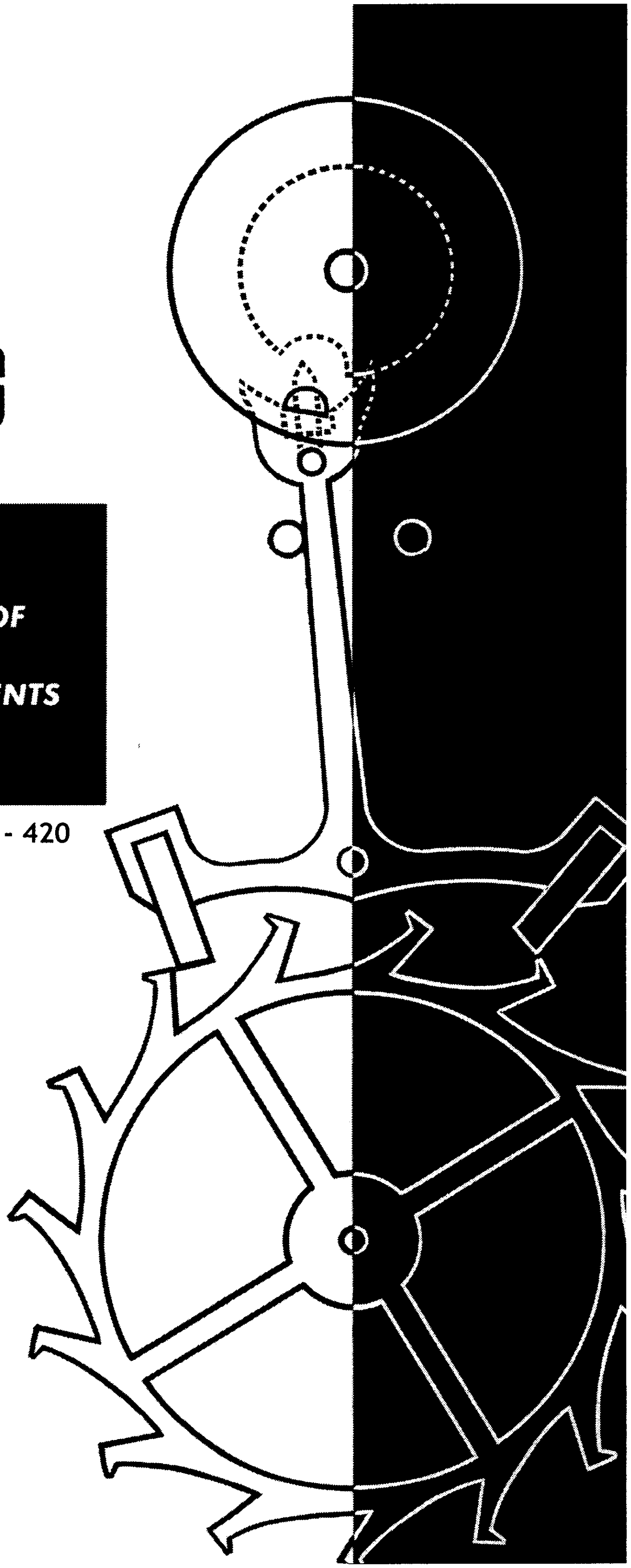
Master WATCHMAKING

LESSON 23

TYPES OF ESCAPEMENTS

Sections 414 - 420



CHICAGO SCHOOL OF WATCHMAKING

Founded 1908 by THOMAS B. SWEAZEY

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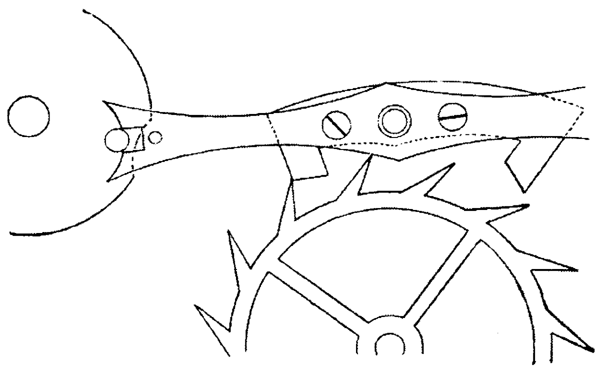

Fig. 23-1

SEC. 414—Other Forms of Lever Escapement

The form of escapement under consideration thus far has been the club tooth, short impulse. The short and the long impulse are generally designated as the short and the long fork. A long or a short fork can be constructed with either long or short impulse. When we come to consider the roller, however, the distance from its center to the roller jewel cannot be changed without altering the arc of impulse of the roller jewel.

The relative distance between the roller jewel and the balance center, as compared with the distance from the pallet arbor to the fork slot, is as four and one-half to one, whereas in in the short fork it is usually about three to one. The effect is that the roller jewel is in contact with the fork for a greater extent of the vibration of the balance in the long impulse—long fork—than in the short one. The short fork being usually about three times the length, it is in action with the roller jewel about 30 degrees —three times the arc of vibration of the fork.

In the first forms of detached lever escapements the active impulse was 10 or more degrees; sometimes as high as 12. This has been reduced from time to time until, in the modern escapement, it is usually found to be about eight and one-half. The roller impulse makes it more difficult to secure the safety action of the guard pin on the single roller, hence the general adoption of the double roller.

The detached lever escapement owes its superiority to the fact that the balance performs so great a portion of its vibration free from contact with any other part of the mechanism. As has been said, in modern forms the fork is only in contact for about 30 degrees. The shorter the duration of contact the better the rate secured. This, however, has its limit. We have been approaching the present form gradually and it would seem as though we had reached the limit. Further reduction would necessarily be secured only by a sacrifice of power, which, as already stated, is now very great.

SEC. 415—The Poised and Unpoised Fork

For many years it was considered to be an important advantage to have the fork and pallets perfectly poised. In order to secure this it became necessary to add considerable weight to these parts. The Swiss usually use the fleur-de-lis pattern for a counterpoise, but whatever is used the adding of weight increases the resistance of inertia which the balance must overcome in unlocking the escapement. This is not compensated for by the questionable advantage of a poised fork.

A fork without counterpoise requires a slight increase in the draft angle. A noted horologist and writer, Mr. Grossman, in his prize essay on the lever escapement, gives 12 degrees draft angle for each stone. Doubtless this would be enough for a poised fork, equi-distant locking, but it would not be safe for an unpoised fork, equi-distant center. This form of escapement should have 14 degrees for the discharging stone and 15 for the receiving stone.

One disadvantage of the unpoised fork is that the additional draft increases the resistance —especially when the watch is in a vertical position with the fork horizontal. This is quite true so far as the lowermost stone is concerned. Assuming the fork points to the right, the resistance on the discharging stone would be increased, but it should be remembered that the resistance on the receiving stone would be decreased in exactly the same amount. Thus the mean of the two resistances would exactly equal the resistance with the fork in a vertical position, either up or down.

Figure 23-1 illustrates the ratchet tooth escapement, which was the first form of detached lever to come into general use. This form of pallet is known as "close-pallet," as distinguished from "exposed pallet." In the "close-pallet" the pallet arm is slotted longitudinally with its plane, while in the "exposed pallet" it is slotted transversely. The "close pallet" method is a more secure way of fastening the stone, but does not permit of alteration as readily as the "exposed pallet." In the "close-pallet" the steel and the stone are finished flush on both locking and impulse faces which precludes the possibility of drawing out or pushing in either stone.

The escapement shown in figure 23-1 is what is known as the right angle escapement, which means that a line drawn from the center of the escape wheel to the center of the pallets and thence to the center of the balance forms a right angle. All the early forms of levers were almost universally laid out on this plan. The inconvenience of having to locate the pallet arbor and the escape wheel under the balance brought about the use of the straight line escapement, which is now the invariable form.

In the right angle-escapement, as shown in figure 23-1, the fork was attached to the pallets by two screws, the threads being in the pallet steel. The pallet arbor was fitted to the pallet steel, the hole in the fork through which it passed being a little larger. The holes in the fork for the screws permitted adjusting the fork with relation to the pallet, so that bending a fork was never necessary.

SEC. 416—Evolution of the Lever Escapement

The evolution of the detached lever escapement is a most interesting history. It is not quite two centuries ago that the idea of transferring the motion from the escape wheel to the balance by means of a lever was successfully applied.

Thomas Mudge, an English watchmaker, in 1765, was the first to produce a lever escapement. Figure 23-2 illustrates his invention.

The pallets were so formed that the locking faces gave no draft. Instead they were inclined in the opposite direction, thus pressing the end of the lever against the roller. The roller was provided with a notch **A** into which the point of the fork entered in delivering its impulse. No bankings were required in this escapement. Its great defect was the constant pressure of the fork against the edge of the roller. Reference to figure 23-2 will clearly illustrate this. The leverage exercised against the edge of the roller was of the same force as that to impart motion, and inasmuch as the pressure against the roller was at an acute angle with its periphery, the retarding effect was great. If the reader will picture in his mind the effect of a guard pin continually pressed against the edge of a roller, he can form an idea of this serious defect in the Mudge escapement. Increasing or decreasing the diameter of the roller in no way helped matters because decreasing the roller diameter decreased the resistance to the revolution of the balance, but it also decreased the force of impulse of the fork. Increasing the diameter of the roller increased the force of the impulse, but also increased the resistance to the motion of the balance. In consequence of this radical defect, Mudge's escapement did not come into use. In fact, he did not adopt it in watches of his own production, using the cylinder and the duplex instead.

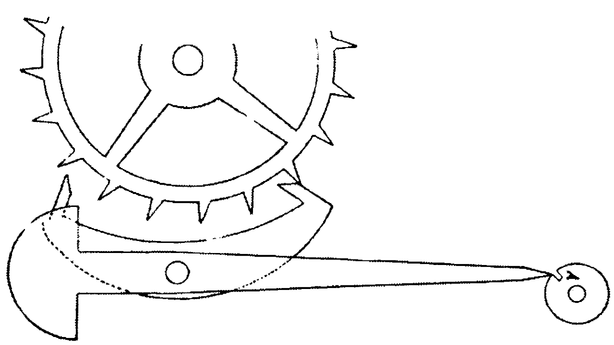

Fig. 23-2

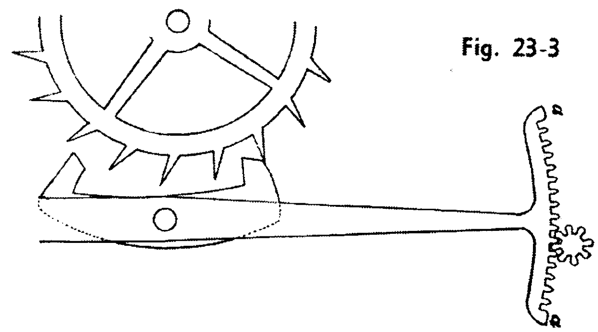

Fig. 23-3

The next important step in development was the rack and pinion lever shown in figure 23-3. In this form the lower part of the balance staff carried a small pinion into which was geared a circular rack on the end of the lever—the term fork was not then used. The pallets were what is technically termed "dead beat," that is, they produced no recoil to the escape wheel. The locking faces of both stones were arcs of circles, the center of which was the pallet arbor. The motion of the balance was limited by the toothless ends of the rack, **aa,** which acted as bankings. When the rack teeth and pinion leaves were properly proportioned and well finished, this escapement gave fairly good results and was in use many years. It was patented by Peter Litherland in 1791, but is said to have been invented by Abbe Hautefeuille half a century prior.

Another form of escapement that came out about the same time is shown in figure 23-4. This escapement was a "dead beat." The escape teeth stood perpendicularly to the plane of the wheel. The balance is not shown. The annular wheel **A** is a part that performs the function of the roller in the modern lever watch. The short segment **a** attached to the under side of one of the arms takes the place of the roller-pin. The projecting arms **bb** include a space that acts as a fork slot. **B** is the escape wheel, **C** the fork.

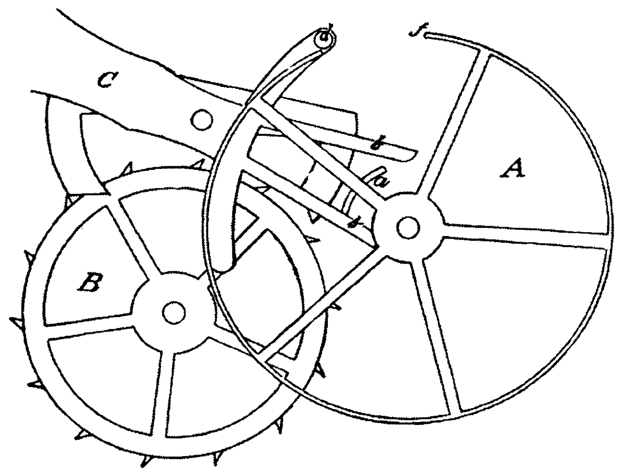

Fig. 23-4

The fork carries two circular arms in the end of one of which is a stud, **d**, which serves as a guard pin. This stud, in connection with the annular rim, **f**, provides the safety device. Bankings are provided but not shown. When the wheel is locked on the receiving pallet the guard pin is on the outside of the safety ring. When the impulse begins, as shown in figure 23-4, the guard pin is in position to enter the opening in the safety ring and pass to the inside thereof. Thus the pin **d** and rim **f** perform the function of the guard pin and safety roller. The fork and pallets required perfect poise, which accounts for the otherwise useless arm extending from the right side of the fork.

The locking faces of the pallets were so formed that they acted as a sort of break to prevent the movement of the fork while locked. The fork and pallets were perfectly poised. Despite this the guard pin must necessarily sometimes be thrown against the safety ring which is located so far from the center that the motion of the balance would be much retarded. It is surprising that draft was not given to the pallets in order to overcome the weakness just spoken of. This, however, is the exact condition of the escapement made, being drawn to scale from the original. This was probably the first attempt at making a detached lever escapement. As will be seen, it was exactly the reverse of the double roller. In the escapement shown in figure 23-4 the impulse was delivered nearer to the balance center than the safety action, while in the double roller the impulse is delivered farther from the center than the safety action.

Figure 23-5 shows a form of escapement suggested by Perron, a French watchmaker. This form is also a detached lever and was probably the first detached lever made. The pallets consisted of two pins, the impulse being entirely

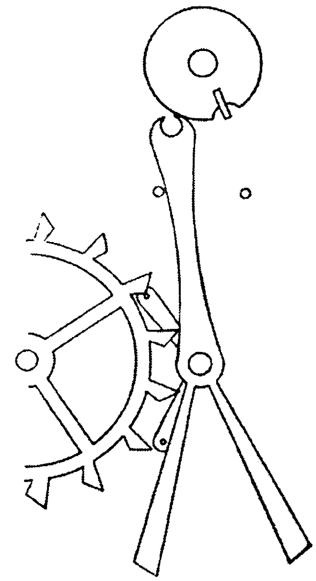

Fig. 23-5

on the teeth, a radical departure from anything heretofor done. Another novel feature was the inclination of the locking faces of the teeth to draw the fork against its bankings. The safety action is performed by the outside of the horns of the fork and the roller edge. The impulse is delivered by a pin projection radially from the roller. A passing hollow, the first device of the kind, permits the passage of the fork during the impulse.

Fig. 23-6

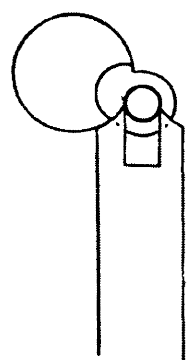

Figure 23-6 shows a form of fork and roller action called the crank lever, so called from its resemblance to the crank of an engine. This form succeeded the rack and pinion and was in use for a long period. It had the advantage over the rack lever of being more simple to manufacture and to adjust. Like the Perron, the safety action was effected between the horns of the fork and the roller edge. The pallets and fork required a vibration of about 25 degrees and the roller about 70.

It has been thought that this form of fork and roller action may have been suggested by the rack and pinion for the reason that a resemblance may be traced to that form. If in a rack and pinion we cut off all but one leaf and all but two rack teeth we shall have, virtually, a crank lever. However, it seems the semblance is more accidental than incidental.

The form of escapement shown in figure 23-1 was the standard for many years, being known as the detached lever. As other forms became popular other terms were added to distinguish them, such as exposed pallets, straight line, club tooth, double roller, anchor, equi-distant center, equi-distant lockings, poised fork, etc., many of which are no longer used.

A form of escapement that deserves special mention is shown in figure 23-7. It is the invention of a London watchmaker named Savage. Theoretically this escapement embraces ideal conditions, especially in the unlocking and impulse. The unlocking is performed at a shorter radius from the roller center than the impulse is delivered. The two pins **AA** perform the unlocking, taking no part in the impulse. The pin **B** which is in the end of the fork performs the double office of impulse pin and guard pin. This form simplifies the production of a non-setting escapement for the reason that both unlocking and impulse are performed under more favorable conditions than any other escapement. Its delicacy of adjustment, however, proved prohibitive to its general use.

SEC. 417—The Cylinder Escapement

The cylinder escapement was invented by George Graham in 1720. It met with little favor at first, being condemned by most of the celebrated watchmakers of that time, among whom was Berthoud who actually attempted to demonstrate that the verge escapement was much its superior.

It is a dead beat escapement which is, of course, a point in its favor. This point is more than offset by the fact that the escape tooth is in constant contact with the cylinder, and at a considerable distance from the center.

Figure 23-8 is a perspective view of the cylinder and its plugs. The letters indicate the names applied to the different parts: **a,** the arbors; **b,** the great or top plug; **c,** the small or bottom plug; **d,** the great shell; **e,** the small shell; **f,** the plug face; **g,** the receiving lip; **h,** the discharging lip; **i,** the banking slot; **j,** the half shell; **k,** the cylinder column.

Figure 23-9 is designed to show the action of the escape tooth on the cylinder. The names applied to the different parts of the teeth are: **a,** the top or flat of the tooth; **b,** the impulse face; **c,** the arm of the tooth; **d,** the locking point; **e,** the heel; **f,** the space. That part of the tooth connecting it with its arm is not shown. It is called the column.

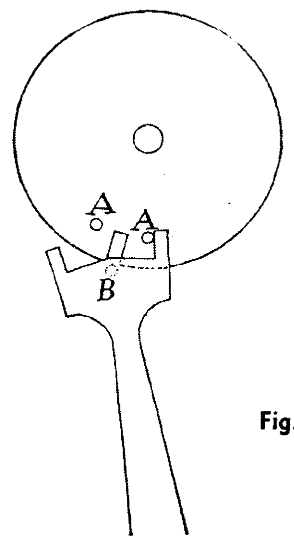

Fig. 23-7

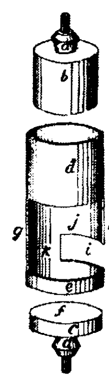

Fig. 23-8

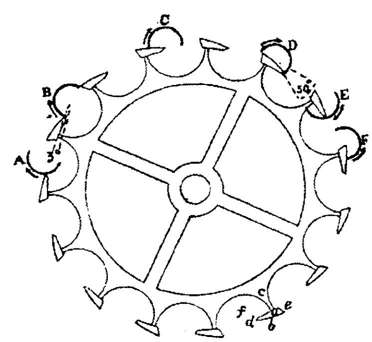

Fig. 23-9

Six positions of the cylinder in action are shown, the cylinder moving as indicated by arrows. At **A** the locking point of the tooth is in contact with the half-shell. At **B** the tooth is about to unlock. At **C** the face of the tooth is delivering an impulse on the receiving lip of the cylinder. At **D** the impulse has been delivered and the tooth is in contact at the locking point with the inside of the half-shell. At **E** the tooth is still in contact with the inside of the half-shell, the cylinder having revolved until the tooth arm has entered the banking slot. The purpose of this slot is to allow the balance a wider arc of vibration than if it were not introduced into the half-shell. At **F** the motion of the cylinder has reversed, the tooth has been released and is delivering an impulse to the discharging lip of the cylinder.

The impulse faces shown in the drawing are slightly curved, but they are more frequently formed of a straight plane. There is some difference of opinion as to the best form.

When a curve is used it can be so formed that equal proportions of its length cause the cylinder to rotate through equal arcs, or it may be so formed that an equal resistance to the changing force of the hairspring is offered throughout the entire impulse. The straight face, however, causes the balance to give the greatest arc of vibration.

A condition brought about by the action of the escapement is that the size of the balance as well as its weight, is confined to comparatively narrow limits. When the balance is heavier than those limits the watch loses with an increase of the motive force, and when the balance is too small it gains. This seems to conflict with mechanical laws but is nevertheless a fact.

There is no other escapement that requires more frequent cleaning. If this is not properly attended to, any approach to a steady rate is not to be expected. Owing to the peculiar shape of the teeth and their constant contact with the cylinder, dirt and thick oil will quickly accumulate on the parts, shortening the arcs of vibration of the balance.

The arc that the cylinder describes during the delivery of an impulse by an escape tooth is called "the lift." This is usually about 30 degrees, as shown at **D**, figure 23-9. The aperture in the cylinder shell is generally about 180 degrees. The thickness of the shell is about 1/16 the length of the impulse face of the tooth. The drop should be as small as possible, consistent with freedom. The smallest drop practical for a lever escapement is 1½ degrees. In the cylinder escapement it need not exceed 1 degree.

The amount of lock of the tooth on the cylinder shell should be 3 degrees, as shown at **B**, figure 23-9.

Le Toy says that in its progress the point of the tooth should pass through the axis of the cylinder. Berthoud says that the middle of the locking face should pass through the axis. The latter seems preferable but in other respects the rules laid down by Berthoud for the construction of the cylinder escapement are not to be recommended.

When this escapement was first introduced the escape wheels were of brass and, as might be expected, gave poor results. Later, when steel wheels were adopted and the parts were highly finished, the time-keeping qualities were much improved.

There has been a great diversity of opinion on the part of experts as to the proportions of the parts, forms of curves, extent of angles, etc. Tavan, Moinet, Wagner, Robert, Jodin, Lepaute, Berthoud and Jurgensen, all eminent watchmakers, differ widely on many points but inasmuch as no good purpose would be served by going minutely into details, particularly as the escapement is fast falling into disuse, their various opinions and arguments will not be discussed here.

There are two important matters to be observed in fitting a new cylinder. First, see that the depth between the cylinder and the escape wheel is so pitched that the center of the impulse face of the tooth passes through the axis of the cylinder. If the depth is too deep or too shallow the friction of the tooth on the cylinder is increased, also the drop will not be equal. Second, see that the drop is equal on the inside and the outside of the shell.

To sum up, the cylinder has in its time given good results and should be appreciated from the fact that it filled the gap in a most satisfactory manner between the old verge and the detached lever. Indeed, Mudge, the inventor of the lever, preferred the cylinder to it and used it in his own watches.

It must not be inferred that the cylinder in its best days made any approach in performance to the detached lever of today. Mudge's lever would hardly be recognized when compared with the modern lever escapement.

The cylinder escapement has degenerated into a poorly executed counterfeit of what it was in its day, when the shell was a ruby and the other parts beautifully executed. Add to this the fact that many of the escape wheels of cylinders as now made up have but six leaves and it will be readily understood why it has fallen into disrepute.

An improperly designed or executed cylinder escapement can only be improved to a limited extent. No amount of manipulation will make it perfect.

Watches having this escapement are usually provided with an adjustable potence which contains the lower jewels and carries the steady pin holes for the balance cock. This enables an adjustment to be made for the depth of the cylinder into the escape wheel teeth. Any other alteration is at best a makeshift.

The description already given will enable the repairer to know when a cylinder escapement is correct. To test its action, move the balance slowly in either direction until the drop takes place. Now reverse the motion a slight amount, just enough to insure a lock, and try the shake of the wheel on the cylinder. Repeat this on the other lip and again try the shake. It should be equal. If it is not it indicates that either the wheel tooth or the cylinder, or possibly both, are not of correct size. If the inside shake, the shake when the tooth is resting against the inside of the shell, is the greatest, it indicates that the cylinder is too large in diameter. If the outside is the greatest, it is too small. The correct way to remedy this is to put in a new cylinder of proper size.

In fitting a new cylinder, see that the shake is equal.

SEC. 418—The Verge Escapement

The verge escapement is so rarely found in use at the present day that only an exceedingly brief description of it is deemed necessary.

This escapement first came into use in clocks in the early part of the 14th century, not being applied to watches until some time later. It continued to be used in watches to a constantly diminishing extent until about a century ago, when it ceased altogether.

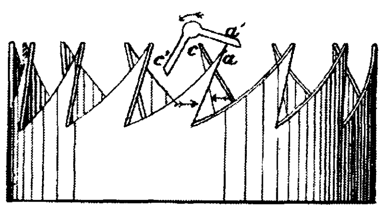

Fig. 23-10

Figure 23-10 illustrates the form and action of the verge escapement. Tooth **a** is delivering an impulse to the pallet, **a'** driving the balance in the direction indicated by an arrow. This tooth moves to the right, also indicated by an arrow. Tooth **c** is moving to the left as indicated. When tooth **a** is released, tooth **c** will drop on the pallet **c'** and deliver an impulse in the opposite direction.

It is evident that this escapement has an excessive amount of recoil, hence its unreliability. Even a slight variation in the power produces a material rate error so that under the most favorable conditions it is unreliable. The wearing of the parts, which in this escapement is always very great, soon causes the watch to gain on its rate, and as the balance, or rather verge, is seldom jeweled this wear soon makes itself manifest.

Another part of the escapement which soon becomes deranged is the escape wheel teeth. These not only wear away, but do so very unevenly, leaving them of varying lengths. In fact, this is one of the most common defects to be found in an old verge watch. It can be remedied by the process known as "topping and filing." The usual method is to fasten a screw collet to the escape staff and, using a Swiss Jacot lathe or an English pivot lathe and a fiddle-bow, true the teeth to length with a slip of bluestone or water of Ayr stone.

The stone should be held firmly against the T rest and brought carefully forward until the longest tooth touches it. Then proceed carefully until all the teeth are of an equal length. Using oil on the stone has the effect of cutting without throwing a burr. After this operation the teeth should be dressed upon the back with a small, fine, half-round file.

When the operation has been performed it will generally be found that the escape wheel does not engage deeply enough into the pallet, but in this escapement that trouble is easily corrected. The escape wheel in a verge watch usually has much more end shake than is necessary. It does no harm for the reason that the action of the escapement keeps the escape wheel constantly pressed away from the center of the verge. The outer pivot finds its bearing in what is called by the English "a follower," which is frictionally inserted into a hole and can be adjusted forward to bring the escape wheel teeth to the proper depth in the verge.

In Swiss watches the same alteration can be made by moving forward the piece called "the counter-potence" which contains the bearing in Swiss verges.

SEC. 419—The Duplex Escapement

This escapement made its appearance about the middle of the eighteenth century. It was the invention of an ingenious French watchmaker, Dutertre, but was perfected by LeRoy. It acquired its name from the fact that in its original form it had two escape wheels, hence the application of the Latin word, duplex—double.

The duplex escapement met with favor among the English watchmakers and was very popular for a considerable period. In this connection it is a remarkable fact that although a French invention it did not become popular in France, but the cylinder, an English invention, was extensively used there and but very little used in England.

Figure 23-11 illustrates the appearance and action of the duplex escapement.

A, the escape wheel.

a, the locking tooth; lying in the plane of the wheel.

a', the impulse tooth; standing at right angles with the plane of the tooth.

B, the impulse arm, carried by the balance staff.

b, the impulse pallet.

C, the roller, carried by the balance staff.

c, the releasing slot.

The impulse arm is located above the roller. The roller is generally of ruby or sapphire, but is sometimes omitted, a slot in the staff taking its place.

The action of the escapement will be made clear by referring to figure 23-11, the parts being represented as moving in the direction indicated by the arrow. **1** shows a locking tooth about to enter the releasing slot in the roller. As the roller moves forward the tooth passes into the slot and is in turn released, thus allowing an impulse tooth to drop on the impulse pallet as shown at **2.** When the impulse tooth has de-

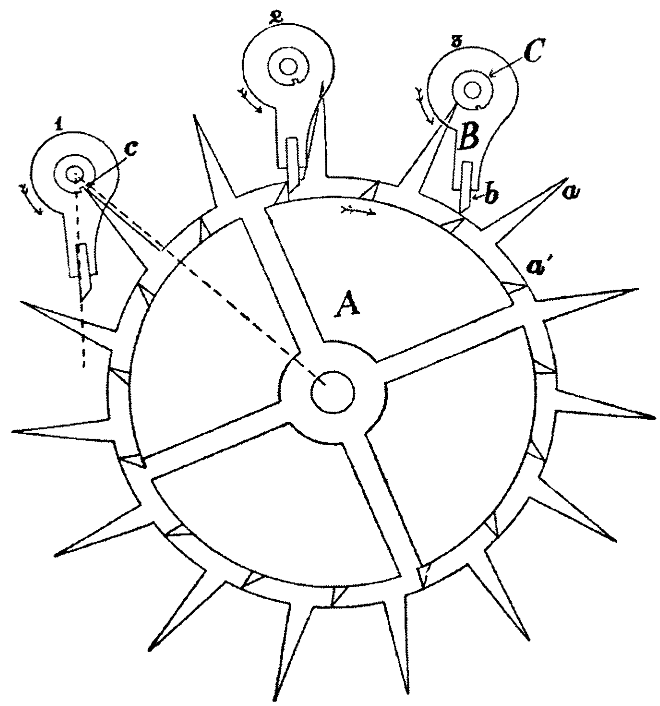

Fig. 23-11

livered its impulse it is released and a locking tooth drops upon the roller as shown at **3**.

On the return excursion the locking tooth again enters the roller slot which allows the tooth to drop forward a slight amount but not enough to release it, and it is immediately forced back to place against the outside of the roller. This exercises a slight retarding influence on the balance which is compensated for when the roller moves in the opposite direction—the direction indicate by the arrow. When it drops into the slot under this condition it delivers a slight impulse which is called "the lesser lift." The lift delivered by the impulse tooth is termed "the great lift."

The adjustment of the rollers to the proper angular relation to each other is of vital importance. The releasing slot must be so placed that it will release a tooth at exactly the right instant. If the tooth is released too soon the impulse tooth will not engage the pallet because the pallet will not have entered the path of the tooth, which will then go forward without delivering an impulse. If the tooth does not enter the slot soon enough and its release is too long delayed, the impulse will be shortened and a poor motion will result.

In the drawing the parts are shown in correct position, but are not strictly correct from a draftsman's point of view, which would require some of the lines to be shown broken.

The duplex escapement requires extreme delicacy in its manufacture and adjustment; a wide side-shake or other slight error being fatal to its proper action. There is comparatively little loss from drop, and it utilizes the movement of the wheel in delivering the impulse to fully as great an extent as in the lever. In the lever the balance revolves without any restraint (except that imposed by the hairspring) except during the brief period that the unlocking and impulse are taking place, whereas in the duplex escapement there is continual contact between the escape wheels and the rollers. For the greater portion of the time a tooth is pressed against the edge of the roller at an extremely unfavorable direction—74 degrees from a right angle, or its complement, 16 degrees from a tangent.

A high authority on horology refers to the duplex as possessing a rate equal to the lever. This might have been true at the time the comparison was made nearly a century ago—but it is far from being the case at the present time. Those who have had much experience with the duplex will agree. The duplex is not manufactured at the present time.

As in laying out the lever escapement, authorities differ to a certain extent as to the proportions that give the best results in the duplex. Saunier in his excellent work, giving for his authority Jurgensen, says:

"The diameter of the roller should be a third of the distance between two adjacent locking teeth of the escape wheel.

"The lifting action on the roller—the small life—extends over an arc of 20 degrees.

"The drop of the impulse tooth on the impulse pallet should be 10 degrees.

"The active impulse on the impulse pallet, measured from the center of the staff, should be 30 degrees."

He quotes many authorities, all of whom, with one exception, agree upon the arc of impulse; the exception referred to is M. Winnerl, who gives the greater lift as 60 degrees, 15 of which is drop, leaving 45 degrees for active impulse.

The lift is determined to some extent by the proportions between the roller, impulse pallet and diameter of the escape wheel.

SEC. 420—The Chronometer Escapement

Next in importance to the lever is the chronometer or detached detent escapement. Its chief value is its adaptability to navigation.

The instrument known as the marine chronometer is capable of close rating when it is kept in a horizontal position and is specially adjusted therefore. It is invariably hung in gimbals which maintain it in a horizontal position, face up.

Marine chronometers are not adjusted to other positions, and if placed in any other than the horizontal will vary in rate.

The fuzee is always used to equalize the power. This facilitates their adjustment and enhances their accuracy. They are frequently to be seen in jewelers' windows as standards of time for the public. The mistaken idea prevails to some extent that a ship's chronometer is a more accurate timepiece than a fine clock. As a matter of fact, a well constructed and adjusted clock with a well compensated seconds, mercurial pendulum, located so as to be free from jar or vibration, is much more reliable.

Many of the chronometers used in show windows are inferior instruments and are often sadly neglected, the owner fondly supposing that cleaning once a year is all that is necessary. Actually frequent cleaning is required. The main spring will have lost a portion of its energy, pivots may need polishing, a readjustment of the escapement may be called for and other things require attention.

When a chronometer receives its annual cleaning, the main spring should be tested with an adjusting rod. The adjusting rod is attached to the fuzee square and the chain is in place connecting the fuzee and barrel. The adjusting rod is provided with one or more sliding weights by which the rod may be balanced in a horizontal position by the force of the main spring. With the chain entirely on the barrel, the mainspring is wound to a certain extent by means of the ratchet on the barrel arbor, the amount of winding—setting up—being changed

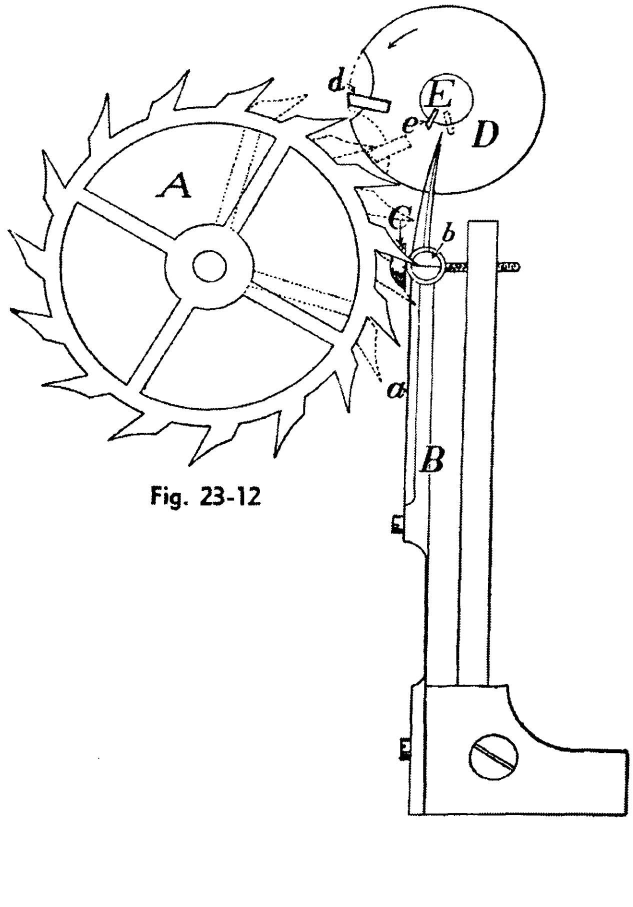

Fig. 23-12

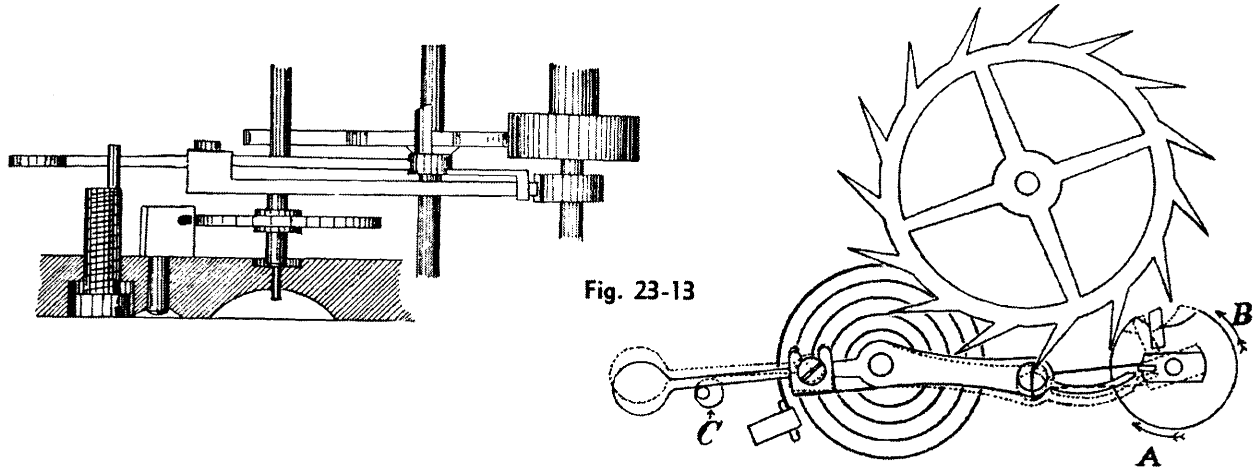

Fig. 23-13

until an approximation to a uniformity of power is attained. When the mainspring becomes set to any extent it is impossible to secure accuracy of rate. This invariably takes place in the course of time, and if the old spring is not replaced by a new one the rate of the instrument is impaired. The same is true to a greater extent of the balance spring. In view of these facts, it will be readily understood that although a chronometer be cleaned at proper intervals, the pivots polished, etc., yet it may become inaccurate and unreliable as a timepiece.

The parts of the chronometer escapement are, referring to figure 23-12:

A, the escape wheel.
B, the locking detent.
a, the unlocking spring, commonly called the gold spring, it being usually made of that metal.
b, the detent jewel.
C, the banking screw.
D, the impulse roller.
d, the impulse pallet.
E, the discharging or releasing roller.
e, the releasing pallet.

There are two principal forms of the chronometer escapement. That shown in figure 23-12 is called "the spring detent" and is generally used in marine instruments. The other, called "the bascule," meaning see-saw, is the form generally used in watches. In this form the detent is pivoted and a coiled spring, called the recovering spring, is colleted to the arbor carrying the detent, the outer end of the spring being secured in a stud attached to the watch plate. The office of the spring is to bring the detent against its banking **C,** figure 23-13.

The chronometer escapement gives impulse to the roller only in one direction, usually when the balance vibrates to the left. Figure 23-12 shows in broken lines the action when the balance, revolving to the left as indicated by the arrow, receives its impulse. In this action the releasing pallet comes in contact with the extreme end of the gold spring and forces the detent aside, releasing an escape wheel tooth. While this is taking place, the impulse pallet has moved into the path of another escape wheel tooth, and when the wheel is released that tooth drops on the impulse jewel thus communicating an impulse to the balance. On the return excursion of the balance the releasing jewel lifts the gold spring from the detent and is allowed to pass on its excursion to the right. The outer end of the impulse jewel is flush with the periphery of the roller and passes between two teeth without contact.

Figure 23-13 shows a plan view and an elevation of the bascule. It is shown in full lines with the balance revolving to the right as indicated by the arrow **A.** The releasing pallet is in contact with the gold spring, lifting it from the detent. The broken lines show the releasing pallet in contact with the other side of the gold spring, forcing the detent from its banking and carrying the detent jewel to a point where it is about to release the escape wheel for the delivery of an impulse. The roller is rotating as indicated by the arrow **B.**

The elevation is for the purpose of showing the position of the parts as in the watch. Note that the extreme ends of the detent, gold spring, releasing roller and releasing jewel, are all located beneath the impulse roller. The same condition prevails in the escapement depicted in figure 23-12.

A close scruitiny of the chronometer escapement will disclose the fact that fully four-tenths of the power is lost in the drop of the wheel tooth on the impulse pallet. There is also a loss of power in forcing the detent aside to release the escape wheel, and in raising the gold spring from the detent to allow the releasing jewel to pass. It has been shown that there is a loss of one-third in the lever escapement. The loss in the chronometer is still greater.

Many modifications of the chronometer escapement have been made from time to time but the two forms shown are those found in general use.