The Centenary of the Institution of Civil Engineers.

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

FOUNDED through the action of six young engineers, the first formal meeting together of whom took place at the Kendal Coffee House in Fleet Street on Jan. 2, 1818, the Institution of Civil Engineers on June 3-7 is celebrating the centenary of its incorporation by Royal Charter. It was in January 1820 that Telford was asked to become the first president of the new society, and it was largely through him its charter was obtained eight years later. The celebrations are to commence with a memorial service in Westminster Abbey at 3 P.M. on Sunday, June 3; on Monday, June 4, the president, Mr. E. F. C. Trench, and the council will receive the delegates, and Sir Alfred Ewing will deliver the thirty-fourth James Forrest Lecture on "A Century of Inventions"; during the three succeeding days there will be a conversazione, a banquet, a conference at which some thirty different problems in engineering will be discussed, and a series of visits to important engineering works and undertakings.

In the petition of a hundred years ago to the Attorney-General for the grant of a charter, it was laid down that "Civil Engineering is the art of directing the great sources of power in Nature for the use and convenience of man," an all-embracing phrase which covers almost all the manifold activities of the engineer, and it is not without interest to find that practically all the subjects to be dealt with at the conference—docks, harbours, shipbuilding, railways, fuels, gas, boilers, domestic lighting and heating, road traffic, tidal power, mining, water supply, and sewage—were all matters of vital interest to the engineer a hundred years ago, while even at the time of the incorporation of the Institution, the internal combustion engine was a subject of practical debate, and in the laboratory of Faraday was being laid the foundation of our electric power and lighting.

The birth of the Institution and its incorporation by charter are but two of many landmarks in the material progress of Great Britain. It was not the first society of its kind, neither did it mark the beginning of any new branch of engineering. Docks, harbours, bridges, viaducts, and aqueducts had been constructed for centuries; France many years before had founded a School and Corps of Civil Engineers, while in Great Britain we see the rise of the Smeatonian Society and the short-lived Society for the Improvement of Naval Architecture. These, however, were but the forerunners of the great modern engineering institutions of Great Britain which really had their foundations in the vast extension of the work of the engineer due to the widespread application of mechanical invention to manufacture and to transport during the eighteenth and the early part of the nineteenth century.

When the Institution was incorporated, Brindley, Smeaton, Arkwright, and Watt had long since passed away, but the movements they inaugurated gained in volume day by day. No one had added more to the roads of McAdam and the canals of

Brindley than Telford himself, while as a bridge-builder he will always be remembered for that most graceful bridge which spans the Menai Straits. In 1828 the steamboat was a recognised factor in overseas transport, though both Bell and Symington still survived in undeserved poverty. Through David Napier the mails were regularly carried by steam vessels: in 1825 the little *Enterprise* had made her historic voyage to India, and in 1827 the British-built Dutch vessel *Curocoa* crossed the Atlantic to the West Indies. In 1828, steam vessels were included in the Official List of the Royal Navy, but another ten years had to pass before Brunel's famous *Great Western* inaugurated regular trans-Atlantic passages. The same period also saw the beginning of the railway systems of England. Blenkinsop's locomotives had been at work since 1812, passengers were carried on the Stockton and Darlington Railway in 1825, and in 1828 George Stephenson was engaged in the construction of the Liverpool and Manchester Railway, with which the epoch-making *Rocket* is associated. On the roads, too, steam carriages such as Goldsworthy Gurney's were seen, and had a more enlightened policy prevailed, the steam motor-car might well have been common eighty years ago.

With the increasing demand for engines and machinery arose a new type of engineer, known as the 'mechanical engineer,' devoted to the founding and fashioning of iron. Not only was he called upon to make steam engines in great numbers for factories, ships, and railways, but it was he who built the iron bridges and the iron ships. Thanks to the work of Cort, the iron masters of Great Britain were able to meet all demands, and the country came to boast of some thousands of puddling furnaces. With these things came the rise of the machine tool makers. From the shops of Boulton and Watt at Soho, the Butterley Iron Works, and Maudslay's shops at Lambeth, came a long line of successful pioneers, such as Roberts, Muir, Whitworth, and Nasmyth, who gave us the planing machine, the true plane surface, the standard screw thread, and the steam hammer.

Among the first members of the Institution of Civil Engineers were to be found men engaged in all the various branches of engineering, and the *Proceedings* of the Institution contain a progressive review of the great achievements of the engineering profession. In the early days of the Institution, however, engineering work was carried out mainly by practical men trained in the hard school of experience. Of scientific education for the engineer, in England at least, there was none, and scientific research was in its infancy. If there is one thing more than another which separates the present from the past, it is the attitude towards scientific discovery, but for many years now in matters of education and investigation the Institution of Civil Engineers has taken a leading part. In connexion with this it is perhaps worth recalling that when William Anderson inaugurated the

annual lectures which keep alive the memory of the most famous of the Secretaries of the Institution, James Forrest, he took for his subject "The Interdependence of Abstract Science and Engineering." That was in 1893. Since then many men famous both as engineers and as men of science have delivered the James Forrest Lecture, but the happy choice of the Council in selecting Sir Alfred Ewing to give the lecture which will mark the centenary of the incorporation of the

Institution will not fail to gain general approval; his lecture on "A Century of Inventions" will be awaited with more than usual interest. In the voluminous publications of the Institution, which in themselves form a veritable engineering library, it may be there are few, if any, more valuable records than these James Forrest lectures, which have often rivalled in interest the famous presidential addresses of Sir John Rennie, Robert Stephenson, Sir William White, and others.

The Accuracy of Shortt Free Pendulum Clocks.

By Dr. J. JACKSON and W. BOWYER.

THE period of vibration of a simple pendulum, swinging in a vacuum through the small semi-arc α is given by $2\pi\sqrt{\frac{l}{g}\left(1 + \frac{1}{16}\alpha^2\right)}$.

Variations in the rate of a pendulum clock are produced by variation in (1) the length of the pendulum; (2) the arc of vibration; and variation in several factors which produce a departure from the above formula; namely: (3) air resistance; (4) elasticity of the spring; (5) interference with the free motion of the pendulum by the escapement and impulsing mechanism.

We will consider these in turn.

(1) The principal cause of variation in the length of the pendulum is change of temperature. This can be overcome by keeping the pendulum at constant temperature. Attempts have also been made with more or less success to compensate the effect by the use of metals of different coefficients of expansion so as to make the effective length of the pendulum practically independent of the temperature. But the parts of such compound pendulums may not take up changes of temperature at the same rate, and those of the grid-iron type are apt to roll. The discovery of invar has greatly simplified the temperature question. But invar is a rather unstable substance and its growth produces slow secular change in the clock rate.

(2) If the bob moves in a cycloid instead of a circle the period is independent of the amplitude. Clocks have been constructed with 'cycloidal cheeks' to guide the pendulum, but these have not proved of value. When the semi-arc of vibration is 1° a change of $1'$ in the amplitude affects the daily rate of a simple pendulum by only 0.05s. The change of arc in precision clocks is not great, and, moreover, as a result of the action of the suspension spring, the effect of change of arc in such clocks may easily be less than the theoretical amount given, so that this source of irregularity is not very serious.

(3) A change of 1 per cent. in the air pressure under ordinary conditions changes the daily rate of a standard type of pendulum by about 0.1s. This can be fairly accurately compensated in various ways, but for the most accurate clocks it is best to keep the pressure constant. For Riefler clocks this is usually about 600 mm. of mercury, but for the Shortt clocks it is of the order of 30 mm.

(4) The effect of the suspension spring does not

appear to be very great, although various methods of supporting the pendulum have been invented. Change of elasticity with temperature and fatigue of the material from continuous bending, may produce variations of arc and so affect the rate of the clock.

(5) The most difficult problem in clock making has been in the escapement. In the usual type of clock the escapement serves a double purpose. It enables the number of vibrations to be counted, and through it the impulse is given which maintains the vibrations of the pendulum. The pendulum is in more or less continuous contact with the escape wheel, and although this is generally situated fairly near the point of suspension, it is clear that frictional forces and continuous interference by the escape wheel may easily produce considerable irregularity in the clock rate.

At the end of 1924 the clock Shortt 3, made by the Synchronome Co., Ltd., was installed at the Royal Observatory, Greenwich, and it proved so reliable that it was introduced as standard on Jan. 1, 1925. It consists of a 'free pendulum' and a 'slave clock.' The free pendulum is made of invar swinging in an air-tight case at a pressure of about 1 inch of mercury. The free pendulum has no escapement. On a bar about one-fifth of the way from the top it carries a very light wheel about 6 mm. in diameter. At every fifteenth swing to the left (30 seconds) a gravity lever carrying a weight of $\frac{1}{2}$ gm. and released by the slave clock, falls on the wheel, giving it an impulse. As this lever gets clear of the wheel a tail-piece releases mechanism which resets the impulse lever and also causes an electric contact to be made which synchronises the slave clock. An action of the synchroniser on the slave clock advances its phase by approximately 0.004s. The slave clock is rated to lose about 5s. a day, or 0.002s. per 30s. Under these conditions the synchronising action on the slave pendulum occurs at alternate half minutes with considerable regularity. The slave clock does all the work of counting the vibrations and releasing the impulse lever. Consequently, the only interference with the free pendulum is the impulsing during a fraction of a second every thirty seconds. The great advantage which the Shortt clock has shown over all other types of clock is undoubtedly due to the relative freedom of the pendulum from mechanical interference.

This clock was started at a practically zero rate