. VERNON explained that the electrical thermometers fitted to the West Smithfield Cold Meat Stores, *Figs. 22*, were on a multiple-wire system. For a range of 11° F. it was necessary to have a six-wire main with six points of contact with the instrument in the chamber, and a six-drop indicator in the engine-room. For a range of 20° it would be necessary to have eleven wires, so that for a long range the multiplication of wires might become an objection. Since the system had been fitted to West Smithfield, further experiments had been made on the three-wire system. The same compound coil of hard brass and steel was used; but instead of the connecting link and movable hand, a small iron bar was attached to the loose end of the coil at a given distance from an electro-magnet, *Fig. 23.* Owing to the unequal expansion and contraction of the two metals, the distance between the bar and the magnet varied according to the temperature, and the quantity of the current taken to draw the bar down to the magnet was measured by the ampere-meter. This was constructed so that when the bar touched the magnet it completed a second circuit and stopped the hand of the ampere-meter at a given point. The ampere-meter was calibrated and marked off into degrees Fahrenheit, and by that means a long range in temperature could be obtained with only three wires, accurate to within a degree, and which could be read at any distance. He might add, although not coming within the subject of refrigerating plant, that the same system had been applied to pressure-gauges, more especially where they were used as weighing machines for hydraulic and other cranes. On a wharf, for instance, where ten coaling cranes were used with the old system, a special man or meter in each box was necessary to take the weighing of the coals, whereas one man in an office could weigh for the whole of the ten cranes with the same speed and accuracy if fitted with electric weighing machines. Mr. Vernon.

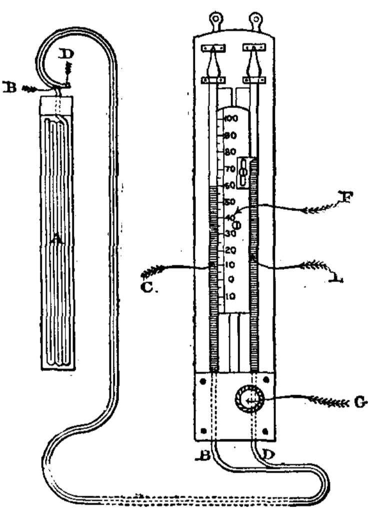
Mr. W. Worby Beaumont thought the relative costs of the materials experimented upon should be added to the results the Author had given of tests of various heat-insulators. Different thicknesses of material were mentioned in the Paper varying between 4½ inches and 11 inches; and the materials used appeared to differ in value probably as much as 150 per cent. The differences in the value for equal thickness from the heat conductivity point of view were very small, as far as two at least of them were concerned. For instance, whereas the silicate cotton—which was the best in all cases—when represented in percentage of mean conductivity was 23·1, magnesia and asbestos fibre came out at 25·4. The difference between those two was so small that the question of the cost of the two materials would probably determine the use of the one or the other. So again with regard to the two other materials which worked out for equal thickness as 48·1 per cent. and 46·1 per cent.—two materials which he should think probably differed in value at least 300 per cent. Flake charcoal at, say, £4 5*s.* per ton, or about 5·5*d.* per cubic foot, would cost 2·75*d.* per square foot of wall insulated 1 foot thick, more than with silicate cotton at £5 10*s.* per ton, or, say, 6·25*d.* per cubic foot, because the conductivities were relatively as 23·1 and 35·15. The space occupied by the less efficient material must also be counted in the cost. The cost, therefore, of those materials, and the cost of the means of packing and holding them, would be seen to be of great importance in connection with the other figures which the Author had obtained. But there were other matters connected with the insulating walls which appeared to be of great import- Mr. Beaumont.

Mr. Beaumont. ance. In all cases brown paper was used, as was also match-boarding, &c., of certain thicknesses. In some of those materials the great desideratum was the prevention of the circulation of the air imprisoned in minute sponge-like or cellular volumes. That being the case, it appeared that investigations which might be of practical value could be extended to other materials than those mentioned, which included silicate cotton, sawdust, peat, charcoal, and magnesia and asbestos fibre. It was questionable whether some of those materials were not much more expensive per square foot and per unit thickness of walls than other materials which would effectively prevent the circulation of the air. If that were the case, it would appear that makers of brown paper and spongy papers might very usefully turn their attention to the production of cellular papers that would be wanted in large quantities for the purposes mentioned in the Paper. Further, it appeared that some of these questions might be usefully and economically borne in mind in connection with ice-making tanks, which were more or less efficiently covered, but still not in a manner to be expected in an apparatus in which the preservation of a temperature vastly differing from the surrounding temperature was of the greatest importance. It was true that in connection with those tanks the difficulties would be much greater than with the dry walls of the storage warehouses, because of the quantity of water and moisture always present, which might destroy the material. But that there was neglect of insulation of those tanks was shown by the great importance that was attached to the proper insulation of the walls in the warehouses.

Mr. Halpin. Mr. Druitt Halpin agreed as to the necessity for regarding the question of cost in all matters of insulation. There were commercial differences of 100 per cent. or 200 per cent., which in a case of that kind were not to be lost sight of. He could not agree that the Author's experiments on the insulation were conducted in the best way to obtain satisfactory results. It was well known that there were different qualities of ice, hard-frozen, soft-frozen, containing greater or less quantities of air, and of different porosity; but there was also the temperature of the ice to be considered. Whether experimenters started with a block of ice, say 1 lb., at a temperature of 25°, or whether the ice was at zero, there would be a totally different number of thermal units to deal with, and without taking special precautions, very irregular and anomalous results might be obtained. Even if the temperature was measured at the outside, by placing thermometers on it, he did not know whether it was known how the temperature varied inside. He agreed that the whole principle of insulation depended on the molecular entanglement of the air. Air was the worst conductor known, but it must not be alone imprisoned, as it could be by two boxes one outside another, forming an envelope, but it must be molecularly imprisoned, so that any motion was practically impossible. Of all the substances that might be used, cork had given the most perfect results. In heat-transmission experiments he had conducted on the Continent some fifteen or eighteen years ago, using a method by the condensation of steam, he had, with a thickness of 1½ inch of cork, obtained reductions in transmission of 93 per cent. In other words, where the condensation without clothing was 100 per cent., with a coating of only 1½ inch of cork, it fell to 7 per cent. Mr. Halpin.

Mr. BERTRAM BLOUNT was struck with the great number of wires which the first instrument described by Mr. Vernon required for even a moderate range of temperature; but the feeling of dismay was removed when Mr. Vernon spoke of the excellent three-wire instrument since devised. The method of measuring the pull requisite to move the Breguet spring down to a determined point was a very happy one; but even with that clever modification, it appeared to him that further simplicity was still to be desired. There was another instrument in existence, and largely in use in a cold storage work, the long distance thermometer devised by Mr. A. P. Trotter, *Fig. 24*. If the stem of an ordinary thermometer were prolonged, the scale could be read at any distance from the stem, provided the temperature throughout the whole distance over which the stem extended was very much the same as that of the bulb. When there was a considerable difference between the temperatures of the stem and the bulb the expansion of the liquid in the stem was different from that in the bulb. That was fully recognised in the usual correction for the column outside the vessel the temperature of which was being measured. By greatly Mr. Blount.

Fig. 24.



TROTTER LONG-DISTANCE THERMOMETER.

Mr. Blount. extending the stem—making the thermometer with the scale at a long distance from the bulb—however capillary the tube connecting the bulb to the scale might be, the differences of temperature through which the stem passed would be sufficient to vitally affect the reading of the scale. Thus a thermometer consisting of a bulb placed in a cold store and a scale outside many feet away would not register correctly the temperature of the store, because the stem would pass through regions where the temperature was other than that of the bulb. In the Trotter instrument by the side of the elongated capillary stem, B, was placed a blind stem, D, which carried at its further end a scale-tube, E, precisely similar to that of the main thermometer, C. Whatever variation in reading was produced by the different temperatures through which the elongated capillary stem ran, the blind stem suffered the same alterations of temperature, and thus a shifting scale, F, adjusted by a thumb-screw, G, was established which precisely compensated the fluctuations of the main instrument. The plan of having a thermometer with a compensating index had been extended to other purposes than cold storage. Wherever it was necessary to read a temperature at a great distance, the thermometer could be applied, provided the temperature were not outside the range of ordinary thermometers. So that within the last year two modifications of the instrument had been devised; one was that in which temperatures ranging up to 260° F. could be read, suitable for drying-chambers, malting-floors, and the like; the other was one where the bulb was at a considerable height above the scale; that would be useful for the control of a ventilating and heating plant when the plant lay below the room to be heated or ventilated.

Sir Frederick Bramwell. Sir FREDERICK BRAMWELL, Past-President, said he might mention that, in regard to the question of there being ice and ice, a few years ago the Ordnance Committee, wishing to test the stability of armour-piercing projectiles against internal strains, were considering the question of keeping them in a cold chamber for a certain length of time. But before proceeding to build the chambers they, in order to ascertain the effect, prevailed on the late Mr. Perkins to freeze a projectile into a block of ice made by his Arktos apparatus and bring it down to zero. The block with a 100-lb. projectile in it travelled all the way from Gray's Inn Road to Woolwich, where it was exhibited at an evening entertainment, and during the whole of the time there was not the slightest dripping of moisture of any kind; the fact being that the block was thoroughly frozen through, and thus maintained a cold surface at such a temperature that there was no thawing whatever, in spite of its warm surroundings. Such a piece of ice, if used in an apparatus to show the value of non-conductors, would have given very abnormal results. Sir Frederick Bramwell.

Mr. DONALDSON, in reply, desired to mention the great care with which Sir William Armstrong & Co. had carried out the construction of the lifts, which had given no trouble, and had worked continuously without accident of any kind. In his remarks as to the transport of frozen meat 200 miles or 300 miles to the port of shipment, he thought Mr. Nelson overlooked the fact that the atmosphere in Australia was very much drier than in England. He did not, however, wish to raise any point as to the feasibility of the transport of meat in Great Britain. It appeared a question of providing the necessary protection in order that the operation might be as satisfactorily carried out here as there. He imagined that before the carcases had started on their journey they were seen to be in a proper condition, that the trucks conveying them were also seen to be in a proper condition. And probably, seeing that they had to deal with a somewhat higher temperature, the animals were thoroughly chilled and frozen through before being started. All that could as easily be done in England, if necessary, as in Australia. The use of dry-air machines appeared to depend very much on the surrounding circumstances: the cheapness of the water, which was essential to its economical working, the dimensions of the store, whether they were of more than one storey, whether it was possible to keep the engine at a sufficient height in order that the dry air might be economically lifted to the top of the building, or the chamber, as the case might be, so as to fall by gravitation. There was no doubt, however, that the dry-air machines had been of great service to his Committee; therefore he looked favourably upon them. The West Smithfield Stores and the Victoria Dock Stores appeared to be very different in the matter of superficial wall area, or exposed or cooling area. He had roughly computed for every 100 cubic feet of chamber capacity, the area of the outer surface of insulation, walls, floors and roof, taking only exposed floors into account. The West India Dock had 29 square feet for every 100 feet of storage; Victoria Dock 15·5 square feet; West Smithfield, a six-storey building, 12·8 square feet. Therefore the Victoria Dock and the Smithfield Stores did not largely vary, not nearly as much as might be expected from the drawings. The size and shape was, no doubt, a matter of great importance. If the insulation experiments were carried out air-tight he could not see that it mattered Mr. Donaldson.

Mr. Donaldson. whether the box containing the ice was sealed or not. With regard to the experiments he had carried out, he was alive to the difference between soft and hard ice; and, with a view to bringing the experiments all in one line as nearly as possible, the pieces of ice had been cut from the same block in each experiment, or, at any rate, taken off the same freezing. Uniformity was aimed at without, as one speaker had suggested, taking the internal temperature of each block. Provided it could always be kept absolutely dry, he thought there was little doubt that peat would give far better results than anything which had been mentioned, silicated cotton, charcoal or cork. He did not think cork could be obtained at a price commercially possible in quantities that would be required for stores like the West Smithfield store. But peat was, as a rule, certainly for building, out of the question, on account of its large capacity for absorbing water. He believed that over ten times its weight of water was absorbed when it floated upon the surface of a basin. He was not able to state the prices of the various materials he had tested, but he had endeavoured to test the thicknesses of the materials in accordance with the relative prices of the different articles. If, therefore, the material was 4½ inches, that was probably owing to the price quoted at the time, and was the extreme thickness he could use as against, say, 11 inches of charcoal. He concluded his remarks with an expression of thanks for the kind way in which his Paper had been received by the Institution.

Correspondence.

Mr. Bost. Mr. W. D. A. Bost, of Paisley, observed, in reference to the Author's thermal conductivity experiments, that there were three kinds of flake charcoal. The original material was manufactured from shavings by the Cartvale Chemical Company, Limited, Paisley, by a special process; a much heavier charcoal was also made from shavings, and the third was made from spent logwood and other such refuse. It would thus have been advisable if the Author had specified which of the flake charcoals he had used. As the tests had been made with different thicknesses of material, the Author must have used either a larger inside box, or a smaller outside box, so that the surfaces exposed either to the cold or to the heat and convection currents were not identical. He had made several experiments to test the conductivity of different insulators, and had been met by the same