Engines.[1]

By Prof. E. N. da C. Andrade.

THERE is a certain appropriateness in 'Engines' as a subject for Christmas lectures at the Royal Institution. Most engines are machines for converting heat into work, and the first man to show experimentally the connexion between heat and work was Count Rumford, who founded the Institution in 1799. The original purpose of the Institution was "for diffusing the knowledge, and facilitating the general introduction of useful mechanical inventions and improvements; and for teaching by courses of philosophical lectures and experiments the applications of science to the common purposes of life." A course of lectures on engines certainly complies closely with this plan. While if it be urged that a physicist trained to occupy himself with vibrations and atoms should not meddle with things outside the usual scope of his studies, the physicist may, perhaps, without exposing himself to the absurd charge of arrogantly claiming kinship with so great a philosopher, point out that Thomas Young lectured at the Royal Institution on architecture and carpentry, on machinery, on hydraulics, and on what he called pneumatic machines, which included Newcomen's and Watt's engines, and the locomotive. In more recent times the present distinguished Fullerian professor of chemistry has lectured on trades. Precedent, then, is not lacking for the choice of so mechanic (using the word in the Shakespearian sense) a subject by a physicist.

Anything about engines has a claim on the attention of a juvenile auditory, but naturally with so vast a subject it is particularly necessary to have a very definite plan if the lectures are to be coherent. It was decided to make the course an illustrative commentary on the first two laws of thermodynamics, pointing out with a variety of examples how these laws operated, but carefully refraining from mentioning them by name, for fear of creating alarm and despondency in the juvenile ranks. The second law of thermodynamics may be held to be tough meat for the young, but it is perfectly easy to make boys and girls understand that you must have two different temperatures if heat is to be turned into work; to point out the two different temperatures in the case of each particular engine; and to show how there is always a striving on the part of the engineer to make the difference between these two temperatures as large as possible, because that enables us to turn the greatest fraction of our heat into work. The two laws were condensed in the phrases "Heat is work and work is heat" and "Lost temperature is lost opportunity," forms open, maybe, to criticism, but which proved convenient reminders of the substance of the rules. The last lecture was devoted to refrigerating engines, with the particular object of bringing home the essential character of the heat engine by showing what happens when it is driven backwards.

The chief difficulty in a course of Royal Institution lectures on engines is clearly the question of experiments and demonstrations. Some two hundred and fifty slides were prepared or borrowed, which helped to provide the necessary something-to-look-at. There is a certain number of simple experiments on mechanics and heat—on vapour pressure and steam, on explosions and on refrigeration—which can be conveniently shown to a large audience. Something more is needed, however, to give the lectures an engineering character, and that something was supplied by a large assortment of actual component parts of engines, and of models of engines and mechanisms, which the lecturer was fortunate enough to obtain on loan. Foremost among the lenders were the Science Museum, the director of which, Sir Henry Lyons, gave the most generous aid, and Mr. George Cussons, of Manchester, whose firm makes excellent working section models of all the chief types of engines and mechanisms, which proved admirably adapted for exhibition to a large audience. Loans from these sources were in evidence at nearly every lecture. Many other gentlemen[2] lent models of the products of their particular firms, models which proved a source of great interest.

In the first lecture, "The Rules which all Engines must obey," it was pointed out that, if there were no friction, the work done by any mechanism of pulleys, screws, or levers would be equal to the work done on the mechanism, but that, owing to friction, it was actually always less. A model hydraulic accumulator was used to emphasise the conservation of energy, and the meaning of power: a little pump slowly forced in the water which raised the accumulator piston, and then the energy so stored was quickly released to crush a cylinder of plasticine in a press. Talk of friction led to ball and roller bearing, and the Michell thrust block. A heavy wheel mounted on Skefko ball bearings (which, although it weighed some hundreds of pounds, turned to a silk handkerchief thrown on the spokes), and an air-lubricated model on the Michell principle provided practical illustrations. From the fact that diminished friction means diminished heat at bearings, passage was made to examples of great friction producing great heat, illustrated by the stock experiment of boiling ether in a rotating copper tube by friction against a wooden holder, the vapour blowing out a cork. Foucault's disc was used to show that, no matter how the resistance to motion arises, work done is turned into heat if no other effect is produced. Simple analogies of money changing were invoked to make clear the first law of thermodynamics. The fact that to convert heat into work special

[1] Summary of the one hundred and second course of Juvenile Christmas Lectures delivered at the Royal Institution on Dec. 29, 31, 1927, and Jan. 3, 5, 7, 10, 1928.

[2] Whose services will be acknowledged in the book which the writer is now preparing, to be published by Messrs. G. Bell and Sons.

conditions are necessary was then simply discussed, and the second law presented from the point of view already mentioned.

In the second lecture, "Learning about Steam," the meaning of vapour pressure and the simple properties of steam — such as the variation of boiling point with pressure, and the difference between saturated and superheated steam—were explained. The experiments on this point included lighting a cigarette at a jet of superheated steam. It was pointed out that steam is only an intermediary in the conversion of heat into work, and has no magical virtues of its own, and, to emphasise this, model engines were made to work with alcohol vapour, hot air, and liquid air. The creation of a partial vacuum by condensation of steam was discussed, with special reference to condensers.

The elementary properties of steam having been exposed, it was possible to run rapidly through the early history of the steam engine. A model working on Savery's principle, and the Science Museum model of Newcomen's atmospheric engine, were shown. Attention was directed to the experiments and inventions of Watt, in particular the separate condenser, the closed-in cylinder, the double-acting engine and the governor. It was mentioned incidentally that Watt did not invent the steam engine. This has caused abundant comment, and has made it clear that the belief that Watt did invent the steam engine is much more widely spread than the lecturer supposed.

The third lecture dealt with the reciprocating engine. First of all, methods of changing reciprocating into rotary and rotary into reciprocating motion were discussed—crank, eccentric, cam, and swash-plate, or slant. This last, an invention of Watt's, is now applied in the so-called crankless engine. A few words were said on valves and valve gear, in connexion with which models built of Meccano strips were demonstrated. The consequences of the modern use of high-pressure steam, the main advance since Watt's time, were mentioned, and the meaning and advantages of compounding briefly explained. The marine reciprocating engine was illustrated by a very fine model lent by Mr. Scott, of Michell Bearings, Ltd., a model which roused enthusiasm and envy among the juveniles. The merits and demerits of the steam locomotive were then discussed, the flexibility on one hand, and the waste consequent on the lack of a condenser on the other hand, being among the points mentioned. The locomotives built for different purposes nowadays differ widely in design, a great contrast being, for example, provided by the enormous American articulated goods locomotives and the elegant high-speed 'crack' English passenger locomotives. The lecturer ventured to put in a word on the beauty of the modern locomotive, in which the English practical genius finds artistic expression, and encouraged boys to continue to admire such engines as the *King George V.*, the *Royal Scot*, and the *Lord Nelson*.

The fourth lecture dealt with turbines. The simplest principle of converting the energy of a moving fluid into energy of rotary motion was illustrated by the windmill, in connexion with which the question of best speed of running was raised. The de Laval turbine led from this to the principle of velocity compounding and pressure compounding. The difference between an impulse and a reaction turbine was illustrated by a model consisting of two bicycle wheels, to the rim of one of which small rockets could be fastened obliquely. When the rockets were lit, the wheel to which they were attached rotated rapidly by the reaction principle if it was free. If, however, this wheel was held, and the other wheel, provided with oblique cup-like projections, brought near to it, then the rockets blew the second wheel round by the impulse principle.

The services of Sir Charles Parsons, who was called the Watt of the turbine, were then outlined, and a large number of slides of different turbines and components were shown, in particular of the Chicago 50,000 kilowatt installation. The special problems of the marine turbine—reversing and gearing—were then indicated. Finally, the turbine locomotive was mentioned, with a special word on the condenser which is fundamental for such a machine.

The subject of the fifth lecture was the internal combustion engine, where the heat is generated in the cylinder itself. Some explosions of gaseous mixtures in long tubes served to illustrate certain fundamental points of the gaseous explosion, such as finite velocity of travel and the effect of confinement. The fundamental importance of the compression stroke was emphasised, and the question of 'knock' consequent upon excessive compression and of anti-knock substances briefly handled. After gas engine and petrol engine followed the Diesel engine, simple physical experiments being shown to demonstrate the heating of air by compression. Two beautiful working sectioned models, some seven feet high, lent by Messrs. Burmeister and Wain, helped to make the action of the Diesel clear. The lecture closed with a word about the Still engine and the new Kitson-Still locomotive.

In the last lecture the principles of refrigeration were discussed, both the absorption and the vapour-compression plan. Water was very rapidly frozen on the Carré principle, by the use of a modern fast-sucking pump. The important part played by mechanical refrigeration in modern life was stressed, examples ranging from mining to food preserving and from ice-making to oxygen-making being cited. After the principles of the vapour compression machine had been demonstrated, the two laws of thermodynamics were restated and now mentioned by name. A simple illustration was provided by the help of a step ladder and a pile of flat wooden blocks, painted 'heat' on one side and 'work' on the other. Starting with the pile at the top of the ladder, it was explained that one unit could be turned from heat to work for every step of temperature through which the pile descended, and the conversion was effected by lifting a block and turning it round. When the heat was at atmospheric level, refrigeration was produced, the heat being made to go up a step by turning a unit of work into heat, and adding it to the pile.

In conclusion, the lecturer put in a plea for the recognition of the importance of a sound foundation of physics for engineering students, and ventured to ask if, perhaps, a little too much stress was not sometimes laid on workshop experience and the 'start at the bottom and sweep up the shavings' precepts. He suggested that workshop experience could always be acquired, but that unless physics was learnt early in life, it was never learnt properly. He therefore told his young listeners that if they wanted to be engineers—good engineers—they must study the working of the few simple rules of mechanics and physics of the operation of which they had seen so many examples in the course of the lectures.

Voices Across the Sea.

A JOINT meeting of the Institute of Electrical Engineers in New York and the Institution of Electrical Engineers in London was held on Feb. 16, between 10.30 and 11 A.M. New York time, and 3.30 and 4 P.M. London time. The occasion was the discussion of a paper on trans-Atlantic telephony at New York. For this purpose the telephone system connecting Great Britain with the United States was employed. Loud speakers were used, so that everyone in the Council Room and Lecture Room of the London Institution heard with perfect distinctness everything that was said by the speakers. Similarly, everyone in New York, at both the principal meeting and the overflow meeting, heard the speeches with perfect clearness, the disturbance from atmospherics being quite negligible.

Mr. Gherardi, the president of the American Institute, moved that Mr. Page, the president of the English Institution, take the chair at the joint meeting. This was agreed to unanimously. Mr. Page then invited Mr. Gherardi to address the meeting. Mr. Gherardi said that in the auditorium from which he was speaking there were present about a thousand electrical engineers, who came from all parts of the New World. He said that, as the result of the accumulated work of the scientific worker, the inventor, and the electrical engineer, this joint meeting had been made possible. In particular he mentioned Faraday, Maxwell, and Kelvin as having laid the foundations on which their art was built. Starting in 1876 with instruments and lines which with difficulty permitted communication over a few miles, telephone conversation now spanned the Atlantic. It had added yet another tie to the many uniting the two electrical institutions.

Mr. Page in his reply said that he represented the thirteen thousand members of the English Institution. He spoke feelingly of the boon that Graham Bell gave to the world by the invention of the telephone. His memory, along with that of Franklin and Henry, will ever be cherished as benefactors of mankind. He paid tribute to the great American Institution which has contributed so largely to the progress of electrical science, and has proved over and over again that the benefits conferred by engineering are truly international.

Colonel Purves, the engineer-in-chief to the Post Office, said it was a privilege to participate in a pioneer demonstration of a wider use of telephony which would tend to bring nations into closer relationship. It was a great thing that two large assemblies, separated by a wide expanse of ocean, could join together in interchanging their thoughts and ideas by the simple and natural medium of direct speech. It will conduce to a better mutual understanding. As we sit and talk to each other our speech is launched into the air by the radio transmitting stations at Rugby and at Rocky Point with an electromagnetic wave energy of more than 80 horse-power. By various refinements and special devices the speech-carrying efficiency of each unit is many thousands of times greater than that of an equivalent amount of power radiated by an ordinary broadcasting station. General Carty, of the American Telephone and Telegraph Company, brought forward a motion to the joint meeting that it express feelings of deep satisfaction that recent advances in radio communication have made it possible to have international assemblies, which should prove to be powerful agencies in the increase of goodwill and understanding among the nations.

In seconding the motion, Sir Oliver Lodge pointed out the various causes that have contributed to the success of radio communication. In the first place, there was the invention of the telephone. Next, in order to transmit speech by ether waves it was necessary to harness electrons by a thermionic valve. That ether waves are constrained by the atmosphere to follow the curvature of the earth's surface is an unexpected bonus on the part of Providence, such as is sometimes vouchsafed on behalf of human effort. The actual achievement of to-day is due to the scientific and engineering skill of many workers, both those in the background and those whose names are familiar to the public. The motion was then put by the chairman and carried unanimously. The meeting was then adjourned, the chairman adding 'good-bye.'

Before the joint meeting a film entitled 'Voices across the Sea' was shown, illustrating the processes that have to be gone through before a person in San Francisco can get into oral communication with a person in Plymouth. The path of the waves by the wires and over the ocean was indicated by luminous lines in motion. The delays at the various stations were also indicated, the whole operation before the lines were complete for speech taking only two or three minutes. From San Francisco to New York is by land line. The next link is to the transmitting station at Rocky Point, Long Island, then by radio to Cupar, and thence to Plymouth by land lines. The first link of the return journey is to Rugby, then by radio to Houlton, Maine, and so to San Francisco. The length of the radio link is about 3000 miles.