ANONYMOUS

WATCH AND CLOCK ESCAPEMENTS

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EAN 8596547342168

DigiCat, 2022
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Table of Contents

PREFACE

Table of Contents

Especially notable among the achievements of The Keystone in the field of horology were the three serials devoted to the lever, cylinder and chronometer escapements. So highly valued were these serials when published that on the completion of each we were importuned to republish it in book form, but we deemed it advisable to postpone such publication until the completion of all three, in order that the volume should be a complete treatise on the several escapements in use in horology. The recent completion of the third serial gave us the opportunity to republish in book form, and the present volume is the result. We present it to the trade and students of horology happy in the knowledge that its contents have already received their approval. An interesting addition to the book is the illustrated story of the escapements, from the first crude conceptions to their present perfection.

CHAPTER I.

Table of Contents

THE DETACHED LEVER ESCAPEMENT.

Table of Contents

In this treatise we do not propose to go into the history of this escapement and give a long dissertation on its origin and evolution, but shall confine ourselves strictly to the designing and construction as employed in our best watches. By designing, we mean giving full instructions for drawing an escapement of this kind to the best proportions. The workman will need but few drawing instruments, and a drawing-board about 15" by 18" will be quite large enough. The necessary drawing-instruments are a T-square with 15" blade; a scale of inches divided into decimal parts; two pairs dividers with pen and pencil points—one pair of these dividers to be 5" and the other 6"; one ruling pen. Other instruments can be added as the workman finds he needs them. Those enumerated above, however, will be all that are absolutely necessary.

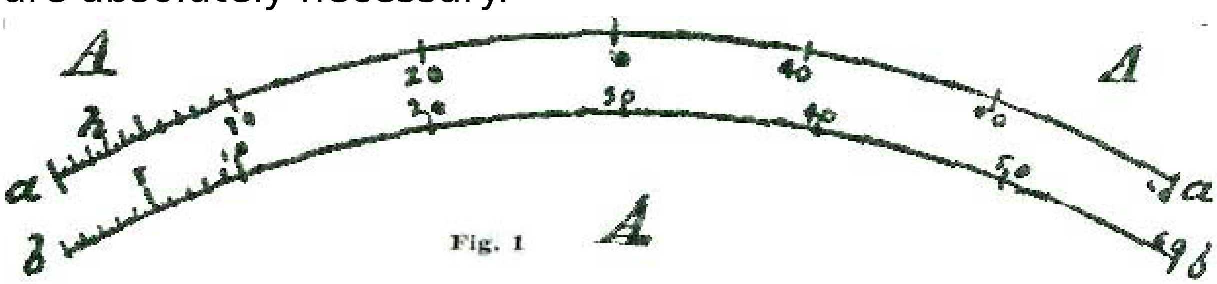

Fig. 1

We shall, in addition, need an arc of degrees, which we can best make for ourselves. To construct one, we procure a piece of No. 24 brass, about 5-1/2" long by 1-1/4" wide. We show such a piece of brass at *A*, Fig. 1. On this piece of brass we sweep two arcs with a pair of dividers set at precisely 5", as shown (reduced) at *a a* and *b b*. On these arcs we set off the space held in our dividers—that is 5"—as shown at the short radial lines at each end of the two arcs. Now it is a well-known fact that the space embraced by our dividers contains exactly sixty degrees of the arcs *a a* and *b b*, or one-sixth of the entire circle; consequently, we divide the arcs *a a* and *b b* into sixty equal parts, to represent degrees, and at one end of these arcs we halve five spaces so we can get at half degrees.

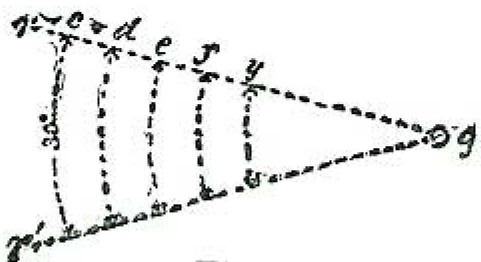

Fig 2

Before we take up the details of drawing an escapement we will say a few words about "degrees," as this seems to be something difficult to understand by most pupils in horology when learning to draw parts of watches to scale. At Fig. 2 we show several short arcs of fifteen degrees, all having the common center *g*. Most learners seem to have an idea that a degree must be a specific space, like an inch or a foot. Now the first thing in learning to draw an escapement is to fix in our minds the fact that the extent of a degree depends entirely on the radius of the arc we employ. To aid in this explanation we refer to Fig. 2. Here the arcs *c*, *d*, *e* and *f* are all fifteen degrees, although the linear extent of the degree on the arc *c* is twice that of the degree on the arc *f*. When we speak of a degree in connection with a circle we mean the one-three-hundred-and-sixtieth part of the periphery of such a circle. In dividing the arcs *a a* and *b b* we first divide them into six spaces, as shown, and each of these spaces into ten minor spaces, as is also shown. We halve five of the degree spaces, as shown at *h*. We should be very careful about making the degree arcs shown at Fig. 1, as the accuracy of our drawings depends a great deal on the perfection of the division on the scale *A*. In connection with such a fixed scale of degrees as is shown at Fig. 1, a pair of small dividers, constantly set to a degree space, is very convenient.

MAKING A PAIR OF DIVIDERS.

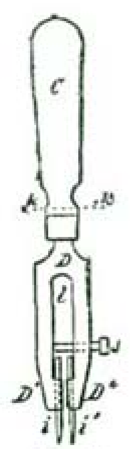

Fig. 3

To make such a pair of small dividers, take a piece of hard sheet brass about 1/20" thick, 1/4" wide, 1-1/2" long, and shape it as shown at Fig. 3. It should be explained, the part cut from the sheet brass is shown below the dotted line *k*, the portion above (*C*) being a round handle turned from hard wood or ivory. The slot *l* is sawn in, and two holes drilled in the end to insert the needle points *i i*. In making the slot *l* we arrange to have the needle points come a little too close together to agree with the degree spaces on the arcs *a a* and *b b*. We then put the small screw *j* through one of the legs *D''*, and by turning *j*, set the needle points *i i* to exactly agree with the degree spaces. As soon as the points *i i* are set correctly, *j* should be soft soldered fast.

The degree spaces on *A* are set off with these dividers and the spaces on *A* very carefully marked. The upper and outer arc *a a* should have the spaces cut with a graver line, while the lower one, *b b* is best permanently marked with a carefully-made prick punch. After the arc *a a* is divided, the brass plate *A* is cut back to this arc so the divisions we have just made are on the edge. The object of having two arcs on the plate *A* is, if we desire to get at the number of degrees contained in any arc of a 5" radius we lay the scale *A* so the edge agrees with the arc *a a*, and read off the number of degrees from the scale. In setting dividers we employ the dotted spaces on the arc *b b*.

DELINEATING AN ESCAPE WHEEL.

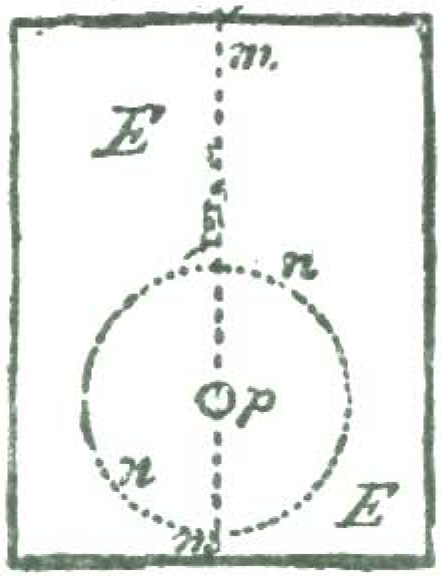

Fig. 4

We will now proceed to delineate an escape wheel for a detached lever. We place a piece of good drawing-paper on our drawing-board and provide ourselves with a very hard (HHH) drawing-pencil and a bottle of liquid India ink. After placing our paper on the board, we draw, with the aid of our T-square, a line through the center of the paper, as shown at *m m*, Fig. 4. At 5-1/2" from the lower margin of the paper we establish the point *p* and sweep the circle *n n* with a radius of 5". We have said nothing about stretching our paper on the drawing-board; still, carefully-stretched paper is an important part of nice and correct drawing. We shall subsequently give directions for properly stretching paper, but for the present we will suppose the paper we are using is nicely tacked to the face of the drawing-board with the smallest tacks we can procure. The paper should not come quite to the edge of the drawing-board, so as to interfere with the head of the T-square. We are now ready to commence delineating our escape wheel and a set of pallets to match.

The simplest form of the detached lever escapement in use is the one known as the "ratchet-tooth lever escapement," and generally found in English lever watches. This form of escapement gives excellent results when well made; and we can only account for it not being in more general use from the fact that the escape-wheel teeth are not so strong and capable of resisting careless usage as the club-tooth escape wheel.

It will be our aim to convey broad ideas and inculcate general principles, rather than to give specific instructions for doing "one thing one way." The ratchet-tooth lever escapements of later dates have almost invariably been constructed on the ten-degree lever-and-pallet-action plan; that is, the fork and pallets were intended to act through this arc. Some of the other specimens of this escapement have larger arcs—some as high as twelve degrees.

PALLET-AND-FORK ACTION.

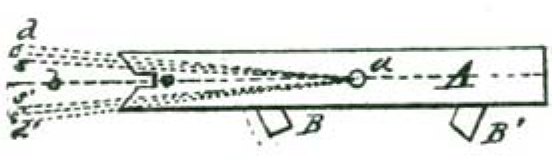

Fig. 5

We illustrate at Fig. 5 what we mean by ten degrees of pallet-and-fork action. If we draw a line through the center of the pallet staff, and also through the center of the fork slot, as shown at *a b*, Fig. 5, and allow the fork to vibrate five degrees each side of said lines *a b*, to the lines *a c* and *a c'*, the fork has what we term ten-degree pallet action. If the fork and pallets vibrate six degrees on each side of the line *a b*—that is, to the lines *a d* and *a d'*—we have twelve degrees pallet action. If we cut the arc down so the oscillation is only four and one-quarter degrees on each side of *a b*, as indicated by the lines *a s* and *a s'*, we have a pallet-and-fork action of eight and one-half degrees; which, by the way, is a very desirable arc for a carefully-constructed escapement.

The controlling idea which would seem to rule in constructing a detached lever escapement, would be to make it so the balance is free of the fork; that is, detached, during as much of the arc of the vibration of the balance as possible, and yet have the action thoroughly sound and secure. Where a ratchet-tooth escapement is thoroughly well-made of eight and one-half degrees of pallet-and-fork action, ten and one-half degrees of escape-wheel action can be utilized, as will be explained later on.

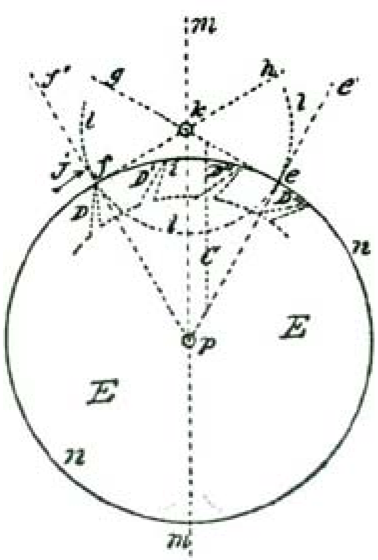

Fig. 6

We will now resume the drawing of our escape wheel, as illustrated at Fig. 4. In the drawing at Fig. 6 we show the circle *n n*, which represents the periphery of our escape wheel; and in the drawing we are supposed to be drawing it ten inches in diameter.

We produce the vertical line *m* passing through the center *p* of the circle *n*. From the intersection of the circle *n* with the line *m* at *i* we lay off thirty degrees on each side, and establish the points *e f*; and from the center *p*, through these points, draw the radial lines *p e′* and *p f′*. The points *f e*, Fig. 6, are, of course, just sixty degrees apart and represent the extent of two and one-half teeth of the escape wheel. There are two systems on which pallets for lever escapements are made, viz., equidistant lockings and circular pallets. The advantages claimed for each system will be discussed subsequently. For the first and present illustration we will assume we are to employ circular pallets and one of the teeth of the escape wheel resting on the pallet at the point *f*; and the escape wheel turning in the direction of the arrow *j*. If we imagine a tooth as indicated at the dotted outline at *D*, Fig. 6, pressing against a surface which coincides with the radial line *p f*, the action would be in the direction of the line *f h* and at right angles to *p f*. If we reason on the action of the tooth *D*, as it presses against a pallet placed at *f*, we see the action is neutral.

ESTABLISHING THE CENTER OF PALLET STAFF.

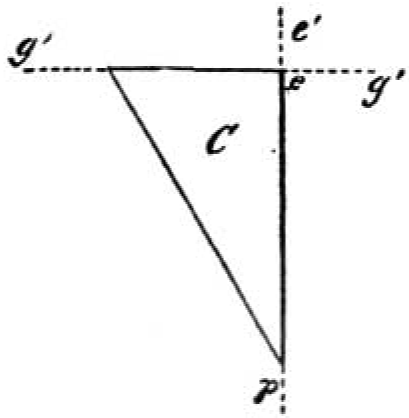

Fig. 7

With a fifteen-tooth escape wheel each tooth occupies twenty-four degrees, and from the point *f* to *e* would be two and one-half tooth-spaces. We show the dotted points of four teeth at *D D′ D′′ D′′′*. To establish the center of the pallet staff we draw a line at right angles to the line *p e′* from the point *e* so it intersects the line *f h* at *k*. For drawing a line at right angles to another line, as we have just done, a hard-rubber triangle, shaped as shown at *C*, Fig. 7, can be employed. To use such a triangle, we place it so the right, or ninety-degrees angle, rests at *e*, as shown at the dotted triangle *C*, Fig. 6, and the long side coincides with the radial line *p e′*. If the short side of the hard-rubber triangle is too short, as indicated, we place a short ruler so it rests against the edge, as shown at the dotted line *g e*, Fig. 7, and while holding it securely down on the drawing we remove the triangle, and with a fine-pointed pencil draw the line *e g*, Fig. 6, by the short rule. Let us imagine a flat surface placed at *e* so its face was at right angles to the line *g e*, which would arrest the tooth *D′′* after the tooth *D* resting on *f* had been released and passed through an arc of twelve degrees. A tooth resting on a flat surface, as imagined above, would also rest dead. As stated previously, the pallets we are considering have equidistant locking faces and correspond to the arc *l l*, Fig. 6.

In order to realize any power from our escape-wheel tooth, we must provide an impulse face to the pallets faced at *f e*; and the problem before us is to delineate these pallets so that the lever will be propelled through an arc of eight and one-half degrees, while the escape wheel is moving through an arc of ten and one-half degrees. We make the arc of fork action eight and one-half degrees for two reasons—(1) because most text-books have selected ten degrees of fork-and-pallet action; (2) because most of the finer lever escapements of recent construction have a lever action of less than ten degrees.

LAYING OUT ESCAPE-WHEEL TEETH.

To "lay out" or delineate our escape-wheel teeth, we continue our drawing shown at Fig. 6, and reproduce this cut very nearly at Fig. 8. With our dividers set at five inches, we sweep the short arc *a a'* from *f* as a center. It is to be borne in mind that at the point *f* is located the extreme point of an escape-wheel tooth. On the arc *a a* we lay off from *p* twenty-four degrees, and establish the point *b*; at twelve degrees beyond *b* we establish the point *c*. From *f* we draw the lines *f b* and *f c*; these lines establishing the form and thickness of the tooth *D*. To get the length of the tooth, we take in our dividers one-half a tooth space, and on the radial line *p f* establish the point *d* and draw circle *d' d'*.

To facilitate the drawing of the other teeth, we draw the circles *d' c'*, to which the lines *f b* and *f c* are tangent, as shown. We divide the circle *n n*, representing the periphery of our escape wheel, into fifteen spaces, to represent teeth, commencing at *f* and continued as shown at *o o* until the entire wheel is divided. We only show four teeth complete, but the same methods as produced these will produce them all. To briefly recapitulate the instructions for drawing the teeth for the ratchet-tooth lever escapement: We draw the face of the teeth at an angle of twenty-four degrees to a radial line; the back of the tooth at an angle of thirty-six degrees to the same radial line; and make teeth half a tooth-space deep or long.

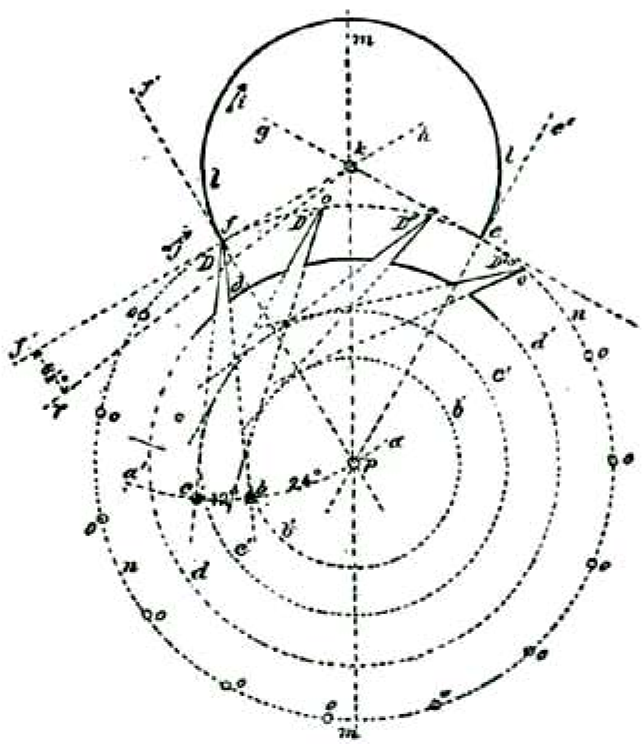

Fig. 8

We now come to the consideration of the pallets and how to delineate them. To this we shall add a careful analysis of their action. Let us, before proceeding further, "think a little" over some of the factors involved. To aid in this thinking or reasoning on the matter, let us draw the heavy arc *l* extending from a little inside of the circle *n* at *f* to the circle *n* at *e*. If now we imagine our escape wheel to be pressed forward in the direction of the arrow *j*, the tooth *D* would press on the arc *l* and be held. If, however, we should revolve the arc *l* on the center *k* in the direction of the arrow *i*, the tooth *D* would *escape* from the edge of *l* and the tooth *D''* would pass through an arc (reckoning from the center *p*) of twelve degrees, and be arrested by the inside of the arc *l* at *e*. If we now should reverse the motion and turn the arc *l* backward, the tooth at *e* would, in turn, be released and the tooth following after *D* (but not shown) would engage *l* at *f*. By supplying motive to revolve the escape wheel (*E*) represented by the circle *n*, and causing the arc *l* to oscillate back and forth in exact intervals of time, we should have, in effect, a perfect escapement. To accomplish automatically such oscillations is the problem we have now on hand.

HOW MOTION IS OBTAINED.

In clocks, the back-and-forth movement, or oscillating motion, is obtained by employing a pendulum; in a movable timepiece we make use of an equally-poised wheel of some weight on a pivoted axle, which device we term a balance; the vibrations or oscillations being obtained by applying a coiled spring, which was first called a "pendulum spring," then a "balance spring," and finally, from its diminutive size and coil form, a "hairspring." We are all aware that for the motive power for keeping up the oscillations of the escaping circle *l* we must contrive to employ power derived from the teeth *D* of the escape wheel. About the most available means of conveying power from the escape wheel to the oscillating arc *l* is to provide the lip of said arc with an inclined plane, along which the tooth which is disengaged from *l* at *f* to slide and move said arc *l* through—in the present instance an arc of eight and one-half degrees, during the time the tooth *D* is passing through ten and one-half degrees. This angular motion of the arc *l* is represented by the radial lines *k f'* and *k r*, Fig. 8. We desire to impress on the reader's mind the idea that each of these angular motions is not only required to be made, but the motion of one mobile must convey power to another mobile.

In this case the power conveyed from the mainspring to the escape wheel is to be conveyed to the lever, and by the lever transmitted to the balance. We know it is the usual plan adopted by text-books to lay down a certain formula for drawing an escapement, leaving the pupil to work and reason out the principles involved in the action. In the plan we have adopted we propose to induct the reader into the why and how, and point out to him the rules and methods of analysis of the problem, so that he can, if required, calculate mathematically exactly how many grains of force the fork exerts on the jewel pin, and also how much (or, rather, what percentage) of the motive power is lost in various "power leaks," like "drop" and lost motion. In the present case the mechanical result we desire to obtain is to cause our lever pivoted at *k* to vibrate back and forth through an arc of eight and one-half degrees; this lever not only to vibrate back and forth, but also to lock and hold the escape wheel during a certain period of time; that is, through the period of time the balance is performing its excursion and the jewel pin free and detached from the fork.

We have spoken of paper being employed for drawings, but for very accurate delineations we would recommend the horological student to make drawings on a flat metal plate, after perfectly smoothing the surface and blackening it by oxidizing.

PALLET-AND-FORK ACTION.

By adopting eight and one-half degrees pallet-and-fork action we can utilize ten and one-half degrees of escape-wheel action. We show at *A A'*, Fig. 9, two teeth of a ratchet-tooth escape wheel reduced one-half; that is, the original drawing was made for an escape wheel ten inches in diameter. We shall make a radical departure from the usual practice in making cuts on an enlarged scale, for only such parts as we are talking about. To explain, we show at Fig. 10 about one-half of an escape wheel one eighth the size of our large drawing; and when we wish to show some portion of such drawing on a larger scale we will designate such enlargement by saying one-fourth, one-half or full size.

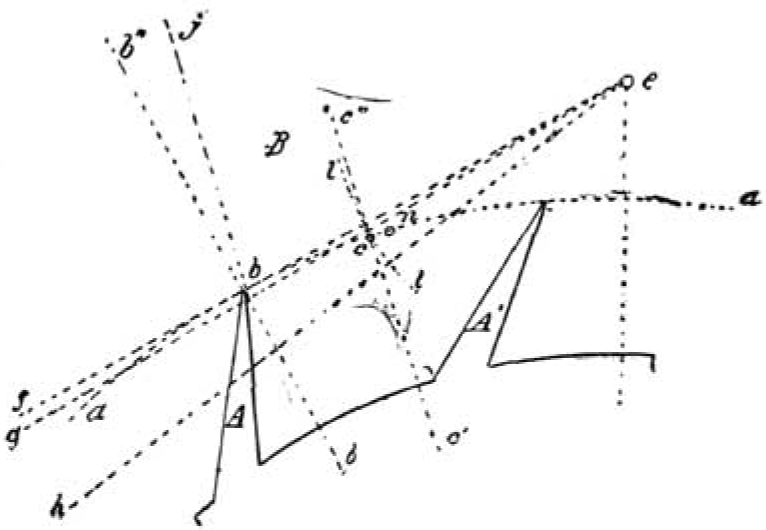

Fig. 9

At Fig. 9 we show at half size that portion of our escapement embraced by the dotted lines *d*, Fig. 10. This plan enables us to show very minutely such parts as we have under consideration, and yet occupy but little space. The arc *a*, Fig. 9, represents the periphery of the escape wheel. On this line, ten and one-half degrees from the point of the tooth *A*, we establish the point *c* and draw the radial line *c c'*. It is to be borne in mind that the arc embraced between the points *b* and *c* represents the duration of contact between the tooth *A* and the entrance pallet of the lever. The space or short arc *c n* represents the "drop" of the tooth.

This arc of one and one-half degrees of escape-wheel movement is a complete loss of six and one-fourth per cent. of the entire power of the mainspring, as brought down to the escapement; still, up to the present time, no remedy has been devised to overcome it. All the other escapements, including the chronometer, duplex and cylinder, are quite as wasteful of power, if not more so. It is usual to construct ratchet-tooth pallets so as to utilize but ten degrees of escape-wheel action; but we shall show that half a degree more can be utilized by adopting the eight and one-half degree fork action and employing a double-roller safety action to prevent over-banking.

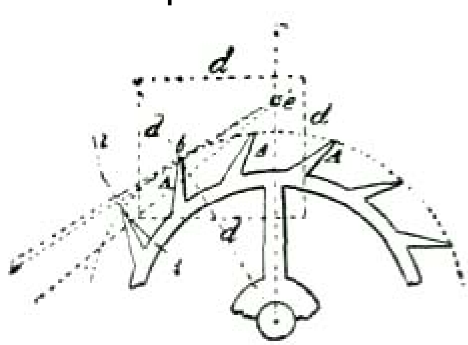

Fig. 10

From the point *e*, which represents the center of the pallet staff, we draw through *b* the line *e f*. At one degree below *e f* we draw the line *e g*, and seven and one-half degrees below the line *e g* we draw the line *e h*. For delineating the lines *e g*, etc., correctly, we employ a degree-arc; that is, on the large drawing we are making we first draw the line *e b f*, Fig. 10, and then, with our dividers set at five inches, sweep the short arc *i*, and on this lay off first one degree from the intersection of *f e* with the arc *i*, and through this point draw the line *e g*.

From the intersection of the line *f e* with the arc *i* we lay off eight and one-half degrees, and through this point draw the line *e h*. Bear in mind that we are drawing the pallet at *B* to represent one with eight and one-half degrees fork-and-pallet action, and with equidistant lockings. If we reason on the matter under consideration, we will see the tooth *A* and the pallet *B*, against which it acts, part or separate when the tooth arrives at the point *c*; that is, after the escape wheel has moved through ten and one-half degrees of angular motion, the tooth drops from the impulse face of the pallet and falls through one and one-half degrees of arc, when the tooth *A''*, Fig. 10, is arrested by the exit pallet.

To locate the position of the inner angle of the pallet *B*, sweep the short arc *l* by setting the dividers so one point or leg rests at the center *e* and the other at the point *c*. Somewhere on this arc *l* is to be located the inner angle of our pallet. In delineating this angle, Moritz Grossman, in his "Prize Essay on the Detached Lever Escapement," makes an error, in Plate III of large English edition, of more than his entire lock, or about two degrees. We make no apologies for calling attention to this mistake on the part of an authority holding so high a position on such matters as Mr. Grossman, because a mistake is a mistake, no matter who makes it.

We will say no more of this error at present, but will farther on show drawings of Mr. Grossman's faulty method, and also the correct method of drawing such a pallet. To delineate the locking face of our pallet, from the point formed by the intersection of the lines *e g b b'*, Fig. 9, as a center, we draw the line *j* at an angle of twelve degrees to *b b''*. In doing this we employ the same method of establishing the angle as we made use of in drawing the lines *e g* and *e h*, Fig. 10. The line *j* establishes the locking face of the pallet *B*. Setting the locking face of the pallet at twelve degrees has been found in practice to give a safe "draw" to the pallet and keep the lever secure against the bank. It will be remembered the face of the escape-wheel tooth was drawn at twenty-four degrees to a radial line of the escape wheel, which, in this instance, is the line *b b'*, Fig. 9. It will now be seen that the angle of the pallet just halves this angle, and consequently the tooth *A* only rests with its point on the locking face of the pallet. We do not show the outlines of the pallet *B*, because we have not so far pointed out the correct method of delineating it.

METHODS OF MAKING GOOD DRAWING INSTRUMENTS.

Fig. 11

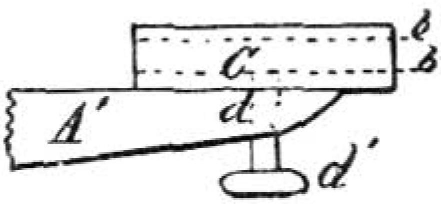

Fig. 12

Perhaps we cannot do our readers a greater favor than to digress from the study of the detached lever escapement long enough to say a few words about drawing instruments and tablets or surfaces on which to delineate, with due precision, mechanical designs or drawings. Ordinary drawing instruments, even of the higher grades, and costing a good deal of money, are far from being satisfactory to a man who has the proper idea of accuracy to be rated as a first-class mechanic. Ordinary compasses are obstinate when we try to set them to the hundredth of an inch; usually the points are dull and ill-shapen; if they make a puncture in the paper it is unsightly.

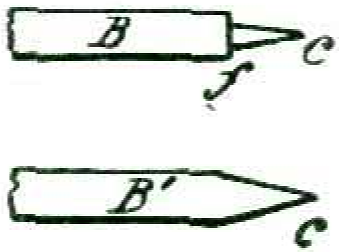

Fig. 13

Watchmakers have one advantage, however, because they can very easily work over a cheap set of drawing instruments and make them even superior to anything they can buy at the art stores. To illustrate, let us take a cheap pair of brass or German-silver five-inch dividers and make them over into needle points and "spring set." To do this the points are cut off at the line *a a*, Fig 11, and a steel tube is gold-soldered on each leg. The steel tube is made by taking a piece of steel wire which will fit a No. 16 chuck of a Whitcomb lathe, and drilling a hole in the end about one-fourth of an inch deep and about the size of a No. 3 sewing needle. We Show at Fig. 12 a view of the point *A′*, Fig. 11, enlarged, and the steel tube we have just drilled out attached at *C*. About the best way to attach *C* is to solder. After the tube *C* is attached a hole is drilled through *A′* at *d*, and the thumb-screw *d* inserted. This thumb-screw should be of steel, and hardened and tempered. The use of this screw is to clamp the needle point. With such a device as the tube *C* and set-screw *d*, a No. 3 needle is used for a point; but for drawings on paper a turned point, as shown at Fig 13, is to be preferred. Such points can be made from a No. 3 needle after softening enough to be turned so as to form the point *c*. This point at the shoulder *f* should be about 12/1000 of an inch, or the size of a fourth-wheel pivot to an eighteen size movement.

The idea is, when drawing on paper the point *c* enters the paper. For drawing on metal the form of the point is changed to a simple cone, as shown at *B′ c*, Fig. 13. such cones can be turned carefully, then hardened and tempered to a straw color; and when they become dull, can be ground by placing the points in a wire chuck and dressing them up with an emery buff or an Arkansas slip. The opposite leg of the dividers is the one to which is attached the spring for close setting of the points.

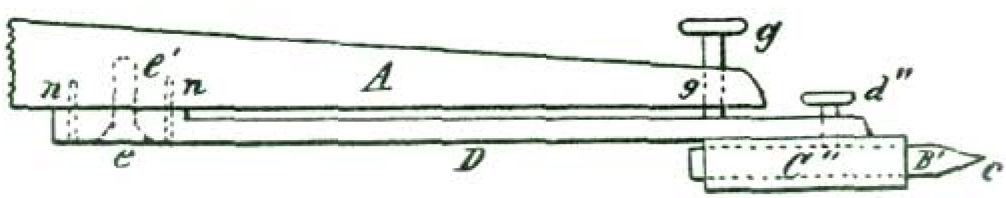

Fig. 14

In making this spring, we take a piece of steel about two and one-fourth inches long and of the same width as the leg of the divider, and attach it to the inside of the leg as shown at Fig. 14, where *D* represents the spring and *A* the leg of the dividers. The spring *D* has a short steel tube *C′′* and set-screw *d′′* for a fine point like *B* or *B′*. In the lower end of the leg *A*, Fig. 14, is placed the milled-head screw *g*, which serves to adjust the two points of the dividers to very close distances. The spring *D* is, of course, set so it would press close to the leg *A* if the screw *g* did not force it away.

SPRING AND ADJUSTING SCREW FOR DRAWING INSTRUMENTS.

It will be seen that we can apply a spring *D* and adjusting screw opposite to the leg which carries the pen or pencil point of all our dividers if we choose to do so; but it is for metal drawing that such points are of the greatest advantage, as we can secure an accuracy very gratifying to a workman who believes in precision. For drawing circles on metal, "bar compasses" are much the best, as they are almost entirely free from spring, which attends the jointed compass. To make (because they cannot be bought) such an instrument, take a piece of flat steel, one-eighth by three-eighths of an inch and seven inches long, and after turning and smoothing it carefully, make a slide half an inch wide, as shown at Fig. 15, with a set-screw *h* on top to secure it at any point on the bar *E*. In the lower part of the slide *F* is placed a steel tube like *C*, shown in Figs. 12 and 14, with set-screw for holding points like *B B′*, Fig. 13. At the opposite end of the bar *E* is placed a looped spring *G*, which carries a steel tube and point like the spring *D*, Fig. 14. Above this tube and point, shown at *j*, Fig. 15, is placed an adjustment screw *k* for fine adjustment. The inner end of the screw *k* rests against the end of the bar *E*. The tendency of the spring *G* is to close upon the end of *E*; consequently if we make use of the screw *k* to force away the lower end of *G*, we can set the fine point in *j* to the greatest exactness.

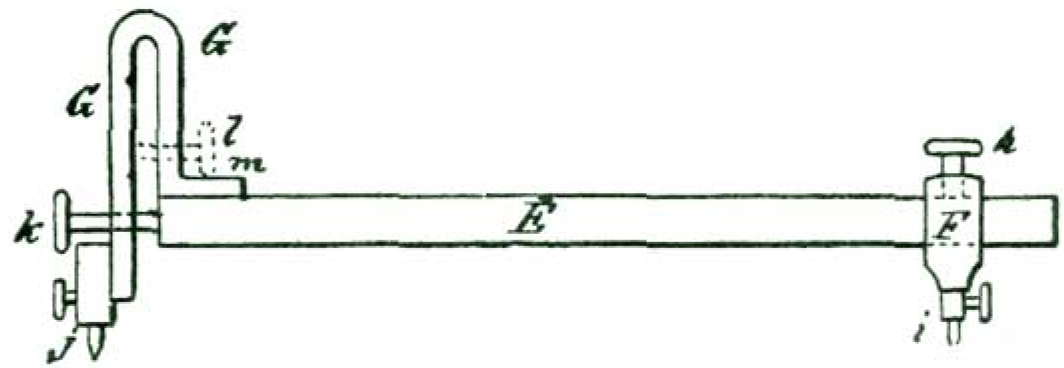

Fig. 15

The spring *G* is made of a piece of steel one-eighth of an inch square, and secured to the bar *E* with a screw and steady pins at *m*. A pen and pencil point attachment can be added to the spring *G*; but in case this is done it would be better to make another spring like *G* without the point *j*, and with the adjusting screw placed at *l*. In fitting pen and pencil points to a spring like *G* it would probably be economical to make them outright; that is, make the blades and screw for the ruling pen and a spring or clamping tube for the pencil point.

CONSIDERATION OF DETACHED LEVER ESCAPEMENT RESUMED.

We will now, with our improved drawing instruments, resume the consideration of the ratchet-tooth lever escapement. We reproduce at Fig. 16 a portion of diagram III, from Moritz Grossmann's "Prize Essay on the Detached Lever Escapement," in order to point out the error in delineating the entrance pallet to which we previously called attention. The cut, as we give it, is not quite one-half the size of Mr. Grossmann's original plate.

In the cut we give the letters of reference employed the same as on the original engraving, except where we use others in explanation. The angular motion of the lever and pallet action as shown in the cut is ten degrees; but in our drawing, where we only use eight and one-half degrees, the same mistake would give proportionate error if we did not take the means to correct it. The error to which we refer lies in drawing the impulse face of the entrance pallet. The impulse face of this pallet as drawn by Mr. Grossmann would not, from the action of the engaging tooth, carry this pallet through more than eight degrees of angular motion; consequently, the tooth which should lock on the exit pallet would fail to do so, and strike the impulse face.

We would here beg to add that nothing will so much instruct a person desiring to acquire sound ideas on escapements as making a large model. The writer calls to mind a wood model of a lever escapement made by one of the "boys" in the Elgin factory about a year or two after Mr. Grossmann's prize essay was published. It went from hand to hand and did much toward establishing sound ideas as regards the correct action of the lever escapement in that notable concern.

If a horological student should construct a large model on the lines laid down in Mr. Grossmann's work, the entrance pallet would be faulty in form and would not properly perform its functions. Why? perhaps says our reader. In reply let us analyze the action of the tooth *B* as it rests on the pallet *A*. Now, if we move this pallet through an angular motion of one and one-half degrees on the center *g* (which also represents the center of the pallet staff), the tooth *B* is disengaged from the locking face and commences to slide along the impulse face of the pallet and "drops," that is, falls from the pallet, when the inner angle of the pallet is reached.

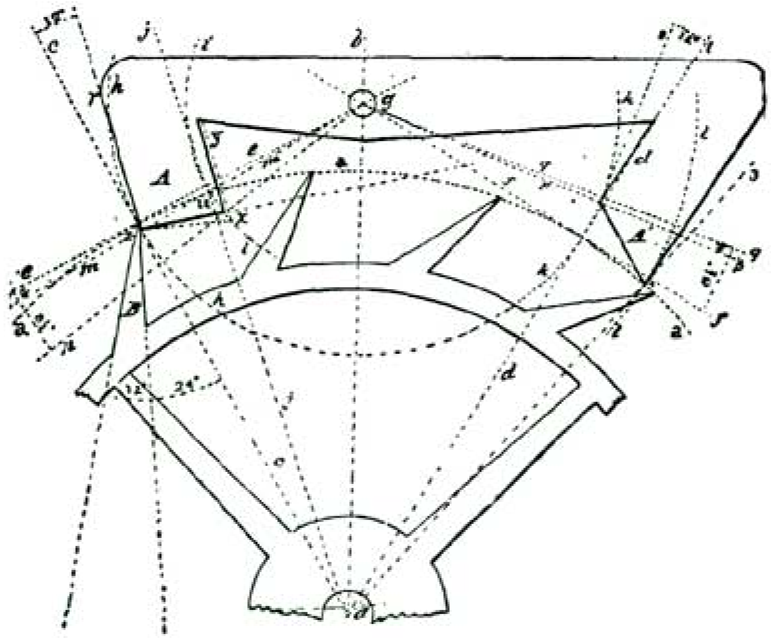

Fig. 16

This inner angle, as located by Mr. Grossmann, is at the intersection of the short arc *i* with the line *g n*, which limits the ten-degree angular motion of the pallets. If we carefully study the drawing, we will see the pallet has only to move through eight degrees of angular motion of the pallet staff for the tooth to escape, *because the tooth certainly must be disengaged when the inner angle of the pallet reaches the peripheral line a*. The true way to locate the position of the inner angle of the pallet, is to measure down on the arc *i* ten degrees from its intersection with the peripheral line *a* and locate a point to which a line is drawn from the intersection of the line *g m* with the radial line *a c*, thus defining the inner angle of the entrance pallet. We will name this point the point *x*.

It may not be amiss to say the arc *i* is swept from the center *g* through the point *u*, said point being located ten degrees from the intersection of the radial *a c* with the peripheral line *a*. It will be noticed that the inner angle of the entrance pallet *A* seems to extend inward, beyond the radial line *a j*, that is, toward the pallet center *g*, and gives the appearance of being much thicker than the exit pallet *A'*; but we will see on examination that the extreme angle *x* of the entrance pallet must move on the arc *i* and, consequently, cross the peripheral line *a* at the point *u*. If we measure the impulse faces of the two pallets *A A'*, we will find them nearly alike in linear extent.

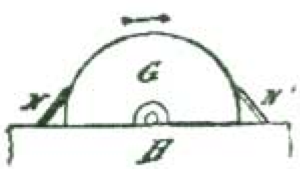

Fig. 17

Mr. Grossmann, in delineating his exit pallet, brings the extreme angle (shown at *4*) down to the periphery of the escape, as shown in the drawing, where it extends beyond the intersection of the line *g f* with the radial line *a 3*. The correct form for the entrance pallet should be to the dotted line *z x y*.

We have spoken of engaging and disengaging frictions; we do not know how we can better explain this term than by illustrating the idea with a grindstone. Suppose two men are grinding on the same stone; each has, say, a cold chisel to grind, as shown at Fig. 17, where *G* represents the grindstone and *N N'* the cold chisels. The grindstone is supposed to be revolving in the direction of the arrow. The