XXI. *Notice regarding a Time-Keeper in the Hall of the Royal Society of Edinburgh.* By JOHN ROBISON, Esq. Sec. R. S. Ed.

(Read 7th February 1831.)

THERE being some peculiarities in the construction of the Clock lately set up in this room, which may prove to have considerable influence on the performance of such instruments, and also on their cost and duration, it is presumed that a short notice of them, together with a few preliminary observations, may not be deemed uninteresting to the Society.

An eminent philosopher, in a work recently published, has defined a clock to be “ nothing more than a piece of mechanism, for counting the oscillations of a pendulum.” This definition cannot be considered as complete, as besides having to register the oscillations of its pendulum, a clock has to communicate successive impulses to it, to enable it to overcome the friction of its suspension, and the resistance of the air. If a maintaining power were not exerted by the clock, the pendulum would soon be brought to a state of rest.

There are therefore two principal points which require to be attended to in the construction of a good time-keeper. One, that the pendulum shall perform all its oscillations in equal times, in spite of the variations of temperature it may be exposed to; and the other, that the clock or mechanism shall communicate unvarying impulses to the pendulum during long periods of time.

Many ingenious contrivances have been fallen on by men of science, and by mechanics, to attain these ends, but some causes of error, which appear to be inseparable from the materials employed, still remained to be removed. As an endeavour has now been made to get rid of these difficulties, by some changes in the mechanism of the clock, and in the material of the pendulum, I shall proceed to explain the peculiarities in their construction.

The principal circumstances in which this time-keeper differs from the usual constructions are these; 1st, In having an escapement which requires no oil; 2d, In having the pendulum and ball formed of a material not hitherto used for this purpose; and 3d, In having the mechanism entirely secured against the effects of dust, and in a great degree against those of hygrometric changes in the atmosphere.

First as to the Escapement.—It is no doubt known to most persons now present, that, in the usual forms of clock-escapements, the teeth of the scape-wheel act alternately on two pallets, or inclined planes, which are placed at the extremities of branches proceeding from an axis, which axis has a third branch or tail, by which it communicates to the pendulum the impulses which it receives from the wheel-work, through the pallets. Thus in Plate XIV., Fig. 1., which is an enlarged drawing of the most commonly used escapement, A is the scape-wheel, which is urged round, in the direction of the arrow, by the maintaining power of the clock; B B are the two pallets; C is the axis from which they proceed; and D is a part of the third branch or tail, by which the successive impulses are communicated to the pendulum.

The chief cause of irregularity in this, and in all other forms of escapements where the teeth of the scape-wheel act on inclined planes, is the oil which is necessarily introduced to diminish the friction of the rubbing surfaces. In good clocks this

friction is reduced as much as possible, by forming the scape-wheel of steel, and the pallets of jewels; but oil is still necessary, and however pure, it must be liable both to chemical change, and to a gradual admixture with dust; its effect therefore on the rubbing parts must vary, and the impulse given to the pendulum must vary with it.

The escapement, which I shall now proceed to describe, is the invention of Mr WHITELAW, a very ingenious artist in this city, who has been employed to make the clock. His escapement possesses the advantage of not requiring oil in any part of its mechanism, and therefore is free from one great cause of irregularity.

In the drawings, at Figs. 2. 3. and 4., A is a scape-wheel, which need not vary much from the usual form; it acts alternately on the pallets D and E. These pallets are not attached to an intermediate axis, as in the former case, but are fixed to the pendulum itself (by which arrangement some sources of irregularity are suppressed). C C are the branches which carry the pallets; and B is the knife-edge on which the pendulum oscillates.

The pallets D and E, instead of being inclined planes along which the teeth of the scape-wheel would be required to slide while giving impulse to the pendulum, are portions of the surfaces of cylinders which revolve (or rather oscillate) on delicate pivots in ruby holes. When a tooth of the scape-wheel drops on one of these cylinders during the motion of the pendulum, the cylinder is turned partly round by the continued action of the tooth, until the pendulum has swung so far that the tooth escapes past the cylinder, having descended through a space equal to half of its diameter: at the moment of its escape, a tooth on the opposite side of the wheel is arrested by the other pallet, and a similar escape takes place with that tooth on the returning swing of the pendulum.

Here, it will be obvious, there can be no friction between the teeth and the pallets, and that oil would be superfluous. The rubbing has been transferred from the surfaces of the pallets to their centres, where, from the slowness of the motion and the smallness of the space moved through, there can be no appreciable resistance between the pivots and their ruby holes, and therefore no oil can be required.

It will be observed, on inspection of the drawing, that the diameter of the pallets is nearly as great as the distance between the teeth of the wheel; the teeth, however, advance only half of that space at each vibration, and if the pallets were solid cylinders, the returning motion of the pendulum would be opposed by their striking against the teeth on the entering side. In order to prevent this, a portion of the cylinder is cut away in the middle part, leaving only enough of surface for the teeth to act on during their descent of half the diameter. A third part of the circumference is sufficient for this action, and any thing less than a half will leave a free passage for the disengaged tooth. In Fig. 2, at *d e*, the pallets are drawn as detached from their frames, and as if half of the circumference were cut away from the middle part. In Fig. 3. and 4. the pallets are shewn in section in their proper positions: in these figures, *w* is a small counterpoise, to bring back the pallet to its position for receiving the next succeeding tooth, after it has been turned aside by the escaping one.

To persons who have paid attention to the subject of Horology, I need not point out the great value of this improvement, nor the benefits which may arise from it in those departments of science where an exact measure of time is a desideratum*.

* The maintaining power in this clock is a weight of 4 lb. 4 oz., descending through about 40 inches in 7 days; the weight of the pendulum and ball $12\frac{1}{2}$ lb., and of vibration 4.4 inches.

I may mention here, that in Fig. 2. the pendulum is supposed to be in the middle of an oscillation, with a tooth of the scape-wheel pressing on the pallet D. In Fig. 3. the oscillation has been completed to the left; the pallet D has allowed the tooth to escape past it, and a tooth of the opposite side of the wheel has been arrested by the pallet E.

In Fig. 4. the pendulum has swung to the right; the tooth which rested on E has in its turn escaped, and another, on the opposite side of the wheel, has dropped on D.

The next peculiarity in this clock which merits attention, is the material of which the pendulum rod and ball have been made. Marble has been adopted for this purpose, in consequence of a suggestion made to me by Dr BREWSTER, and since repeated by him in the *Philosophical Transactions* for 1830, page 94, where, in speaking of Mr MITSCHERLICH, he says, "This eminent philosopher has found, by direct experiment, that heat expands a romb of calcareous spar in the direction of its axis, and contracts it in directions at right angles to that axis." Dr BREWSTER adds, in a note: "It follows from this fact, that massive carbonate of lime, in which the axes of the molecules have every possible direction, should neither contract nor expand by heat, and would therefore form an invariable pendulum*."

In constructing this pendulum, care has been taken to exclude every thing which could interfere with its principle, and the whole of the pendulous portion, from the point of suspension downward, is continuously of marble, without the intervention of metal, and even the convenience of an adjusting screw at the bottom has been sacrificed to insure this. A method of

* Some experiments made since this paper has been read, seem to shew, that a rod of Carrara marble, on being measured at 32° and at 211° Fahrenheit, will be found to have expanded $\frac{7}{1000}$. A rod of Lucullite marble, $\frac{5}{1000}$.

adjustment has been substituted, which has the advantage of being applied without stopping the vibrations.

If experience shall confirm the accuracy of Mr MITSCHERLICH's experiment, and verify Dr BREWSTER's inference from it, an important advantage will have been gained by this application, as a pendulum invariable in its own nature, must have a great superiority over a compensation one, which, however well adjusted to isochronism under differences of temperature, when all its parts are affected simultaneously, must always be liable to derangement from partial currents and changes. The small expense at which such a pendulum can be procured, would, in that case, lead to making good time-keepers come into more general use.

The last peculiarity which I shall notice is of less importance than those above mentioned, but, nevertheless, merits some remark, as it tends to obviate another cause of irregular action in the mechanism of time-keepers, viz. the gradual accumulation of dust in the interior of the case. In order to understand the utility of the contrivance which has been resorted to, to prevent this, it is necessary to explain the way in which the accumulation of dust takes place. If a clock-case be closed up when the air of the apartment is of a medium temperature, air will be drawn into the case through the readiest apertures, as soon as a diminished temperature causes a contraction of bulk in the included air. The air which enters will carry with it a portion of the dust which is always floating (as we see distinctly when a sunbeam shines through a small aperture into a darkened room). This dust is soon deposited, from the comparative stillness of the air within the case, and when, by increase of temperature, air is pressed out of the case, it leaves the dust behind it; by which means a small addition is made to the quantity of dust in the case every time a contraction takes place, and thus, in process of time, the action of the mechanism is impeded by

the accumulated deposit. To prevent this process taking place here, the case has been made carefully air-tight against moderate pressure, excepting in one place, where a short tube is fixed in an opening from which it projects externally about two inches. On this projection a half distended air-bag is made fast*. It follows from this arrangement, that when a contraction takes place within the case, the pressure of the external air will compress the bag, and make a portion of its contents enter the case to make up for it; and when, on the contrary, an expansion takes place, the expressed air will enter the bag and distend it; in this way, if the capacity of the bag be great enough, no foreign air (if it may be so termed) can enter the case, but the equilibrium will be kept up by a circulation of the same air between the bag and the case, like the mercury in the basin and tube of a barometer, and no dust can ever be added to the quantity originally shut up with the clock. It is evident that this must conduce essentially both to regular performance and to the durability of the clock, and as the application of the contrivance occasions little expense or inconvenience, there is no reason why it should be omitted in any observatory clock-case.

* The air-bag is concealed within the pediment of the top of the clock-case.