4 The Action of the Cycloid on the Spring where it touches it tends to quicken its Vibrations.

A Gold Balance is best. Steel may be magnetical. Platina might do well.

7 Tried an Adjustment for mean times once, but did not answer.

8 Whilst Heat is increasing the Watch will sometimes go slower $\frac{1}{10}$ of a Second in three hours

8 He adjusts it in Cold weather by placing it near a Fire with a Thermometer, & adjusts the Thermometer first.

The Watch goes a little slower now owing to it's wanting to be cleaned.

Inquire, Why do some common Watches go so much better than others made with equal Care? Answer It lies in the disposition of the Weight of the Balance. A Combination of Errors accidentally corrects one another.

~~Does the thickness~~ of the Pot serves partly to counteract the Variations that should arise from the Changes of heat & Cold.

Yes.

How can Mr Harrison make common Watches in a more certain manner so that all shall go nearly with equal Perfection?

He can do something this way:

4 The Cycloid by taking the Spring shorter accelerates the Vibrations; and the Spring leaving it for a longer time in the larger Vibrations is less accelerated by it in that Case.

10 The Momentum in the Balance acquired by Velocity is better than that acquired by Weight, as Friction is not thereby increased, perhaps if any thing diminished, & the Resistance of the Air only is increased, the Effect of which is of great Service

10 The Force of the Balance as the Squares of the Diameter as will be shewn by the pendulum Clock.

This latter goes sensibly larger Arcs in hot weather,

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3 The Watch is adjusted to vibrate great & small Arcs in equal time in the following manner.

To go the same in four different positions vertically, by making the Weight of the Balance different in different parts.

When the Watch lies flat, to go the same as vertical by the joint Effect of the Cycloid & the Back of the Pallets.

1. Note, the Balance naturally vibrates largest Arcs when flat; next when 1256 are uppermost, least when 389 are uppermost.

Quere, what alteration was made to the Watch after it came back from Jamaica? — Answer, Cycloid was applied. —

8 The Thermometer takes heat sooner than the Spring, & he hence concludes that Brass takes heat sooner than Steel, & that Brass rods of a Grid Iron pendulums should be made thicker than the Iron ones. —

~~The weight of the Thermometer Spring~~ makes a Difference in the Vibrations. Quere, which way? if put in rarified Air.

8 The Effects of the Thermometer is increased ~~by making it thinner~~ by rubbing the Sides, thinner & is lessened by thickening the Edge by burnishing it.

2. He says, large Arcs are naturally performed in less time than small ones. This he inferr because the watch went slower in a vertical position than in the horizontal ones, & the vibrations are visibly larger in the latter case.

7 He has no adjustment for meane times. As soone as the Watch is put together, it will shew it's rate of going in three hours accurately the same which it will keep afterwards; so that he can soon determine it by Companison with his Clock.

5 If the pendulum Spring is too strong, weakens it by rubbing it away a little, but if too weak he changes it for another.

7 He does not alter the fastning of the Spring at the End.

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10 The Force of the Balance is as the Square of the Velocity also as the Square of the diameter

4 The Spring at rest touches the Cycloid pin, & also while it has coil'd it self one Eighth of a turn.

11 The diameter of the Balance is 2,2. of the plate Inches 3,8.

6. The Balance Spring is fastned to a Stud which takes off the plate with a Screw, & is put on again without taking it off the Spring.

16 The main Spring has two Barrels

17 The Fusee has 6¼ turns.

18 The Fly takes off the superfluous Force used in winding up the Spring nearest the Balance Eight times every Minute, as the drag back takes off the superfluous Water at a Mill.

Always avoid giving it a circular Motion. — a little Watch was once kept this way. It stopped 3 or 4 times when in Capt. Campbell's possession.

the Watch should have a Case, & only a Box, no Case,

Mr. Matthews says it would be best to fix, the Clock plate, pendulum & all to the Wall. —

Harrison's Watch is affected by the Changes of the Air indicated by the Barometer. This was remarked when the Gentlemen attended him, before the Watch went to Barbadoes, when the Barometer fell one Inch during the time, which made a difference of two or three Seconds per day in the going of the Watch.

The ballance without the pendulum spring tends to vibrate once in two seconds. Mudge

The Thermometer (Mr. Mudge says) should lay with its length across the ship, else it may shift the place of its touching the spring every ~~time~~ shock the ship received from the rolling of the waves, & so make the watch go continually too fast or too slow as long as the ship goes upon one tack. Mudge.

4 The spring begins to leave the cycloid, when the ballance has vibrated 45° beyond the point of rest, while the spring is coiling itself up.

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A Contrivance to fit the pendulum to the Clock before it is fastned to the Wall, in order that it may be at a proper height.

The Shape of the pallets.

The Clock is all of Wood except the pallets.

It Strikes.

The Case ought to be very close.

The Bob of the pendulum is not heavier than in common ones.

N.B. The Steel Rods ought to be thinner than the Brass ones.

Quare what Oyl? What Shape of the Cycloid? Is it a Part of a Circle? yes.

Quere, how many degrees does the pendulum vibrate on each Side of the perpendicular? [redacted]

[redacted]

The Wires connecting the Wheels with two Balances in Mr. Harrison's third Machine cross one another.

13. A certain rise both for the pallets or rather a certain proportion between the diameter of the pallets & the Balance Wheel in the Watch, this he found by Bellringing, for he could bring the Bell better into a Motion, by touching it some time to time, somewhere near the Centre, than near the Circumference, because in the first Case his hand moved quick enough to follow the Bell.

14. The Grand principle of Harrison's watch, is that of giving the greatest Motion possible to the Balance with a given Force. This is done by the Scaping & proper Quantity of the Arc described.

15 There are four Springs in the Watch, first a Maine Spring Secondly a Spring in the Fusee to keep it going whilst it is winding up, thirdly a Spring which is wound up Eight times every Minute, fourthly the Balance Spring. The three first made by Mabilly. —

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19 Pivot-holes all Rubies with Diamonds at the Ends.

12 The Watch makes just five Beats in a Second

12 A pocket Watch of this Sort would do better with Six Beats in a Second.

One End of the Watch in the late Voyage, was not higher because not equally adjusted in all positions. Also it was altered as the Ship lay down on one or the other Tack. For this purpose a little pendulum was placed with a divided Arch.

12 Degrees was the greatest lie down of the Ships, the greatest Roll 15 Degrees. –

When in a vertical position, hold the Watch a little back that the Face may be a little up.

If the Spring be not exactly parallel to the Plates, it will make a small difference when the Face is up or down. –

8 The Watch may be put with Fig. 12 each day alternately, turned different days for fear one part of the Box may be hotter than the other.

Care is to be used in turning the Watch over to wind it up. Give it three turns.

If the Watch was put in Vacuo, it would hit the banking.

11 If the Balance vibrated faster the Resistance of the Air would be too great, & might perhaps even stop it.

Query Could not the Cycloid or some thing like it be applied to large Machines?

The Pendulum Clock has two Cycloidal Cheeks at the Spring at top.

Brass & Steel Bars are made adjustible by only shifting a Brass pin into different Holes.

The Pendulum vibrates a very large Arch.

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Notes taken at the discovery of Wm. Harrisons time-keeper

The clicks, which act on the fusee ratchet B B, turn upon pins on the opposite wrings or bars d d of the perpetual ratchet, fig. 3.

The 20 external teeth of the secondary spring barrel enter into corresponding notches in the two supporters of the barrel. The spring within side the fusee is set up to the proper strength by putting these into different notches.

The steel arbor of the 4th. wheel is hollow: the arbor of the contrate wheel goes through it.

The inner end of the spring, which gives motion to the to the balance wheel, & is itself wound up eight times every minute, is hung to the contrate wheel arbor at, O; the other end to the spring box at, n; see fig: 7th. The spring box is connected with the 4th wheel in the following manner. The middle of the spring box has a socket of somewhat more than the depth of the spring box; the hollow arbor of the 4th wheel has a notch like that in the socket of a bayonet; the brass socket has a pin that goes into & locks in that notch: this pin must be no longer than the thickness of the hollow arbor, lest it should touch the arbor of the contrate wheel within it: the spring box has two arms, the ends of which are reversed & lock against two of the six bars of the contrate wheel, when the spring is set up to its proper height; but, in the time of action, these ends never touch the bars of the contrate wheel. When this spring is in its middle state of force in drawing the contrate wheel, a weight of 13 grains hung upon the rim of the contrate wheel balances it: & with this force the balance, without the balance spring, tends to vibrate once in two seconds.

The weight of the contrate wheel, with the seconds wheel & their common arbor is 37½ grains.

The palets are made of diamonds: The pivot holes are all made in rubies with diamonds at the ends.

The diameter of the circle described by the edge of the palets is 1/7th of the diameter of the balance wheel from the middle of its thickness. The diameter of the spindle is 1/24th of the diameter of the circle described by the edge of the palets.

The two flat faces of the palets are nearly parallel to each other (but this must be determined by close examining) & are tangents to a circle whose diameter is 2/5th of that described by the edge of the palets. The curve of the back of the palets is an arch of circle, whose center lies in the line joining the edges of the palets & the centre of the spindle, the distance of the two centres being 2/5ths, and the radius

of the curve of the back of the palets 3/5 ths of the radius of the circle described by the edge of the palets. The teeth of the ballance wheel pass as near the spindle as they can with safety. The escape or interchange of the palets is performed at full 3/4 ths of the whole circle of the ballance from the point of rest. ——————

A certain size is best for the palets, or rather a certain proportion between the diameter of the circle described by the edge of the palets & the diameter of the ballance wheel. This was first suggested to Mr. Harrison by bell-ringing; for he could bring the bell better into a motion by touching it from time to time somewhere near the centre than near the circumference, because in the first case his hand moved quick enough to follow the bell. The ballance wheel arbor should point on that side of the axis of the contrate wheel, which should make the contrate wheel tend to drive it towards the follower. ——— The ballance wheel arbor lies from 6 to 12 with respect to the figures of the dial plate. The diameter of the ballance is 2 3/10 inches, but would be better a little larger or 2 1/4 inches. The weight of the present ballance with the three bars rims 28 5/10 grain. The weight of the ballance wheel with its pinion & arbor is 8 grains. ——————

There should be 1/100 of an inch between the ballance & the ballance cock, as also between the ballance & slide, that the air may not be too much confined.

The thermometer kirb is composed of two thin plates of brass & steel rivetted together in several places, which, by the greater expansion of brass than steel by heat & greater contraction by cold, becomes convex on the brass side in hot weather, & convex on the steel side in cold weather; whence, one end being being fixed, the other end obtains a motion corresponding with the changes of heat & cold, & the two pins at this end, between which the ballance spring passes, & which it touches alternately as the spring bends & unbends itself, will shorten or lengthen the spring, as the changes of heat & cold would otherwise require to be done by the hand in the manner used for regulating a common watch. ——————— The thermometer kirb lies from 9 to 3 with respect to the figures of the dial-plate. ——————

The pin called the artificial cycloid, touches or presses the ballance spring on the inner side, while the spring is in the state of unbending itself, & till the ballance has passed the middle point or point of rest, & by the bending of the spring has vibrated 45° further: then the spring ceases to touch the pin for the remainder of this vibration & till the ballance returns to the same point back again. ——

Thus the spring is pressed by the pin for half every vibration, & as much time longer as the ballance takes to vibrate 45° from the middle state or point of rest while

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the spring is coiling it self up; &, as this is, bearing a less proportion to the larger vibrations than the smaller ones will be performed in less time in the large vibration than the the smaller; the cycloid pin will act for a somewhat less time in the large than in the small vibration; & as its effect is always to accelerate the vibrations, it will accelerate the large vibrations less than the smaller ones, & consequently, as the former are, according to Mr. Harrison, of themselves quicker, it should tend to reduce the times of these unequal vibrations nearer to equality. The cycloid pin was not applied to the watch till after it came back from the voyage to Jamaica. ——— If the ballance spring was weaker at the outer end the cycloid would have more effect. ———

When the ballance has vibrated from the point of rest 6 such parts of which the whole circumference contains 24, the palets will overturn, as it is called, the point of the tooth going round the edge of the palet & beginning to act upon the curved back of the palet, & the point of the tooth will continue to act thereupon for 2 of these parts more, & 4 or 5 degrees over when the watch is in a horizontal position. ———

After this the ballance by the force of the spring begins to return. ———

The ballance spring is fastened at the outer end to a stud, which is fastened to the plate with a screw & a steady pin, by which means it may be taken off the plate, stud & all, & put on again exactly as before, without undoing the fastening of the end of the spring to the stud. ———

There is no adjustment for mean time, as in common watches; there was one, but it did not answer. As soon as the watch is put together, Mr. Harrison says, it will shew its rate of going in 3 hours accurately the same which it will keep afterwards; so that he can soon determine it by comparison with his pendulum clock. A small correction in the time will be made by setting the pendulum spring a little in or out at the ballance collet.

The length of the main-spring is 5 feet; its weight 23·18 dwts 6gs & it is poised by 3 oz. Troy at 7,2 Inches from the centre of the spring-box. The length of the second spring or secondary main-spring, which is within side the fusee, & keeps the watch going whilst it is wound up, is 16 inches, & its weight 56 grains.

The length of the 3 or remontoir spring, which is wound up 8 times every minute, & acts at the contrate wheel & keeps the ballance wheel in motion, is 10 inches, & its weight 3½ grains. These three were made by Maberly.

The fusee has 6¾ turns. ———

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The fly serves to moderate the velocity with which the 3d spring would otherwise be be wound-up.

If the ballance spring is too strong, it must be made weaker by rubbing it away a little, but if it be too weak it must be changed for another.

If the ballance spring is stronger in one part than another, the centre of the ballance will be thrown at right angles to the spring in the place where it is strongest.

The ballance vibrates largest arcs when its plane is in a horizontal position; next greatest when the hours 12 & 6 are uppermost & the plane of the ballance is perpendicular to the horizon: least when the hours 3 & 9 are uppermost, for then both the contrate & ballance wheels have their axes horizontal.

Large arcs, in general, are performed in less time than small ones:

This Mr. Harrison inferred, because the watch, before any correction was applied on this account, went slower in a vertical position than in the horizontal one, & the vibrations are visibly larger in the latter case.

The watch is adjusted to vibrate great & small arcs in equal times in the following manner; To go the same when placed vertically with the hours 3, 6, 9 & 12 upwards successively by making the weight of the ballance different in different parts. To go the same when placed horizontal as when vertical by the joint effect of the back of the palets & the cycloid pin.

Mr. Harrison adjusts the thermometer herb first, that is to say before he adjusts the watch to go, in different positions the same. Mr. Harrison requires cold weather for adjusting the thermometer herb, & he places the watch near a fire with a common thermometer by it, to try if it keeps the same time as in the cold air. If not he alters or adjusts the thermometer herb, till it goes the same in these two different degrees of temperature of the air. The effect of the thermometer herb is increased by rubbing the sides thinner, & is lessened by thickening the edge by burnishing it.

Whilst the heat is increasing, the watch will sometimes go $\frac{1}{10}$ of a second slower in 3 hours than when the heat is come to a stand. The thermometer herb takes heat sooner than the ballance spring, & Mr. Harrison thence concludes that brass takes heat sooner than steel, & that the brass rods of a gridiron pendulum should be made thicker than the steel ones.

The thermometer herb must bend a little by its weight, when the watch is in a vertical position with the hours 6 or 12 uppermost; this effect must be corrected by making the ballance a little lighter towards 6 hours; the quantity of the alteration to be determined by trials.

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In constructing the thermometer originally it is necessary to leave the brass too short at first, as it stretches more than steel in the working. Three hours time is enough to try the thermometer in different degrees of heat till it comes very near. Oil should be applied to the palets & pivot holes of the watch, but very sparingly. The watch will go 3 years without requiring to be cleaned.

At the time of the discovery in August 1765, Mr. Harrison said, that the Watch then went a little slower than it had done, owing to its wanting to be cleaned; Viz. 2 or 3 Seconds p^r Day.

The force or momentum of the ballance, Mr. Harrison says, is as the square of its diameter, also as the square of its velocity, its weight being given. The momentum of the ballance, acquired by increasing the velocity is better than that acquired by increasing the weight, as friction is not thereby increased, perhaps of any thing diminished & the resistance of the air only is increased, the effect of which is tolerably uniform & of great service.

The watch makes just 5 beats in a second of time. If the balance vibrate faster, the resistance of the air would be too great. A pocket watch of this kind would do better with 6 beats in a second.

The grand principle of the watch, is that of giving the greatest motion possible to the ballance with a given force. This is done by the various & proper quantity of the arc described.

Care is to be used in moving the watch, as in turning it about in order to wind it up, not to give it any quick circular motion in the plane of the ballance; as it might possibly stop it. A pocket watch, which Mr. Harrison has made of this kind, once stopped this way. Turn the watch over upon some diameter of the dial-plate as an axis, in order to bring it into a convenient position for winding up.

The watch should have a cap & no outer-case; the wooden box, in which it should be kept, serving that purpose better.

Hold the watch a little back, when in a vertical position, that the face may be a little up.

If the ballance spring be not exactly parallel to the plates, there will be a small difference in the going of the watch when the face is up or down.

The watch may be put with fig: 12 turned each day alternately different ways, for fear one part of the box may be hotter than the other.

One end of the watch, in the late voyage to Barbadoes, was a little

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elevated, because it was not equally adjusted in all positions. Also it was altered & brought back to the same position with respect to the horison, as the Ships lay down on the one as the other tack, by the help of a moveable arch.

Mr. William Harrison reckons the greatest roll of a Ship 15 Degrees; & the greatest lie down, when when going upon one tack, 12 Degrees.

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