must be based on different materials, and for such new developments she is not ill-situated. There are in Assam and in the Punjab developed sources of petroleum, and even if these fields are relatively small as compared to those of Russia and America, they should provide sufficient materials for the manufacture of chemicals which recent research has shown to be readily obtainable from the oil and gas. It seems likely also that the manufacture of calcium carbide will soon be undertaken, and if this were done, acetylene would be available from which, as has been found in Canada, a host of subsidiary chemical industries can be developed. Finally, thanks to the research work initiated by Barber at Coimbatore and since extended by many other workers, cane sugar is now produced on a very large scale. By well-established processes, sugar provides a source of a great variety of products such as alcohol, acetone, butanol, citric and gluconic acids.

In India, a chemical industry based upon petroleum, sugar and calcium carbide might prove to be far more economical than one based upon coal tar. Development on these lines will necessarily involve much fundamental research and may appear to be speculative at the present time, but it seems to be more likely to lead to success than one based on older and well-established methods. It would certainly be profitable for the younger chemists now being trained in India to devote some of their energy and skill to a consideration of these problems. A further large field for research is to be found in the development of India's reserves of cellulose. In Sweden the exigencies of war have emphasized how very valuable a raw material this is. In the post-war years, we may anticipate that India will lead in this and in other fields of technical research.

PIONEERS OF REFRIGERATION*

By ENG.-CAPT. EDGAR C. SMITH, O.B.E., R.N.

DURING the greater part of the nineteenth century, there was a considerable trade in natural ice, and ice cut from Wenham Lake, near Boston, in the United States, was known in many parts of the world. Some of this ice came to Great Britain, which also obtained supplies from Greenland and Norway. It was this trade which led the famous engineer, Richard Trevithick, in 1828 to suggest to his friend, Davies Gilbert, that ice could be made by the compression and expansion of air.

The earliest apparatus for making artificial ice was that of William Cullen, who described his water evaporating device so long ago as 1755, while he still held the chair of chemistry at Glasgow. He was the first of many Scotsmen to further the practice of artificial cooling, and about half a century after he had made his evaporation apparatus, John Leslie, while holding the chair of mathematics at Edinburgh in 1810, devised his water absorption apparatus, in which water evaporated in a vacuum was absorbed by sulphuric acid. Writing in the seventh edition of the "Encyclopædia Britannica", Leslie referred to his method of "producing congelation on a large scale" and added that with a proper system of air-pumps,

worked by a steam engine of six horse-power, it might be possible in the climate of London to produce ice at the rate of a ton a day. The need for means of cooling was felt most in breweries, and the patents taken out for cooling worts and other liquids are very numerous. The first of such patents is that taken out in 1819 by Robert Salmon, the ingenious mechanist to the Duke of Bedford, at Woburn Abbey, in conjunction with William Warrell. This patent was No. 4331 of January 15, 1819.

As is well known, the three principal types of refrigerating plant which have been used on a large scale are the ammonia absorption machine; the air refrigerating machine, first visualized in a crude manner by Trevithick; and the vapour compression machine, the first example of which was made in an East London engineering shop for the American engineer, Jacob Perkins (1766-1849), according to his patent No. 6662 of August 14, 1834. Though a trial was made with the Perkins machine, it was not very successful and the inventor, having many other things on hand, did not pursue the matter.

About ten years later, the idea of using machines for cooling air in sick-rooms, hospitals, etc., occurred almost simultaneously to the American physician, James Gorrie (1803-55), of Apalachicola, Florida, and to the Astronomer Royal for Scotland, Charles Piazzi Smyth (1819-1900). Both these men spent about ten years trying to develop their ideas, and on May 6, 1851, Gorrie secured the United States patent No. 8080, the first patent for an air refrigerating machine. Smyth in his work had the assistance of Rankine, and of James Stirling, the brother of the Rev. Robert Stirling, who had invented the hot-air engine. Though Smyth's proposals were the subject of a report to the Indian Government, nothing came of them. Gorrie, on the other hand, did apparently see some of his plans adopted, but when he tried to get them introduced on a larger scale, his funds failed, his health broke down and he died at the early age of fifty-two. His merits, however, have not been forgotten and his statue now stands in the Statuary Hall, Washington, D.C.

By the time of Gorrie's death, artificial cooling had become a matter of great interest in Australia, where some far-sighted individuals saw that the surplus meat of the Colonies would readily find a market in Europe if means existed of preserving and transporting it. Among those whom this question stimulated was the Scottish journalist, James Harrison (1816-93), and the Lancashire wool broker and business man, Thomas Sutcliffe Mort (1816-78), both of whom had emigrated to Australia about 1838. Harrison had a long career as a journalist and at one time edited the *Melbourne Age*. He was also the parliamentary representative for Geelong, Victoria, where he had settled. It is said that he corresponded with Faraday and Tyndall, but however this may be, in the 'fifties he began experimenting on ice-making, and in 1855 took out an Australian patent; then coming to England, he secured patents No. 747 of March 28, 1856, and No. 2362 of September 10, 1857, for a vapour compression machine using ether. His earliest machines were made in Holborn by the German engineers, Siebe Brothers, the founders of the well-known firm, Siebe, Gorman and Co., Ltd., the first machine being set up at the famous paraffin works of James Young at Bathgate, Scotland, the cradle of the Scottish shale oil industry. Previously, to separate the solid paraffin from the oil, it had been necessary to store the oil in summer and then expose

* Substance of a paper read before the Newcomen Society on March 10.

it in flat dishes in winter. Another Harrison machine was set up at the brewery of Truman, Hanbury and Co., Ltd., London, and a third was taken back by Harrison to Australia, where his machines were afterwards made in the works of P. N. Russell and Co., of Sydney.

The introduction of the Harrison machine had two unexpected results: it led to the Siebe firm becoming makers of refrigerating plant, and to the invention by Alexander Carnegie Kirk (1830-92), the engineer of the Bathgate paraffin works, of the closed-cycle air refrigerator which he described very fully to the Institution of Civil Engineers in January 1874, when one of his machines had been running successfully for ten years. Kirk had had a good scientific and practical training, and afterwards became widely known as one of the chief pioneers of the marine triple expansion engine. His refrigerating machine was introduced because the use of ether had been found dangerous and the Harrison machine too small. In his inquiries, Kirk learnt about Gorrie's machine and also studied the Stirling hot-air engine.

Meanwhile, there had been progress in other directions. In 1860, Ferdinand Carré patented the ammonia absorption machine; in 1861, Mort at Sydney founded the first freezing works in the world; in 1864, Charles Tellier (1827-1913), the French pioneer of cold storage and of marine refrigeration, took out his first British patent; in 1867 the American inventor, Thaddeus S. C. Lowe (1832-1913), was granted provisional protection for a patent which included the use of liquified carbonic acid, and in 1869 Franz Windhausen, of Brunswick, secured a British patent, the first of several, for a cold-air machine. To this period also belong some of the patents of Mort, who had the assistance of the French engineer, E. D. Nicolle, manager of P. N. Russell and Co. Applications for patents in connexion with cooling were reaching the British Patent Office at this time at the rate of about one a week.

The next decade, 1870-80, was perhaps the most fruitful, as it is certainly the most interesting period in refrigeration history. It saw the initial work at Munich of Carl von Linde, the introduction of his ammonia compression machine and the founding at Wiesbaden of the Gesellschaft für Linde-Eismaschinen; the invention in France by Paul Giffard of an air machine which was taken up and improved in England; the introduction by Raoul Pictet, of Switzerland, of the use of sulphur dioxide as a refrigerant; the building by Tellier of a cold store at Auteuil and the fitting out by him of *Le Frigorifique*, the steamer which in 1876 brought a consignment of meat from the Argentine to France; the collaboration of the Bells with Coleman, which resulted in the voyage of the first refrigerator ship on the North Atlantic and the voyage of the first refrigerator ship to carry meat to England from Australia; and also the early work of Alfred Seale Haslam (1844-1927) of Derby, of Thomas Bell Lightfoot (1849-1921), the founder of the Lightfoot Refrigerator Co., and of Everard Hesketh (1854-1942), for fifty years the inspiring head of H. and E. Hall, Ltd., of Dartford. Hesketh, who died at Johannesburg last year, was the last of this band of pioneers.

Of outstanding importance was the work of Joseph James Coleman (1838-88), with whom the Bells formed the Bell-Coleman Mechanical Refrigeration Co., of Glasgow. Henry Bell, born in 1848, and James Bell, born in 1850, were the sons of John Bell, a successful Glasgow butcher, whose business they

carried on and extended, possessing in the end more than three hundred shops, which passed into the hands of Eastman, of New York. In the middle 'seventies, a certain amount of meat was imported from North America in ships fitted with ice chambers. Looking for better means of cooling, the Bells sought the advice of Sir William Thomson (Lord Kelvin), by whom they were placed in touch with Coleman, who curiously enough was research chemist at the Bathgate oil works. Born in Lincolnshire in 1838, Coleman had passed his youth with a pharmacist in Halifax, where he attended the Mechanics' Institute. His progress was such that at the age of twenty-two he contributed a paper to the British Association on atomic weights and atomic volumes. For several years he taught science in Chester Training College, but was led to the study of mineral oil manufacture and was offered the post at Bathgate. While there, in 1874, he patented a machine for compressing and cooling the waste gases from shale oil works, this machine being the precursor of his cold-air refrigerating machine, patented jointly by Coleman and the Bells on March 3, 1877. With the assistance of D. and W. Henderson, shipbuilders and engineers, of the Clyde, experiments with machines, insulation and so forth were carried out, and in 1879 a Bell-Coleman machine was placed on the Anchor liner *Circassia*, in which Coleman made a trip to and from America.

The results of this trip were so successful that the Anchor Line decided to fit up all its thirteen ships in the same manner. The second Bell-Coleman machine, however, was not placed aboard a liner but aboard the cargo boat S.S. *Strathleven*, which had been chartered by Messrs. McIlwraith, McEacharn and Co. to make an experimental trip to Australia and back. Unlike to-day, the meat was taken on board fresh and then frozen. Having received and frozen a consignment of about forty tons, the *Strathleven* left Sydney on November 29, 1879, and Melbourne on December 6, and arrived in London on February 2, 1880, with the meat in good condition. Two years later, the sailing ship *Dunedin*, fitted with a Bell-Coleman machine, brought home the first cargo of frozen meat from New Zealand. By then other engineering firms had begun the construction and installation of air refrigerators, and in the early 'eighties the Bell-Coleman patents were acquired by Haslam. Coleman retired to Bearsden, near Glasgow, where he died at the age of fifty. Both the Bells, on the other hand, lived to a good age, and both were made baronets for their public services.

While von Linde in Germany found the widest scope for his activities in installing ammonia compression plants in breweries, British refrigerating engineers were more concerned with the new frozen meat industry. Cold-air machines continued for many years to be fitted in both cold stores and in ships, but the higher efficiency of ammonia and carbonic acid machines gradually gained them a place in the food industry, ammonia machines being installed in large numbers ashore and carbonic acid machines in ships. There was at first a prejudice against the use of any chemicals afloat, and there was always a question of supplies when ships were abroad. These factors also affected the introduction of refrigerating plant into men-of-war when the cooling of magazines was found necessary. The first mercantile vessel with a carbonic acid machine for carrying meat was the *Highland Chief*, 1890. The first British man-of-war with a carbonic acid magazine-cooling plant was the battleship *Sans Pareil*, 1897.