such services beyond the boundaries proper of certain urban museums, the Carnegie United Kingdom Trust is prepared to give grants, any one of which is not likely to exceed £200.

The Museums Association is closely identified with the scheme, and applications or enquiries concerning these grants should be made to The Secretary, Museums Association, Chaucer House, Malet Place, London, W.C.1.

We would remind our readers in the Colonies that their museums also stand to benefit from the activities of the Museums Association, for the *Museums Journal* states that the Association is now prepared, through its Empire Secretary, at the above address, to receive applications for grants towards museum developments in the Colonies. These grants will be made from a fund of 54,000 dollars placed at the disposal of the Museums Association by the Carnegie Corporation of New York.

No single grant is likely, in the early stages of this interesting and highly-important experiment, to exceed £1,000, and although no limitations are placed upon the purposes for which a grant may be given, there is an understanding that it will be used towards purely scientific purposes, such as investigation of original collections and publication of results, or towards general museum organisation, such as the employment of expert help in reorganising collections and the purchase of cases for organised collections, or for educational work, on behalf of the people and on behalf of the curator himself, so that he may learn by visiting the best museums.

Here again there must be some sort of limitation; but the restrictions are very reasonable. No grant will be given to any museum which has not a qualified curator, whether paid or honorary; and no grant will be given to any museum unless there is definite proof that the authorities concerned intend to continue their active support of the institution.

In these provisions for the museums of the British Isles and of the Colonies, museums have placed before them such opportunity as has never before offered, and such as may not offer again. It is for them to show, by the devising of methods of arrangement and exhibition and of peaceful penetration which will create new links of interest between them and the people, that museums can become effective forces for the instruction and intelligent pleasure of the community, so that no man dare ignore their services. When museums have carried their progress so far, the Carnegie United Kingdom Trust can withdraw, having completed its mission; for from that time onwards public authorities will see to it that the museum is retained in its proper place in the framework of education. But if municipalities and museums allow these opportunities to slip through their grasp would the plain man not be justified in thinking (as some think) that many museums ought to take their place on the stage of life beside the "Sleeping Clergyman"? J. R.

The Engineer and Modern Civilisation*

By SIR FRANK SMITH, K.C.B., SEC.R.S.

REFRIGERATION AND FOOD SUPPLY

TO pass from the prime mover to food, the prime necessity of life, may seem a very big step. Indeed, so far as our food supply is concerned, many may wonder what particularly notable achievements, apart from transport, are to be credited to the engineer.

If we attempt to conjure up a picture of our food supply our view must include not only the produce of our own farms and fisheries, the great wheat fields of Canada, the sheep farms of Australia and New Zealand, the cattle ranches of the Argentine, the orchards of South Africa and other countries, but also the great ships which bring much of the food to our shores, the refrigerated stores in the docks, and in the market, the great chemical factories which turn out fertilisers and the products of a lesser known man who may be described as a biological engineer. To make the picture even more complete we might examine the contents of a grocer's shop with its hundreds of eggs in varying stages of freshness, a portion of Smithfield market with hundreds of carcases of New Zealand lamb, or even a hawker's barrow on a winter's day crammed with fruit which in former times would have been regarded as out of season.

To put a quantitative touch to the picture let us examine the returns of the Board of Trade. In 1932, we find that we imported on an average about one million pounds' worth of food every day. Of those eggs in shells which we saw at the grocers' shop we imported 2,000 millions. Those carcases of lamb we all know come mostly from New Zealand. How many carcases in all New Zealand sent us in 1932 I do not know, but the value of them was more than seven million pounds, and this represents but a small proportion of our imports of meat, which in 1932 were valued at more than 78 million pounds. What of those apples on the hawker's barrow? If they weigh from 3 to 4 to the lb. it is easy to calculate from the figures given by the Board of Trade that about 3,000 millions were imported; and there were about the same number of oranges.

The people of London could not be fed in this way in olden times. In the summer, food was of good quality and usually plentiful; in the winter it was poor and often scarce; sometimes very scarce; meat and fish were kept by curing with salt, and many vegetables such as carrots and turnips were preserved with honey to form a jam.

* *Continued from p. 129.*

During the last fifty or sixty years, and particularly during the last fifteen years, there has been a new outlook on food, and the outlook is in part that of the biologist and in part that of the engineer. Let us for a moment consider that New Zealand mutton in Smithfield Market. There was none such a hundred years ago, or even eighty years ago. It was not because New Zealand could not produce the mutton or because we did not want it; it was because it could not be transported. There was no engineer's ice in those days. In 1860, an attempt was made to bring a cargo of meat from Australia to England. The meat was preserved for as long a time as possible with natural ice, but the ice failed to last through the journey and the meat was thrown overboard. The engineer got over the difficulty; he made ice on the ship, and with this engineer's ice the first cargo of frozen beef and mutton reached us in 1877 from Australia. It may be truly said that there would be no New Zealand mutton eaten in England to-day were it not for the engineer learning how to produce cold by the application of heat. To-day, practically all the ice used for preserving food is engineer's ice, and it is to the engineer that the refrigerating machinery in ships, in the docks, in trains, and in the home is due. In ships alone, the freezing space carrying cold stored produce to Great Britain amounts to about 100 million cubic feet, equivalent to a cold store 20 feet high, 50 feet wide and 20 miles long, and the capacity of the public cold stores of Great Britain is approximately one half of this. Half a million tons of ice are made by the engineers for domestic and commercial land purposes, and three-quarters of a million tons are made for the sea fishing industry.

Let us look at this picture of refrigeration and see how it commenced. Exactly how long cold in the form of ice has been used to preserve food we do not know. Macaulay tells us that a little more than three hundred years ago Francis Bacon on a very cold day in spring bought a fowl and stuffed it with snow. He caught a chill and died about a week afterwards, but before he died he stated in the last letter he ever wrote that the experiment with the snow had succeeded "excellently well".

To the refrigerating engineer, however, the most interesting figures in the background are those of Count Rumford and Joule, whom we see once again demonstrating the convertibility of heat into work, and proving that heat is a mode of motion. It follows directly from these principles that since a particle of water vapour has more energy of motion than a particle of water of the same mass and at the same temperature, that if the vapour is continually removed by a vacuum pump or by absorption by sulphuric acid, and the water continues to give off vapour, that is, to evaporate, it will not only cool, but ultimately it will freeze owing to the loss of energy which has been transferred to the vapour. Here is a simple freezing machine based on the Rumford-Joule principle.

In the case of the prime mover, the working medium may be one of many fluids. It is usually steam, and in the internal combustion engine it is what Sir Dugald Clerk called 'flame'. Similarly, with the refrigerating machine, practically any medium which is liquid at ordinary temperatures and has a reasonable vapour pressure may be used, but for efficient and economical working the choice is limited to such fluids as ammonia, sulphurous acid, ether and carbon dioxide.

As with the steam engine, the first refrigerating machine was an atmospheric one and the medium was water and its vapour. It was made by William Cullen, who used a vacuum pump to remove the vapour. More and more heat was given up by the water to replenish the vapour above its surface, and eventually the water froze. Later, Leslie invented the sulphuric acid absorption machine which was developed by Carre and Windhausen.

The development of the steam engine was in the direction of increased pressure and that of the refrigerating machine was in a corresponding direction. It follows that if work is done on a gas by compressing it heat is produced; the heated gas may be allowed to cool or it may be cooled artificially. When it is cool it is allowed to expand; in the process it does work, loses heat and falls in temperature. A repetition of this cycle of changes produces a lower temperature than before, and a rapid series of such cycles constitutes the modern compression refrigerating machine.

I do not propose to deal with the developments of refrigerating machinery, but as some indication of the growth of the engineer's importance in this field it is of interest to note that in the United States alone there are more than 150,000 refrigerated cars, and in that country more than 8 million tons of meat are submitted to mechanical refrigeration before reaching the consumer. In Great Britain our debt to the refrigerating engineer is more simply expressed by saying that on an average every person consumes per day 6 oz. of food which has been subjected to refrigeration. As a nation, I suppose we produce little ice-cream compared with the United States of America, but in 1933 the total consumption of ice-cream was about 30 million gallons.

To the engineer there is, however, an even more interesting feature of food preservation than that of refrigeration. If we go back to the hawker's barrow the biologist will tell us that those apples are alive and to freeze them means death. When frozen apples are thawed they become pulp and are only fit for jam. Like other kinds of fruit, the apple is a living structure whose preservation demands that it shall be kept alive. Sir William Hardy described the apple as a biological internal combustion engine with a large store of available fuel, and to keep it alive the external conditions must be such as not to stop it functioning in a normal fashion. The apple takes in oxygen from the air just as an internal combustion engine does, and it gives out carbon dioxide and other products as a result of the chemical changes taking place. I do not wish to suggest that there is a close comparison between the internal combustion engine invented by man and that far more perfect one designed by Nature for the apple, but there are parallels of interest. Conditionally that there is an ample supply of fuel—as there is in an apple—an internal combustion engine will consume that fuel faster, get hotter, and wear itself out more quickly the greater the supply of oxygen. The same is largely true in the case of the apple ; the rapidity of change is largely dependent on the atmosphere in which it is kept ; if the atmosphere surrounding the apple contains too much carbon dioxide the apple will die, and decay known as brown heart sets in. If, on the other hand, the carbon dioxide is maintained at a somewhat higher rate than that present in a normal atmosphere the rate of change is delayed and the apple loses weight at a reduced rate. This very roughly is the basis of the method of preservation known as gas storage. The fruit subject to a certain amount of refrigeration is contained in an atmosphere containing a certain percentage of carbon dioxide, the optimum percentage like the optimum temperature varying for different kinds of apples.

It is a simple method and presents no great difficulty to the engineer. Temperature and carbon dioxide recorders must be installed, and there must be some cold storage arrangements. The carbon dioxide is supplied by the apples themselves ; and the engineer has devised arrangements which ensure that the concentration shall not rise to a level which will kill the apples. In Great Britain during the coming season there will be about thirty of these gas stores and very good results are being obtained. Unfortunately the best temperature of storage of apples varies with the variety ; thus for Newton Wonder it is 1° C. and for King Pippin 4·5° C. and the best conditions for each variety have to be worked out.

Let us now consider the engineer's task in 1932 when he brought here 84,000 tons of apples from Australia and 28,000 tons from New Zealand in refrigerated ships. Roughly speaking, apples keep best at about 3° C., and the ship's engineer had to keep each ship's hold, packed with boxes of fruit, at about that temperature. To the walls of each hold refrigerating pipes were fixed and through these pipes cold brine was pumped to carry off the heat. Each unit of the cargo was alive and giving off heat, water and carbon dioxide, and the refrigerating plant had not only to absorb all the heat passing into the hold from external sources but also absorb that produced by the cargo. It was important therefore to know the amount of heat produced per hour by the apples. The heat produced rises with the temperature of storage, and an apple attacked by fungus gives off much more carbon dioxide and much more heat. It is due to the engineer's skill in controlling the average temperature, in preventing large temperature gradients and in arranging for appropriate ventilation to prevent an excessive accumulation of carbon dioxide at any point that such large consignments of apples can be shipped to us every year from Australia and New Zealand in comparative safety. Of course, disasters do occur at times, and suffocation by carbon dioxide has cost in a single year more than one hundred thousand pounds.

I have not time to tell you about the engineer's share in the care and transport of other fruits, but in 1932 more than 100,000 tons of oranges and 7 million bunches of bananas were brought here in refrigerated ships. It may therefore be said with truth that without refrigerating engineers we should have neither plenty of fruit nor much of good quality.

Normally, one example, such as that of the apple, should suffice to show the part the engineer has played in preserving food, but during the past two years there has been a development in the meat trade which promises to be of great importance.

Notwithstanding its apparent advantages, freezing has been applied to very few foodstuffs with complete success. Lamb, some kinds of fish and butter may be frozen with success, but freezing has been applied to beef with only partial success. It has been urged that freezing entails the separation in the tissues of a solid ice phase and that in the complex structure of food mere mechanical shattering will account for the damage. While it is certain that this is not the complete story, the damage done to beef by complete freezing is such that when the thawed carcase is cut the flesh is wet and a red fluid drips from it. Chilled beef, that is, beef kept a little above the freezing point, undergoes no such change, and it is not surprising therefore that of the 560,000 tons of beef we imported in refrigerated ships in 1932 about 80 per cent was chilled. Of the frozen beef, Australia sent us 47,000 tons ; of the chilled beef none. The reason for this is that chilled carcases of beef can be maintained in good condition for only about four weeks, and that suffices to bring them from South America but not from Australia.

The biological engineer has, however, made the discovery that if chilled beef is kept in an atmosphere containing 10 per cent of carbon dioxide the growth of moulds is inhibited and the 'life' of chilled beef is increased to such an extent that after a 65 days' voyage from Australia in a 10 per cent carbon dioxide chilled atmosphere beef might be delivered in London free from moulds and in good condition. In the *Times* Trade and Engineering Supplement of May 19 last the engineer no doubt read with interest that the steamship companies are alive to this method of transportation, and that three ships of one company alone are being fitted with carbon dioxide chambers. Thus the engineer with his refrigerating machines and automatic regulation of the carbon dioxide content of the chambers has enabled increased supplies of chilled beef to be placed at the disposal of the consumer of Great Britain. He has, in fact, increased both quantity and quality.