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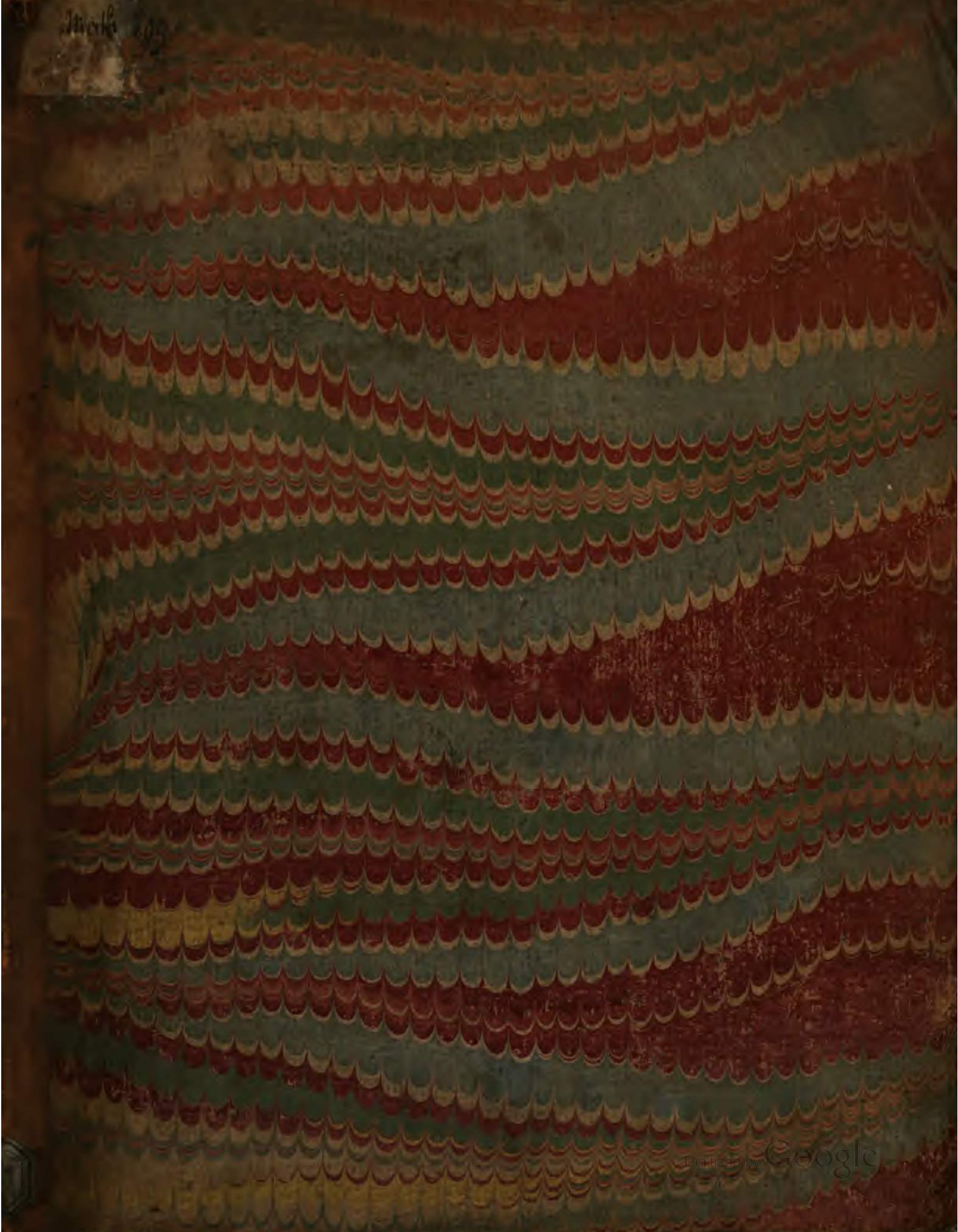
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THE
P R I N C I P L E S
OF
MR. HARRISON'S TIME-KEEPER.

WITH
PLATES OF THE SAME.

THE
P R I N C I P L E S
OF
MR. HARRISON'S TIME-KEEPER,
WITH
P L A T E S O F T H E S A M E .

PUBLISHED BY ORDER OF
THE COMMISSIONERS OF LONGITUDE.

L O N D O N :
PRINTED BY W. RICHARDSON AND S. CLARK ;
AND SOLD BY
JOHN NOURSE, AND MESS. MOUNT AND PAGE.
M DCC LXVII.



P R E F A C E.

THE original drawings, from which these plates were engraved, together with the written paper annexed, intituled, **PRINCIPLES OF MR. HARRISON'S TIME-KEEPER**, were delivered to the Commissioners appointed by act of parliament for the discovery of the longitude at sea, by Mr. John Harrison and Mr. William Harrison his son, upon oath, as containing a full explanation of the principles upon which Mr. John Harrison's watch or time-keeper for finding the longitude at sea is constructed.

Mr. Harrison and his son gave also, upon oath, to the Reverend John Mitchell, the Reverend William Ludlam, and Mr. John Bird, gentlemen well-skilled in mechanics, and Mr. Thomas Mudge, Mr. Larcum Kendal,

Kendal, and Mr. William Matthews, watch-makers, by appointment of the board of longitude, and myself, such further explanation of the construction of the said watch, by word of mouth and experimental exhibitions, as we required; producing the watch, taking it to pieces in our presence, and answering to such questions as we proposed relative thereto. Some notes taken by myself on this occasion I have subjoined hereto.

The original drawings of the watch were delivered to me at the board of longitude, which I have since caused to be carefully engraved, under my own eyes, at the Royal Observatory, and think I can answer, that the lines on the copper-plates every-where correspond with the measure of the drawings within one, or at most two breadths of the lines, which are so very fine. Nevertheless, the reader must not expect to find the impressions taken off upon common paper agree so nearly, either with the originals or with themselves,
owing

owing to the shrinking of the paper after the water has been pressed out of it in going through the press. But, for the sake of the curious, and particularly artists who may be desirous to construct other watches after the model of Mr. Harrison's, I have caused a few impressions of the plates to be taken off upon India paper; which, if it be only made a little damp, by being put for a few minutes between two wet sheets of paper, will receive the impression from the plates perfect, and will not shrink at all in the drying.

It may not be improper to take notice here of a difference in the position of the pallets in the 8th and 9th figures, plates VI. and VII. which might otherwise puzzle the inspector, or, at least, induce him to think there was some error made in engraving the plates from the original.

In figure 8th, the centre of the curve of the pallets lies in the circumference of the dotted circle, whose radius is two fifths of the radius of the circle described
by

by the edge of the pallets ; but, in figure 9th, the centre of the pallets lies just without the circumference of the little black circle, representing the spindle, whose radius is one fourth of the radius of the circle described by the edge of the pallets. The latter figure shews Mr. Harrison's former design, which he has since altered, as is represented in the 8th figure.

N O T E S

N O T E S
TAKEN AT THE
D I S C O V E R Y
O F
MR. HARRISON'S TIME-KEEPER.

THE balance naturally vibrates largest arcs, when in a horizontal position ; next greatest, when the hours XII and VI are uppermost, and the watch is in a vertical position ; least, when the hours III and IX are uppermost.

Large arcs are naturally performed in less time than small ones. This Mr. Harrison inferred, because the
B watch,

X NOTES TAKEN AT THE DISCOVERY OF

watch, before any correction was applied, went slower in a vertical position than in the horizontal one, and the vibrations are visibly larger in the latter case.

The watch is adjusted to vibrate great and small arcs in equal times, in the following manner:

To go the same when placed vertically with the hours III, VI, IX, XII upwards successively, by making the weight of the balance different in different parts.---
To go the same when placed horizontal as when vertical, by the joint effect of the back of the pallets and the cycloid-pin.

The curve of the back of the pallets is an arch of a circle, whose centre lies in the line joining the edges of the pallets and the centre of the spindle, the distance of the two centres being two fifths, and the radius of the curve of the pallets three fifths of the radius of the circle described by the edge of the pallets.

The action of the cycloid-pin, when it touches the balance-spring, tends to quicken its vibrations; and the spring, leaving the pin for a longer time in the large vibrations than in the small ones, is less accelerated by it in the former than in the latter case; and, consequently, the action of the pin tends to reduce the time of the
different

different 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 balance-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 a stronger.

The balance-spring is fastened at the outer end to a stud, which takes off the plate with a screw, and is put on again with the same screw, and steady-pins, exactly in the same position as before, without undoing the fastening of the spring to the stud at the end.

There is no adjustment for mean time, as in common watches; there was once, but it did not answer.

As soon as the watch is put together, Mr. Harrison says, it will shew its rate of going in three hours accurately the same which it will keep afterwards; so that he can soon determine it by comparison with his pendulum clock.

The balance-spring, when at rest, touches the cycloid-pin; and does not begin to leave it, till the balance has vibrated an arch of forty-five degrees beyond the point of rest, while the spring is in the state of coiling itself up.

xii NOTES TAKEN AT THE DISCOVERY OF

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

Mr. Harrison requires cold weather for adjusting the thermometer kirb, and 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 kirb till it goes the same in these two different degrees of temperature of the air.

The thermometer kirb takes heat sooner than the balance-spring, and he thence concludes that brass takes heat sooner than steel, and that the brass rods of a grid-iron.

iron pendulum should be made thicker than the steel ones.

Whilst the heat is increasing, the watch will sometimes go one tenth of a second slower in three hours, than when the heat is come to a stand.

The effect of the thermometer is increased by rubbing the sides thinner, and is lessened by thickening the edge by burnishing it.

Mr. Harrison adjusts the thermometer first, that is to say, before he adjusts the watch to go the same in different positions.

The watch may be put with figure XII turned each day alternately different ways, for fear one part of the box in which it is kept may be hotter than the other.

The force or momentum of the balance, Mr. Harrison says, is as the square of its diameter, also as the square of the velocity, its weight being given.

The momentum of the balance acquired by increasing the velocity is better than that acquired by increasing the weight; as friction is not thereby increased, perhaps, if any thing, diminished, and the resistance of the air only is increased, the effect of which is tolerably uniform, and of great service.

The

xiv NOTES TAKEN AT THE DISCOVERY OF

The diameter of the balance is 2,2 inches, of the plate 3,8 inches.

The balance should be a little larger, or $2\frac{1}{4}$ inches, according to a memorandum taken by Mr. Bird.

The watch makes just five beats in a second of time.

If the balance vibrated faster, the resistance of the air would be too great.

A pocket watch of this kind would do better with six beats in a second.

A certain size is best for the pallets, or rather a certain proportion between the diameter of the circle described by the edge of the pallets and the diameter of the balance-wheel. This was first suggested to Mr. Harrison from 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 grand principle of the watch is that of giving the greatest motion possible to the balance with a given force. This is done by the scaping and proper quantity of the arc described.

This

This note was communicated by Mr. Mudge, as also the following; That the balance, by the force from the wheels, without its spring, tends to vibrate once in two seconds.

There are four springs in the watch; first, a main spring; secondly, a spring in the inside of the fusee, to keep it going while it is winding up; thirdly, a spring, which is wound up eight times every minute; fourthly, the balance-spring. The three first were made by Ma-berley.

The fusee has six turns and a quarter.

The fly serves to moderate the velocity with which the spring nearest the balance would otherwise be wound up.

The pivot-holes are all made in rubies, with diamonds at the ends.

The pallets are diamonds.

One end of the watch in the late voyage to Barbadoes was set higher, because it was not equally adjusted in all positions. Also it was altered and brought back to the same position, with respect to the horizon, as the ship lay down on the one or the other tack,

xvi NOTES TAKEN AT THE DISCOVERY OF

tack, by the help of a moveable box, with a divided arch.

Mr. William Harrison reckons the greatest roll of a ship fifteen degrees, and the greatest lie-down, when going upon one tack, twelve degrees.

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

If the balance-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.

Care is to be used in moving the watch, or in turning it about, in order to wind it up, not to give it any quick circular motion in the plane of the balance, 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, when you want to wind it up.

Oil must be applied to the pallets and pivot-holes of the watch, but very sparingly.

The watch will go three years without requiring to be cleaned.

At

MR. HARRISON'S TIME-KEEPER. xvii.

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. two or three seconds per day.

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

NEVIL MASKELYNE,
ASTRONOMER ROYAL.

C

PRIN

P R I N C I P L E S OF MR. HARRISON'S TIME-KEEPER.

IN this Time-keeper there is the greatest Care taken to avoid Friction as much as can be, by the Wheels moving on small Pivots, and in Ruby-holes, and high Numbers in the Wheels and Pinions.

The Part which measures Time goes but the eighth Part of a Minute without winding up; so that Part is very simple, as this Winding-up is performed at the Wheel next to the Balance-wheel; by which Means, there is always an equal Force acting at that Wheel, and all the rest of the Work has no more to do in measuring Time, than the Person that winds them up once a Day.

C 2

There

There is a Spring in the Inside of the Fusee, which I will call a secondary Main-spring. This Spring is always kept stretched to a certain Tension by the Main-spring, and during the Time of winding up the Time-keeper, at which Time the Main-spring is not suffered to act, this secondary Spring supplies its Place.

In common Watches in general the Wheels have about One-third the Dominion over the Balance that the Balance-spring has; that is, if the Power the Balance-spring has over the Balance be called *Three*, that from the Wheels is *One*; but in this my Time-keeper, the Wheels have only about *One-eightieth* Part of the Power over the Balance that the Balance-spring has; and it must be allowed, the less the Wheels have to do with the Balance, the better. The Wheels in a common Watch having this great Dominion over the Balance, they can, when the Watch is wound up, and the Balance at rest, set the Watch a-going; but when my Time-keeper's Balance is at rest, and the Spring is wound up, the Force of the Wheels can no more set it a-going, than the Force of the Wheels of a common Regulator can, when the Weight is wound up, set the Pendulum a-vibrating; nor will the Force from the Wheels move the Balance, when at rest, to a greater Angle

Angle in Proportion to the Vibration that it is to fetch, than the Force of the Wheels of a common Regulator can move the Pendulum from the Perpendicular, when it is at rest.

My Time-keeper's Balance is more than three times the Weight of a large fixed common Watch-balance, and three times its Diameter; and a common Watch-balance goes through about six Inches of Space in a Second, but mine goes through about twenty-four Inches in that Time: So that had my Time-keeper only these Advantages over a common Watch, a good Performance might be expected from it. But my Time-keeper is not affected by the different Degrees of Heat and Cold, nor Agitation of the Ship; and the Force from the Wheels is applied to the Balance in such a Manner, together with the Shape of the Balance-spring, and (if I may be allowed the Term) an artificial Cycloid, which acts at this Spring; so that from these Contrivances, let the Balance vibrate more or less, all its Vibrations are performed in the same Time; and therefore, if it go at all, it must go *true*. So that it is plain from this, that such a Time-keeper goes intirely from Principle, and not from Chance.

The

22 DESCRIPTION OF THE DRAWINGS OF

The following is a Description of the DRAWINGS from which my *fourth* Time-keeper was made, and the Drawings are also hereunto annexed.

FIG. 1.

AA is the Chain-barrel, and BB is a Section of it. CC is the Spring-barrel, and DD is a Section of it. EE is a Ratchet at the Spring-barrel, and FF is a Section of it. This Ratchet is screwed to the Spring-barrel by four small Screws at *aaaa*. There is a Hole in the Pillar-plate of the Diameter from the dotted Lines *bb*, and that Part of the Spring-barrel *cc* is to move in this Hole without any Shake, in order to set the Spring up. The Ratchet is also shewn in Figure 13th, by the Circle *bb*, and it has thirty Teeth, and *c* is the Click that holds it.

FIG. 2.

AA is the Brads Edge, BB the Hole in the Middle of it, and CC is a Section of it. This Brads Edge is supported by six Pillars, and their Places are represented in Figures 13 and 14, by six Circles *aaaaaa*.

FIG.

FIG. 3.

A A is the first Wheel, and *aaaa* is a Section of it. *bbb* is a Section of the Fusee. B B is the outer Diameter of a Ratchet which is fixed to the Inside of the Fusee, and the inner Circle C C is its inner Diameter, and it has 55 Teeth in it. *dddd* is what I call the perpetual Ratchet, of which *cccc* is a Section; there is a Ratchet with 75 Teeth in it on that Part marked *ff*, this is also shewn in Figure 13 by the Circle *ee*, and this perpetual Ratchet is to carry the Barrel D D, which Barrel contains the secondary Main-spring, and will be in the Inside of the Fusee at *gg*, and at that Part of the first Wheel *bb* the inner End of this Spring is to act, as that Part *bb* will be its Arbor. The dotted Lines E represent the Grooves in the Fusee. The dotted Lines *ll* represent the upper Plate. The dotted Lines *mm* represent the Pillar Plate. The dotted Lines *nn* represent the Cock, which carries the lower End of the Arbor of the first Wheel. This Cock is also represented in Figure 13 at *dddd*. The Ratchet *ee* in Figure 13 has two Clicks, whose Centres are at *ff*,
and

24 DESCRIPTION OF THE DRAWINGS OF

and gg are the Springs which act at these Clicks. In Figure 14 bb represents the first Wheel with 96 Teeth, acting in a Pinion of 21 at c .

FIG. 4.

AA represents the second Wheel acting in a Pinion at a . BB represents the third Wheel, which is concave, and acts in a Pinion at b . The second Wheel is described in Figure 14 by the Circle dd , and acts in a Pinion of 18 at e . The third Wheel is represented in Figure 14 by the Circle ff , acting in a Pinion of 16 at g .

Note, The third Wheel is larger than is represented in Figure 14, and has 144 Teeth, and the second Wheel has 120 Teeth.

FIG. 5.

AA represents the contrate Wheel, BB a Section of it, with a Section of the Spring-barrel aa . At cc is a Piece with eight Pins in it, that discharges the running Wheels every eighth Part of a Minute. This Wheel is also represented in Figure 14 by the Circle bb ; it has 120 Teeth, and acts in a Pinion of 12 at i .

FIG.

FIG. 6.

Is the Dittent, by which is the Discharge for winding up eight Times in a Minute. The Part *a* acts at the eight Pins on the contrate Wheel-arbor. *b* is a Roller acting against a Piece of Brass on the fifth Wheel-arbor. *c* is a Piece that stops against a Pin in the Rim of the fifth Wheel. *dd* are Pieces of Brass to make it in an Equilibrium in itself; and *E* is the Spring which acts upon it. The Centre of this Dittent is at *x* in Figure 14.

FIG. 7.

A is a Section of the Frame, with the Balance-cock, the Slide, and the Brass Edge; and *a* is the Centre of the Joint-pin. *B* is a Section, where *aa* represents the Balance-cock, *bb* the third Wheel-cock.
c the Cock at the End of the contrate Wheel.
d the Cock at the End of the fourth Wheel.
e the fourth Wheel.
f the Follower.
g the Balance-wheel.
h the Potence.

D

i the

26 DESCRIPTION OF THE DRAWINGS OF

- i* the Balance-wheel Pinion.
- k* the Counter-potence, which also carries the other End of the fourth Wheel.
- m* the Spring-barrel.
- n* the Hook in it, where the out End of the Spring hangs.
- o* the Hook at the contrate Wheel, where the inner End of the Spring is hung.
- r* the fifth Wheel, with the Pin where the Dittent is to stop.
- s* the upper Plate.
- T* the Pillar-plate.

FIG. 8.

aa are the Pallets of ten times the Size that they are in the Time-keeper. The dotted Lines, from 24ths. of the Circle, shew the Power the Balance-wheel has to impede the Motion of the Balance by the Declivity on the Back of the Pallets, at any the same time whenever it shall have the greatest Power to give it Motion.

FIG.

FIG. 9.

Is to shew the Proportion between the Balance, the Balance-wheel, the Balance-wheel Teeth, the Pallets, and at what Distance the Wheel acts from the Centre of the Balance. *AA* represents the Balance, *BB* the Balance wheel, *aa* the Pallets, and *bbbbbb* the Balance-wheel Teeth.

FIG. 10.

A is the Counter-potence, with the Follower *a*, and a small Screw at *c*, to stop when at its proper Place, and *x* is the Centre of the fourth Wheel.

B is the Cock for the Minute-wheel.

C is the Steel Bridge.

D is a Cock for the contrate Wheel.

E is a Cock at the first Wheel.

F is a Cock at the contrate Wheel on the Pillar-plate.

FIG. 11.

Is the Dittent, which is to stop the Balance before the Watch be down. It turns upon a Centre at *t* in Figure 14. *A* is the Locking-spring.

FIG. 12.

AA represents the upper Plate. *BB* the Balance.

aa the Thermometer.

bb the Balance-spring.

cc Slider to adjust the Thermometer end-way.

d the Stud.

e the artificial Cycloid.

f a Piece to adjust it so as to bear properly against the Spring.

FIG. 13.

aaaaaa the Feet of the Brads Edge.

bb the Ratchet at the Spring-barrel.

c the Click.

dddd the Cock at the End of the first Wheel.

ee

ee a Ratchet.

ff the Centres of the two Clicks which act in it.

gg the two Springs that act at them.

hhhhhh the fix Pillars of the Frame.

ii the Steel Bridge.

kkk two Wheels that carry the Seconds, one being on the contrate Wheel-arbor, the other moving on the Cannon-pinion.

l the Cannon-pinion.

mm the Minute-wheel.

n the Hour-pinion.

oo the Hour-wheel.

FIG. 14.

aaaaaa the fix Pillars of the Brass Edge.

bb the first Wheel.

c the Centre-pinion.

dd the second Wheel.

e the second Pinion.

ff the third Wheel.

g the third Pinion.

bb the contrate Wheel, and the fourth Wheel.

i the

30 DESCRIPTION OF THE DRAWINGS, &c.

- i* the Balance-wheel Pinion.
- k* the fourth Pinion.
- ll* the fifth Wheel.
- m* the fifth Pinion.
- nn* the Fly.
- oo* the Balance-wheel.
- p* the Potence.
- rrrrrr* the six Pillars of the Frame.
- r* the Stud.
- t* the Centre of the Dittent, to stop the Balance.
- x* the Centre of the discharging Dittent.
- uu* the upper Plate.
- zz* the Pillar-plate.

FIG. 15.

Is what was designed for the Work on the upper Plate,
which is now done in the Manner as represented in
Figure 12.

For

THE TEMPERING AND MOTION. 31

For tempering the Balance-spindle, the Balance-spring, and the Pinions.

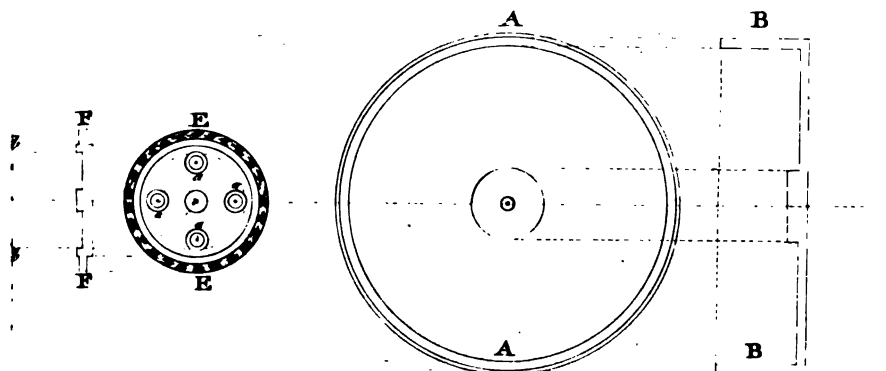
Before their being immerfed in the Metal (as juft melted) let them be oiled over.

The Heat for the Balance-spindle 567 on Fahrenheit's Scale, the which is given by one of Pewter to 12 of Lead; but for the Balance-spring and the Pinions, let the Mixture be One of Pewter to 17 of Lead.

Each Turn of the first Wheel (or Fusee) is $4\frac{4}{7}$ Hours; fo $5\frac{1}{7}$ of its Turns is juft 24 Hours; and $6\frac{1}{7}$ is $28\frac{4}{7}$ Hours; and $6\frac{2}{10}$ Turns equal to 30 Hours.

F I N I S.

Fig. 1.



..... about $1,64$ of $\frac{1}{4}$ Inch

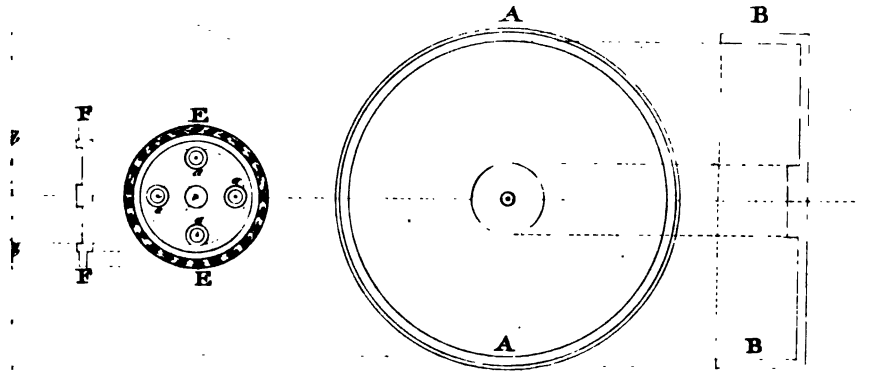
Centre of the Chain Barrel about $0,38$

..... $0,23$

..... $0,215$

within $1,4$ Inch.....

Fig. 1.



..... about $1,64$ of $\frac{1}{4}$ Inch
 Centre of the Chain Barrel about $0,38$
 $0,23$
 $0,215$
 within $1,4$ Inch.

Fig. 2.

Height of these pillars about 0.55 of $\frac{1}{4}$ Inch.

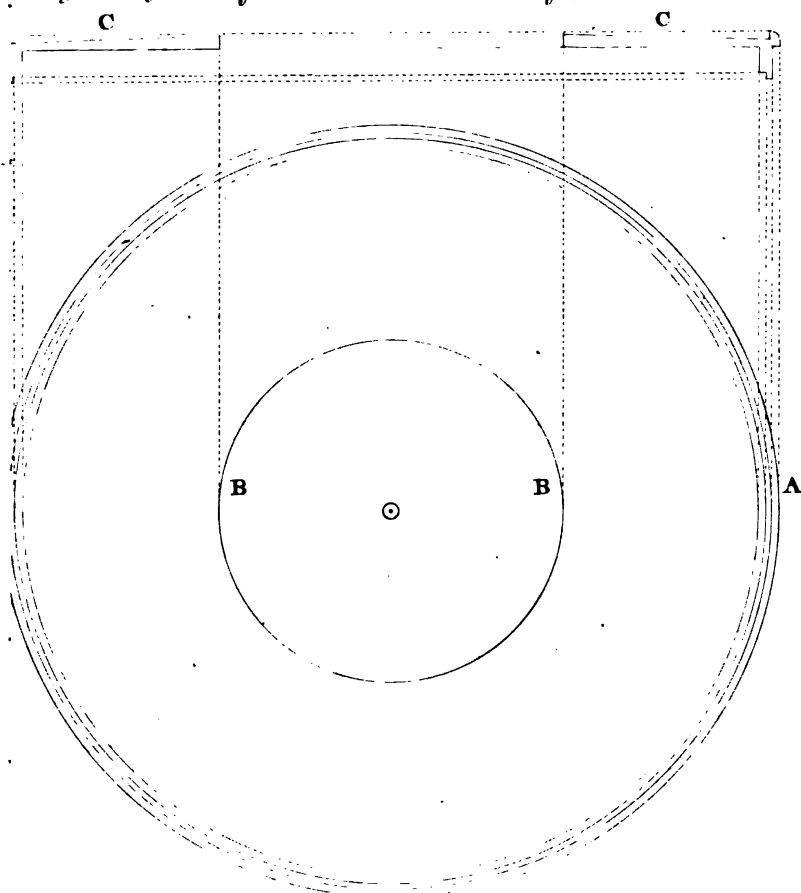


Fig. 3.

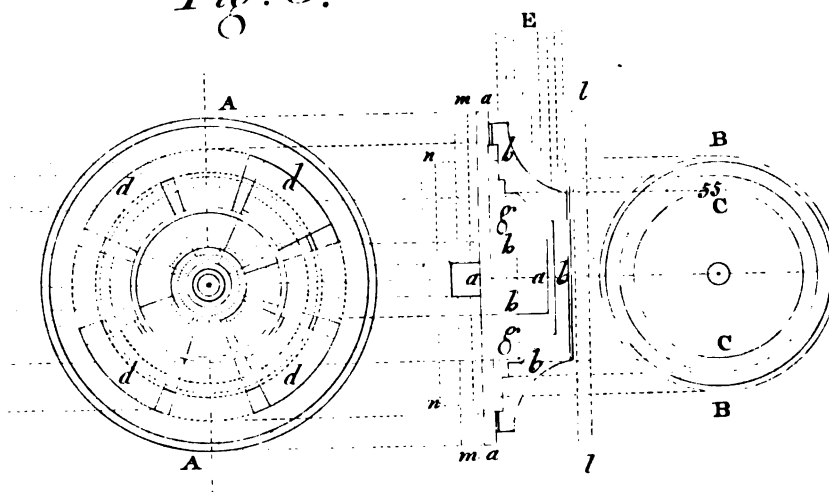
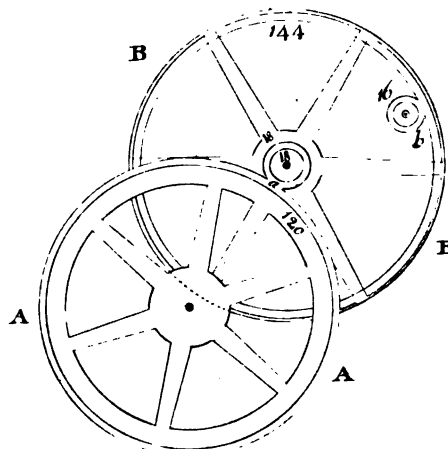


Fig. 4.



The Discharger
 & Dial Plate than according to
 may be even with the plain of
 are also drawn too broad at the
 Hole in the Centre of the Wheel
 that part of the Spindle which
 is 0.108 of $\frac{1}{4}$ Inch
 of the Spring 10 Inches.

Fig. 7.

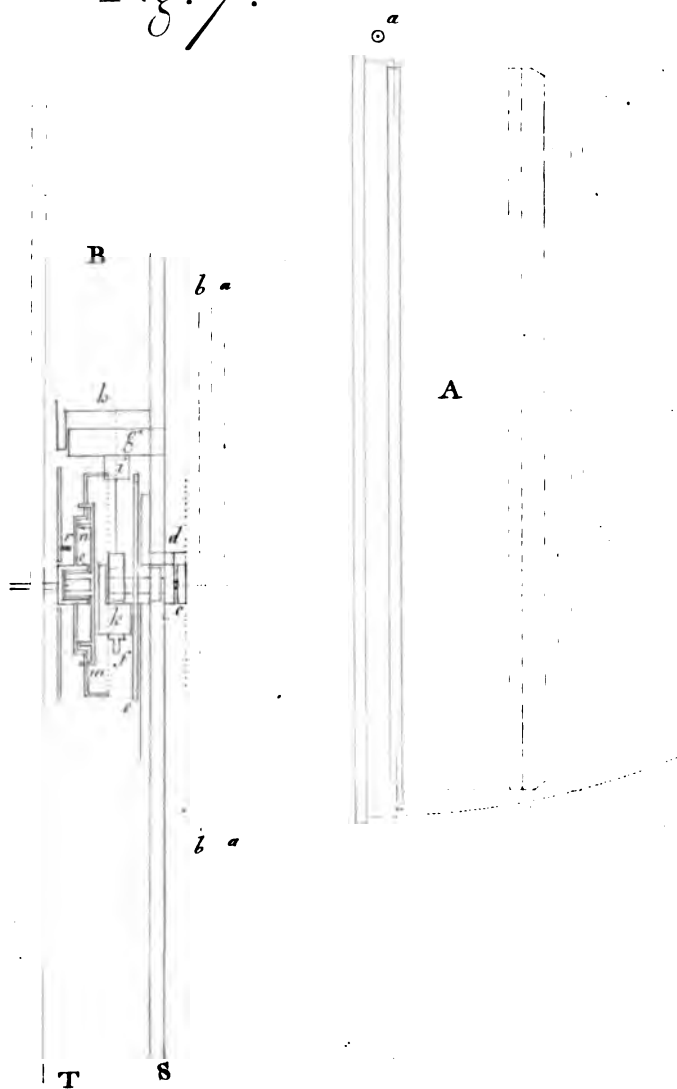


PLATE VI.

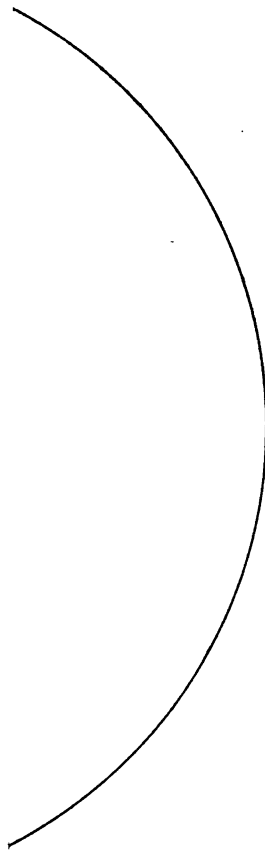
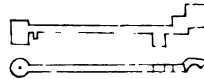


Fig. 11.



Diameter of the Hole in the Socket,
(its wider End) about 0, 12 of $\frac{1}{4}$ Inch.
Diameter of the Upper pivot 0, 22.
Diameter of the Lower pivot 0, 09.

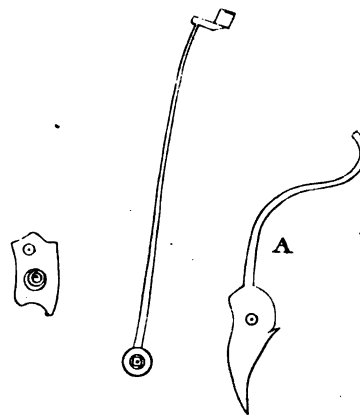


Fig. 13.

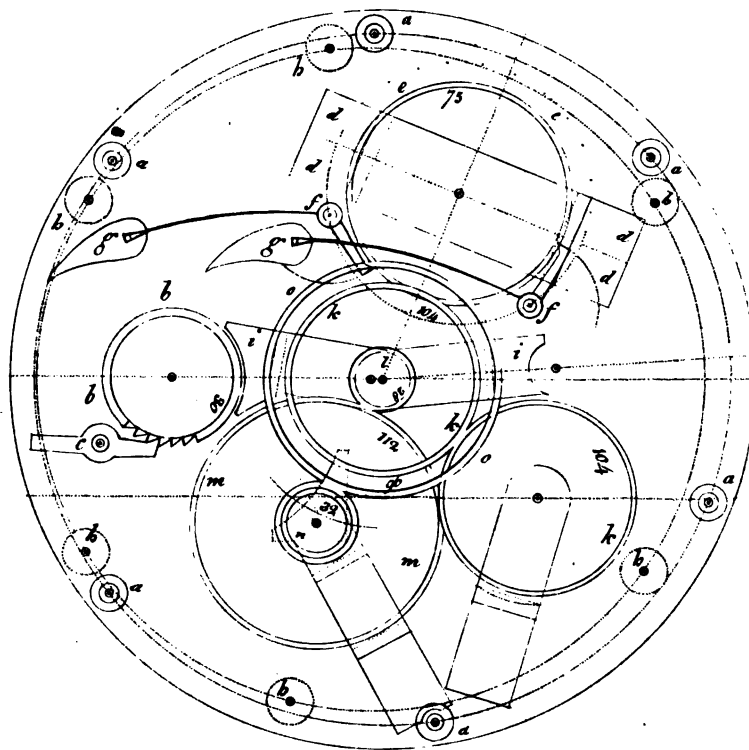


Fig. 15.

scr plate be $\frac{1}{16}$ inch more?

