PRINCIPLES OF TIME-MEASURING APPARATUS [1]

III.

Clock Escapements.

AN escapement in general is to be considered a good one just in proportion as it prevents variations of friction in the clock-train from reaching the pendulum.

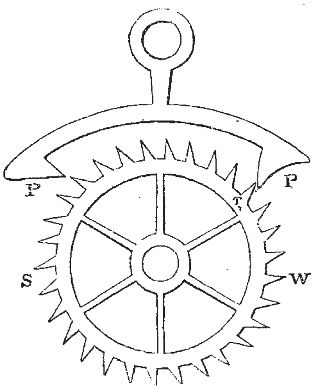

FIG. 14.

The first form of escapement with which the pendulum was used is that early form mentioned in our description of the clock from Dover Castle; but this was speedily abandoned on account of the unduly large arc through

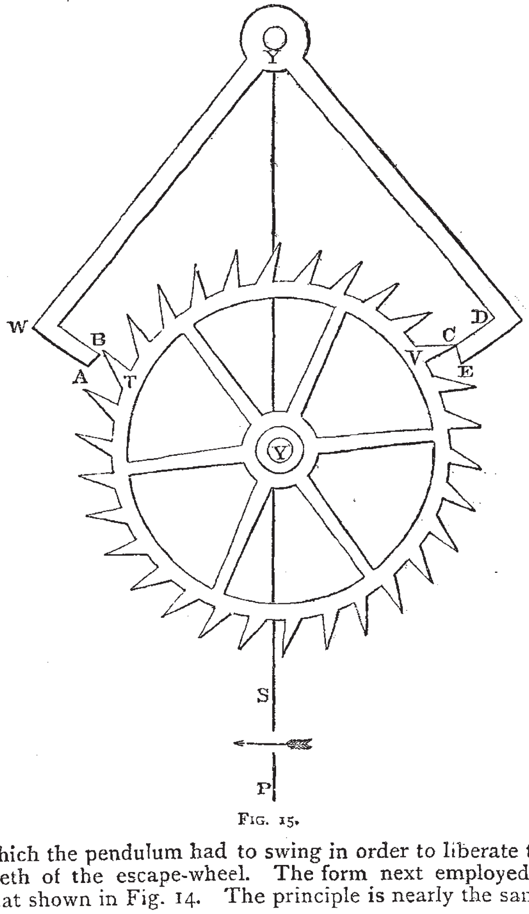

FIG. 15.

which the pendulum had to swing in order to liberate the teeth of the escape-wheel. The form next employed is that shown in Fig. 14. The principle is nearly the same, except that the pendulum need only swing 2° or 3° in order that the teeth may pass.

S W is the escape-wheel. The tooth T is now being held by the right-hand pallet, P; in point of fact, as the pendulum is swinging to the left, the pallet is actually recoiling or driving it back a little. By-and-by the pendulum will return, lift the pallet, and allow the tooth to escape, when the same action will take place upon the opposite pallet. You can readily see what the effect would be, supposing a little more force to be occasionally transmitted by the clock-train; it is obvious that the pendulum would be beaten backwards and forwards by the action of the pallets, and the time of the clock would be greatly accelerated. The reverse action would take place supposing a little less force to be transmitted. This escapement is called the recoil escapement.

We now come to the dead escapement (see Fig. 15), invented by the same Graham who discovered the mer-

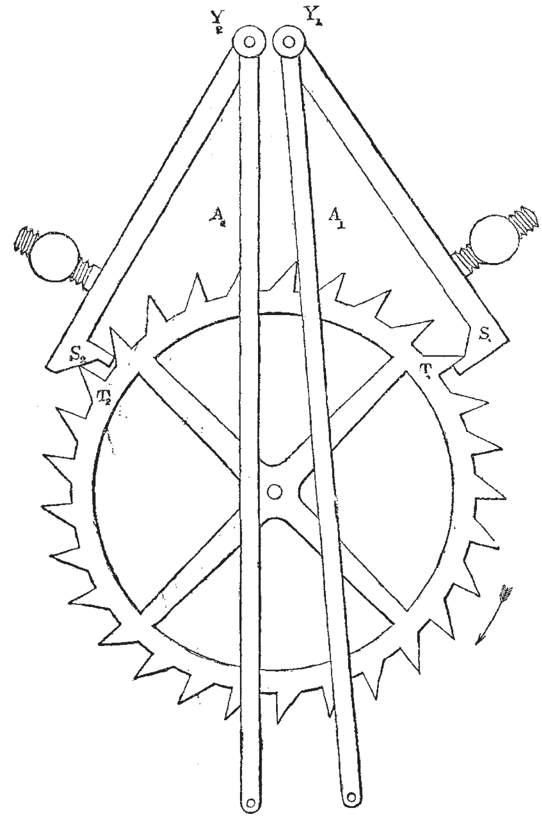

FIG. 16

curial pendulum. The escapement is so called because, during the greater part of the swing of the pendulum, the seconds hand lies motionless or dead, upon the division of the clock dial.

That tooth T of the escape-wheel has just got clear of the left-hand pallet, and V has fallen upon the face C D of the right hand. W A and C D are portions of circles described from Y, the axis of motion of the pallets, and you see they have therefore no tendency to drive back or recoil the escape-wheel.

In order to understand its advantage, I must ask you to follow very carefully what I am now going to say. As I told you when we were discussing barometric compensation, any force acting upon the pendulum in the same direction as gravity, will cause it to swing faster, and any force against gravity to swing slower. The force of the clock train, when it gives impulse to the pendulum, may act either *with* or *against* gravity; that is to say, it may

[1] Lectures by Mr. H. Dent Gardner, at the Loan Collection, South Kensington. Continued from p. 556.

be given when the pendulum is *falling* or *rising*. In the first case any variation in the friction of the clock-train tending to increase the impulse will make the clock gain, in the second, to make the clock lose. But why could we not so arrange an escapement that the impulse should be given, half when the pendulum is falling, and half when it is rising? and then any variation in the force of the impulse will simultaneously cause the clock to gain and lose, and so correct itself.

This is what can *nearly* be done in the dead escapement, but not exactly, because the condition of so doing is that each tooth of the escape-wheel, shall drop exactly upon the corners C and A, dividing the dead faces C D, W A,

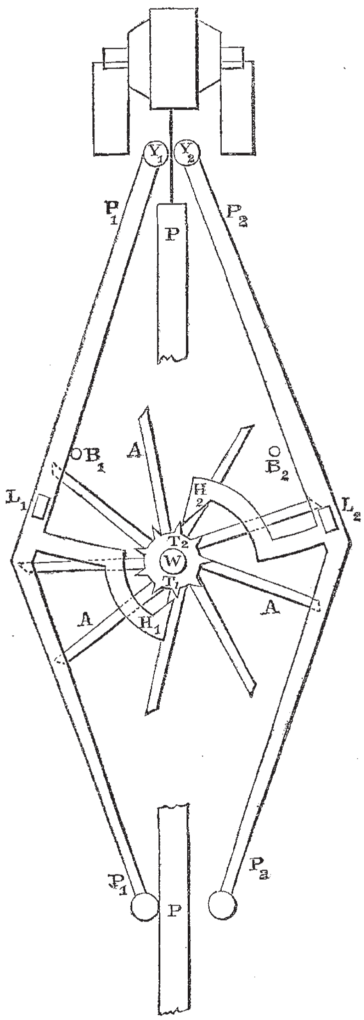

FIG. 17.

from the impulse faces C E, A B, and you are bound to allow a little margin for safety. But just in so far as this condition is fulfilled, so the escapement is a good one.

Gravity Escapements.

To understand the principle of these you cannot do better than refer to Fig. 16, which shows the original form invented by Mudge. The tooth of the escape-wheel T_1 by operating upon the slant S_1 has lifted the pallet S_1 Y_1 to its present position, and the tooth is now being held by the hook at the end of the pallet. The pendulum, which is detached from the pallets, is advancing towards the arm Y_1 A_1 connected with this pallet, and will by-and-by lift it, freeing the escape-wheel: the other tooth of the wheel will then operate upon the slant S_2, of the other pallet S_2 Y_2, and lift that until it is in turn detained by the hook at its extremity. Meanwhile the pendulum carries the first pallet to the extremity of its swing, and then returns with it; but as there is now no tooth in the way to receive it, the pallet S_1 Y_1 will drop, until it occupies a corresponding position to that in which the pallet S_2 Y_2 is at present situated.

Thus you see the pallet falls upon the pendulum a greater distance than the pendulum lifted it, and this difference—the weight of the pallet multiplied into this space—forms the impulse. This impulse, of course, is constant, and any variation in the force of the clock-train will only cause either pallet to be lifted with greater or less rapidity.

This escapement used to "trip," that is to say, that occasionally the pallets were lifted with so much rapidity, as

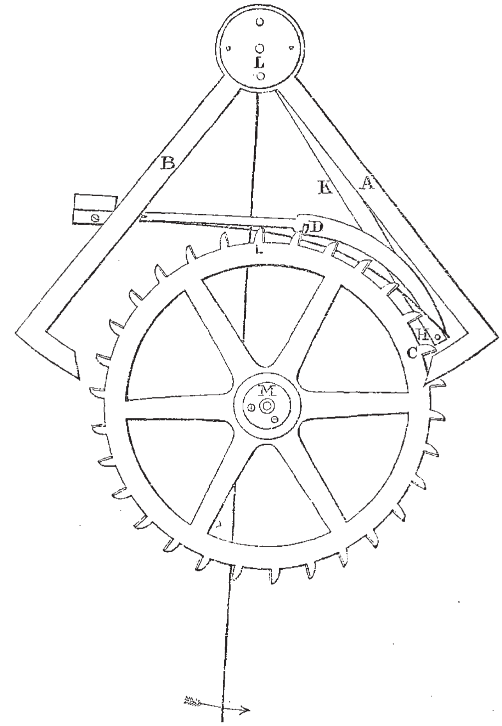

FIG. 18.

to be thrown completely away, and then the hooks at the extremities of the slants failed to catch the escape-wheel teeth, and the wheel ran on (apparently making the clock gain).

This escapement was improved by the late Mr. Bloxam,[1] who put cogs near the axis of the wheel to do the lifting, which was thus effected more slowly (see Fig. 17).

That collection of arms, A A A, and the cog-wheel, W, to which they are fastened form the escape-wheel. The pendulum, P P, is now passing through the vertical position or zero, and the pallet P_1 P_1 has fallen as low as it can, and is resting upon the banking pin B_1. But the other pallet, P_2 P_2, has been lifted, and is now being held by the cog T_2, the cog can lift it no further because one of the arms, A A A, is caught by the locking stud L_2 (which is situated upon the opposite side of the pallet). By-and-by, however, the pendulum will reach the pallet, push it away,

1 Mr. Bloxam discovered that the pendulum should quit and take up each pallet at angles depending upon its arc of vibration. The reader who wishes for further information cannot do better than consult Mr. Bloxam's elaborate paper, *Memoirs* R.A.S, vol. xxii. p. 103; and another, vol. xxvii. p. 61.

and liberate the wheel; the cog T_1 will then immediately operate upon the hook H_1 and lift the other pallet. Meanwhile the pendulum swings away to the right, carrying the pallet $P_2 P_2$, and returns with it, but as there is now no cog P_2 to receive it, it falls to the lower position corresponding to that now occupied by $P_1 P_1$, the excess of its fall over its rise, upon the pendulum as in the preceding case constituting the impulse.

This form of gravity escapement has been further modified and improved for ordinary use by Sir Edmund Beckett.[1] The only way in which variations in the force of the clock-train can disturb the pendulum in these escapements is by putting more or less pressure upon the locking studs, giving the pendulum more or less trouble in liberating the escapement; and with reference to this you must not be deceived by so-called improvements for detaching the pendulum completely from the escapement, for they really never do so, and generally by the number of pieces employed, hamper the pendulum with much more friction than that to which it would be exposed by direct communication with the clock-train.

You will see that the general effect of a gravity escapement is to make the pendulum move rather faster than if it were a free one, because the weight of the pallets is equivalent to two smaller pendulums attached to it during the greater portion of its swing. And the effect of any increase of pressure is quite the reverse of what would happen with a direct escapement, for it increases the pressure upon the lockings without increasing the impulse, and will consequently cause the arc of vibration to fall off.

The last clock-escapement I shall describe is a detached one (see Fig. 18), the design of the Astronomer Royal, Sir George Airy.

There is only one pallet, A, the other arm, B, being merely a safety-catch and counterpoise. That tooth of the escape-wheel, C, is not really resting upon the dead face of the pallet, though it is very close to it, the wheel being at present held by the detent, D, fastened to the clock frame.

The pendulum is supposed to have reached the limit of its excursion towards the left, and to be now returning. When it reaches a certain angle before zero, a pin, H, in the arm K (which swings with the pendulum and pallets), passes under the detent, lifts it, and unlocks the wheel at just that instant that the tooth C shall fall immediately upon the *impulse face* of the pallet without touching the dead face at all. The tooth slides down the impulse face, giving impulse to the pendulum; meanwhile, the pin H passes on and allows the detent to fall in time to catch the succeeding tooth L. The tooth quits the impulse face when the pendulum is at the same angle after zero that it was at before zero when the impulse began. Thus you get an equal impulse when the pendulum is falling as when it is rising, the advantage of which I pointed out to you when we were discussing Graham's dead escapement. Besides this, you get no dead friction, and the pendulum is almost completely detached from the clock-train. Upon returning the pin H clears the detent this way. You see that long spring beneath the detent, commencing near its middle, and projecting beyond its extremity upon the right; just now, in unlocking, the extremity of the detent supported this spring, and detent and all gave way before the pin H. But upon returning, the extremity of the detent of course gives no support to the spring, and the pin H pushes it upon one side without disturbing the detent. This escapement is used in the normal sidereal clock at Greenwich.

(*To be continued.*)

[1] The Westminster Clock has one of his forms. A locking stud is placed upon the back of one pallet and the front of the other, and there are two collections of arms (of three each) on either side of the cog-wheel, to meet them. The cog-wheel itself has also three cogs. This escape-wheel, with a seconds pendulum, turns once in six seconds, and its velocity is controlled by a fly.

CHARLES SAINTE-CLAIRE DEVILLE

M. CHARLES SAINTE-CLAIRE DEVILLE, the distinguished geologist and meteorologist, and brother of M. Henri Sainte-Claire Deville, the well-known chemist, was born of French parents in 1814, at St. Thomas, in the West Indies. At the age of 19 he was enrolled a pupil of the School of Mines, in Paris, and after a course of study there undertook, at his own expense, a scientific expedition extending from 1839 to 1843, to the Antilles, Teneriffe, and Cape Verd Islands. He spent upwards of a year investigating the geology of Guadaloupe, and wrote a detailed account of the terrible earthquake which laid waste that island in 1843. The results of this expedition he published in two series of memoirs, the one appearing from 1856 to 1864, on the geology of the Antilles, Teneriffe, and Cape Verd Islands, and the other from 1861 to 1864, principally on the meteorology of the Antilles. He was sent by the Institute to Italy in 1855 to examine the great eruption of Vesuvius which occurred in that year. After attentively following and investigating the eruption through all its phases, he wrote a description of it in a series of letters addressed to M. Élie de Beaumont, which were published in the *Comptes Rendus* and the *Moniteur* during 1856. He also, in 1858, published an interesting account of the volcanic eruptions of Stromboli, in the Lipari Isles, and in later years, various papers on other volcanic eruptions. Several memoirs on different points in chemistry and physics were written by him about 1852, and for several years he filled with distinction the chair of geology in the College of France, formerly held by the illustrious Élie de Beaumont. On December 28, 1857, he was elected a member of the French Academy of Sciences in the place of Dufrenoy, and on August 13, 1862, was made an officer of the Legion of Honour.

During the time he worked in the laboratory of his friend M. Dumas, he discovered the amorphous and insoluble form of sulphur, thus pointing out for the first time the fact that an elementary body may at will be made to assume two totally distinct states, differing from each other not only as regards their physical characters, but also as regards their essential chemical properties. This discovery was published in 1852.

Shortly after this his attention began to be more decidedly attracted towards meteorology; so much so, indeed, that for the past twelve years he appears in his writings almost exclusively as a meteorologist. Indeed the meteorological work, both scientific and administrative, which he undertook to do, and which he did, was so laborious and harassing as to leave him little time for other pursuits. By this work, however, he has left his mark unmistakably on the meteorology of France.

The fruits of his meteorological researches were given to the world in a remarkable series of papers in the *Comptes Rendus* during 1865-67, on the "Periodic Variations of Temperature." The object of this investigation was to prove the existence of annual and super-annual periodic perturbations of temperature, and to state with precision the character and nature of these periods. Having shown the occurrence of similar perturbations of temperature on four days of the same date in February, May, August, and November, these days being placed on the terrestrial orbit at equal intervals, and which, by the way, correspond with the dates of the festivals of the "Ice Saints," he inquired how far similar perturbations occur on any four days of the year separated from each other by equal intervals of time. Since the observations showed that some years and groups of years presented for the same days perturbations different from those of other years, being sometimes above and sometimes below the normal means of the days, an inquiry was raised as to the limits of the antagonism thus disclosed both as regards the amount and the cycle of years it embraced. Lastly, since these perturbations, if they exist, must exercise an important influence on all the