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IV. *On the Irregularity in the Rate of Going of Time-pieces occasioned by the Influence of Magnetism. An original Communication, by Mr. VARLEY.*

HAVING studied the theory of clock and watch-making many years, as well as been, part of this time, concerned in an extensive manufactory of watches, I have had many opportunities of observing a circumstance which has surprised every one in the trade as well as myself; that watches of considerable price, and from the hands of excellent workmen, often perform no better than a plain one of inferior workmanship and much lower price. Being anxious, as may naturally be supposed, to furnish my friends with watches or clocks which would go well, I made it my business to pay particular attention to whatever could contribute to their perfection. With this view, I made almost numberless experiments and observations on the various escapements now in use, the different constructions of balances, pendulums, pendulum springs and compensations, both for clocks and watches, which have been applied by very ingenious mechanics and excellent workmen to correct the errors in the rate of going, especially of watches, occasioned by the various degrees of heat and cold, change of position, external agitation, influence of oil, friction, variation of maintaining power, and other causes.

Some of these contrivances are extremely well adapted to answer the intended purpose; but, notwithstanding all their advantages, the maker and purchaser are frequently disappointed in the performance of the machine to which they are applied. Many instances might be produced where the best workmen have been employed, no expense spared by the maker, and the above-mentioned improvements applied with the utmost care and attention; and yet the rate of going of the watch has been more irregular than in some ordinary watches. When such a circumstance occurs, it is extremely unpleasant; the purchaser not understanding the difficulties

difficulties which the maker has to encounter, thinks himself ill used, and the latter suffers at the same time in his reputation as an artist, and in his character as a man ; and when the watches happen to have been made for nautical purposes, or for exportation, the whole community, in some measure, become sufferers.

The intention of the present paper is to point out a defect in the construction of time-pieces of every description in which balances are used, and at the same time a source of error in their performance, which has been hitherto little if at all suspected, but which, where it occurs, completely defeats all the ends intended to be answered by the application of the above-mentioned ingenious contrivances : and that it does occur very frequently, will be made sufficiently obvious by a simple detail of facts supported by actual experiments.

That the balances of watches, when manufactured of steel, as they mostly are, might be in a small degree magnetic, and consequently have some influence in disturbing their vibrations, has been suspected by some and denied by others : but that a circular body, such as a balance is, should possess polarity ; that a particular point in it should have so strong a tendency to the north, and an opposite point an equal tendency to the south, as to be sufficient materially to alter the rate of going of the machine when put in different positions, has never, I believe, been even suspected. If it had, the use of steel balances would have been laid aside long ago, particularly where accurate performance was indispensable, as in time-pieces for astronomical and nautical purposes. Though I have frequently examined, with great care, watches that did not perform well, even when no defect in their construction or finishing was apparent, and suspected the balance to be magnetic, yet I never could have imagined that this influence, operating as a cause, could produce so great an effect as I found upon actual experiment ; for I did not expect to find that a balance, even when magnetic,

should have distinct poles. Happening to have a watch in my possession, of excellent workmanship, but which performed the most irregularly of any watch I had ever seen, and having repeatedly examined every part with particular attention, without being able to discover any cause likely to produce such an effect, it put me upon examining whether the balance might not be magnetic enough to produce the irregularity observed in its rate of going.

I took the balance out of its situation in the watch, and, after removing the pendulum spring, put it into a poising tool, intending to approach it with a magnet, but at a considerable distance, to observe the effect, while at the same time the distance of the magnet should preclude the possibility of the magnetic virtue being thereby communicated to the balance. I had no sooner put it into the tool than I observed it much out of poise; that is, the one side appeared to be heavier than the other: but, as it had been before examined, in that particular, by a very careful workman, more than once, I was at a loss to determine what to think of the effect I saw; when happening to change the position of the tool upon the board, the balance then appeared to be in poise. As there could be no magic in the case, it appeared that the balance had magnetic polarity, as no other cause could produce the effect I had witnessed, and which was repeated as often as I chose to move the tool from the one position to the other. It happened that I was then sitting with my face to the south: a circumstance that led me, in placing the plane of the balance vertically, to put it north and south, and of course the axis east and west—the only position in which the magnetic influence could make itself most apparent, and which will account for the circumstance not having been observed by the workman who examined the poise of the balance before I did; for, as often as I placed the plane of the balance vertically between east and west it was in poise, whichever end of its axis was placed towards the south.

Having

Having pretty well satisfied myself as to the cause, I now proceeded to determine the poles of the balance. With that view I placed its axis in a vertical situation, and of course its plane was horizontal; and I was much surprised to find that, in that position, it possessed sufficient polarity to overcome the friction upon its pivot; for it readily turned on its axis to place its north pole towards the north. Making a mark on that side that I might know its north pole, I then repeatedly turned that point towards the south; and, when left at liberty, it as often resumed its former position, performing a few vibrations before it quite settled itself in its situation and came to rest—exactly as a needle would do if suspended in the same manner.

I was extremely happy that I had observed these effects before I brought a magnet to make the experiment I first intended, as I might, and as others also might have concluded, that the polarity had been produced by the approach of the magnet. I now, however, brought a magnet into the shop, and, presenting its south pole to the marked side, that is, to the north pole of the balance, the balance continued at rest; but upon presenting the north pole to the marked place, it immediately receded from the magnet: it resumed its former position whenever the magnet was withdrawn.

No doubt now remaining as to the facts, and being in possession of the position of its poles, I proceeded to examine the effects produced by this cause upon the watch's rate of going. Having put on the pendulum spring, and replaced the balance in the watch, I laid the watch with the dial upwards, that is, with the plane of the balance horizontally, and in such a position that the balance when at its place of rest should have its marked side toward the north:—in this situation it gained 5' 35" in twenty-four hours. I then changed its position so that the marked side of the balance when at rest should be towards the south, and, observing its rate of going for the next twenty-four hours, found it had lost 6' 48"—producing, by its change of position only, a difference of

12' 23" in its rate. It must be obvious to every person, that even this difference, great as it was, would be increased or diminished as the wearer should happen to carry in his waistcoat pocket a key, a knife, or other article made of steel. This circumstance, taken along with the amount of the variation occasioned by the polarity of the balance, was fully sufficient to produce all the irregularity observed in the going of the watch.

I then took away the steel balance, substituted one made of gold, and, having brought the watch to time, observed its rate of going, and found it as uniform as any watch of the like construction; for, though it was a duplex escapement, which is perhaps the best yet invented, at least for common purposes, it had no compensation for the expansion and contraction occasioned by heat and cold, and therefore a perfect performance was not expected.

Steel balances being commonly in use, and, on that account, easiest to be procured, and being on many accounts preferable to any other, I was unwilling to abandon them entirely; but resolved to take the precaution of always trying them before I should apply them to use. The mode I adopted was, to lay them upon a slice of cork sufficient to make them float upon water, and I was in hopes that out of a considerable number I might be able to select sufficient for my purpose; but to my surprise, out of many dozens which I tried in this manner, I could not select one that had not polarity. Some of them had it but in a weak degree, and not more than one or two, out of the whole quantity, appeared to have it so strong as the one which gave birth to these experiments and to the present paper, which is perhaps more prolix than could be wished: but the subject appeared to be not uninteresting, and I hope the remarks I have offered will not be altogether useless, as every thing that can tend to add to the perfection of time-pieces, or to remove any cause that operates against their perfection, is of some importance.

My only motive in sending this for publication in the

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Philosophical Magazine is to render some service to a science which I at first studied for amusement only, having never been instructed in any part of it, and for some years without the most distant idea of ever following it as a business. Should it prove acceptable, I may perhaps follow it up with a demonstration, and a few diagrams to illustrate the foregoing experiments, and to cast some light on other branches of this science; particularly on the various escapements now in use, and the advantages and disadvantages of their different constructions and applications in clock and watch work. In doing this a compensation for pendulums will be pointed out, simple and cheap in its construction, yet calculated to obviate the inconveniences attending the ingenious but expensive contrivances that have hitherto been resorted to, and at the same time capable of the nicest adjustment possible. This improvement, for such I consider it, will serve at the same time to show how our very amusements, and the study of our leisure hours, when directed to useful objects, though with slender abilities and under many disadvantages, may eventually be of service to our friends in particular, and beneficial to society in general.

*Hatton-house,
May 31, 1798.*

S. VARLEY.

P. S. As I am persuaded a Journal carried on upon the plan you have proposed cannot fail to be useful to the community, and as even hints may sometimes pave the way to greater improvements, I shall look over my memorandums, from among which I may perhaps be able to furnish you with some, on a variety of subjects, for the amusement of your scientific readers.