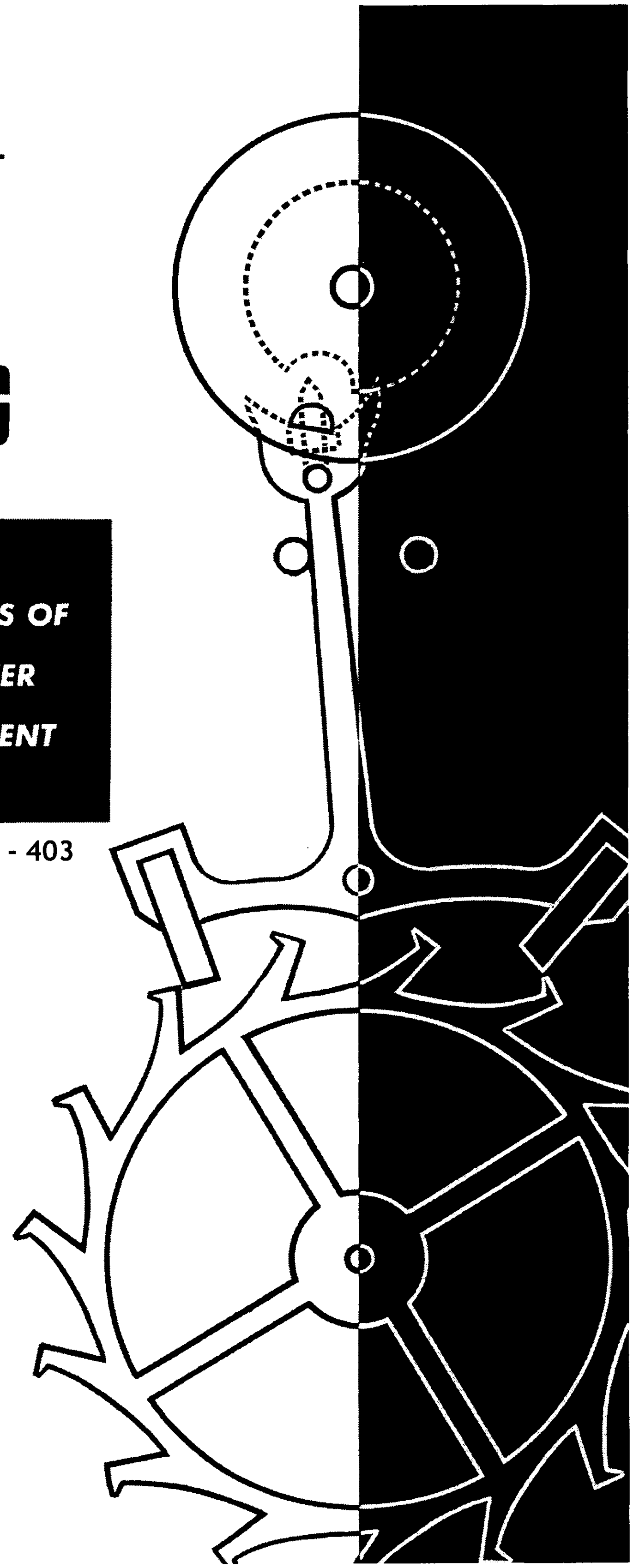
Master WATCHMAKING

LESSON 21

PRINCIPLES OF THE LEVER ESCAPEMENT

Sections 395 - 403



CHICAGO SCHOOL OF WATCHMAKING

Founded 1908 by THOMAS B. SWEAZEY

SEC. 395—The Detached Lever Escapement

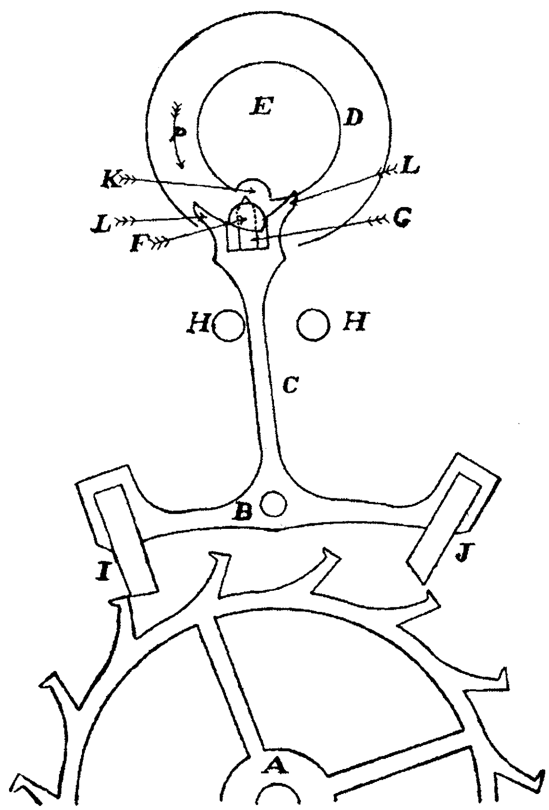


Fig. 21-1

There is no part of a watch that involves so many complications or requires such an amount of study and practice as the escapement. There is no part of its mechanism about which more has been written, yet half has not been told.

In order to adjust an escapement intelligently, a thorough knowledge of the nature of all its functions is essential. Theory and practice are both required. Theory alone will not make a good workman. Practice without theory may do so, after a fashion; the two united make the rapid and skillful workman.

The escapement is complex in its character. The various individual functions are so intimately related to each other that no single one can be altered without affecting others to a greater or lesser degree. The consequence is that a workman will often make an alteration to correct an error, and in doing so will create another error, or aggravate a previously existing one. Without a good theoretical knowledge, hours may be spent over an escapement that, with sound theoretical knowledge, might have been made right in minutes.

The theory will be presented in plain language, accompanied by a multiplicity of illustrations so that the problems involved will be clear. The effects produced by the different alterations that may be made will be described and illustrated, thus directing the practice of the student. Every operation performed will be for definite results, results that may confidently be expected.

SEC. 396—Names of Parts

The term escapement is applied to that part of the watch by means of which the rotary motion of the wheels is transformed into the vibratory motion of the balance. The members included in the escapement are: The escape wheel, the pallets, the fork, the roller jewel and the roller table or rollers. The balance is not properly a part of the escapement. Inasmuch as more than one term is frequently used to designate the same part, it is deemed well to give the different names in general use.

In figure 21-1 the letters refer to the following list:

A—escape wheel.
B—pallets.
C—fork.
D—impulse roller or roller table.
E—safety roller or guard roller.
F—roller jewel, impulse pin—or jewel pin.
G—guard pin or guard dart.
H—banking pins or bankings.
I—receiving stone or R stone.
J—let-off stone—L stone or the discharging stone.
K—passing hollow or roller crescent.
L—fork horns.

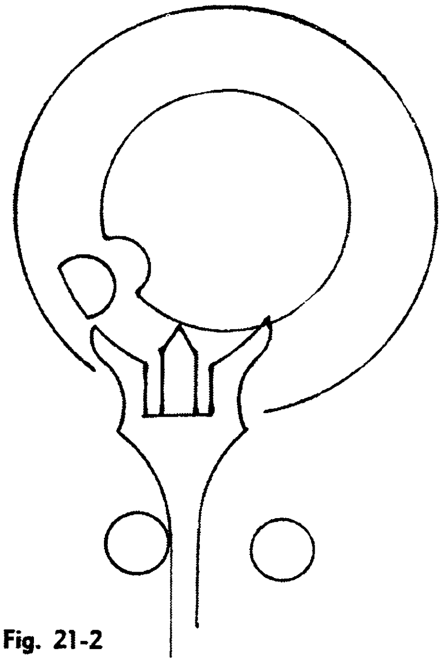


Fig. 21-2

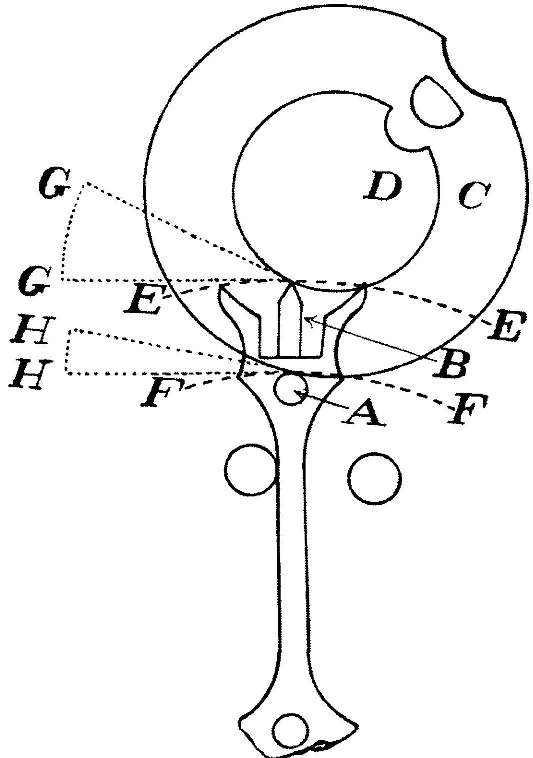


Fig. 21-4

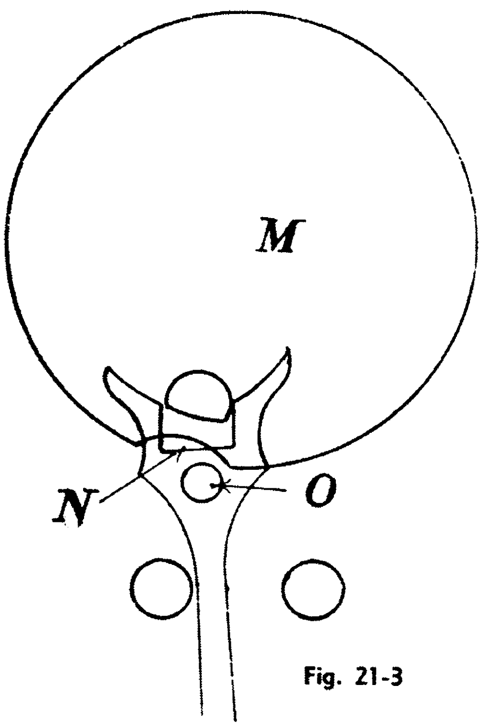


Fig. 21-3

SEC. 397—Comparison Between the Single Roller and the Double Roller Escapements

The difference between the single and the double roller escapement is entirely in the safety action; the escape and pallet action and the fork and impulse action may be identical in both forms.

The guard pin and safety roller are provided for the sole purpose of preventing what is commonly called "overbanking" or more properly speaking, "going out of action."

Referring to figure 21-1 it will be seen that the fork is to the left, and that the roller is making its excursion in the direction indicated by the arrow, **P.** The roller jewel is in the act of unlocking the escapement and in this position the fork cannot go out of action, as it is held in place by the roller jewel. When the roller jewel is out of reach of the fork horn the fork is kept in position by the safety roller; it cannot pass the safety roller until the passing hollow comes into position.

Figure 21-2 illustrates the latter condition. This figure shows the fork at the left as in figure 21-1, but the roller jewel is farther to the left, and out of reach of the fork horn. The fork is now prevented from overbanking by the edge of the safety roller projecting beyond the path of the guard pin. It is not deemed necessary to letter the parts in this drawing.

Figure 21-3 shows a single roller under the same conditions as the double roller in figure 21-1. **M** is the roller table, **N** the passing hollow, **O** the guard pin. The roller table, **M,** performs the offices of both rollers **D** and **E** in figure 21-1. In the double roller, the guard pin projects forward, under and beyond the roller jewel. In the single roller it stands perpendicularly with the fork and is back of the fork slot. The roller table, **M,** not only carries the roller jewel, but its edge in conjunction with the guard pin provides the safety action.

SEC. 398—Advantages Claimed For Each Form of Safety Action

Figure 21-4 shows a portion of an escapement with both forms in combination. The guard pin **A** is for the single roller action; the guard pin **B** is for the double roller action; **C** is the impulse roller in the double roller form; **D** is the safety roller in the double roller form; **C** takes the place of both rollers in the single roller escapement.

The fork is shown against the left banking pin. The broken line **EE** is the path of the double roller guard pin; the broken line **FF** is that of the single roller guard pin. It will be seen that line **EE** penetrates beyond the periphery of the safety roller to a much greater extent than line **FF** penetrates beyond the periphery of the roller **C.** The dotted lines **GG** are drawn tangent to the circumference of the safety roller and to the path of the guard pin at their point of contact in the double roller escapement; the dotted lines **HH** are in the same relation in the single roller escapement. These lines embrace the angles at which the respective guard pins make contact with their rollers. It will be observed that the angle embraced by lines **GG** is more than twice that embraced by line **HH.** It is therefore justly claimed that the double roller is much less liable to allow the escapement to overbank than is the single roller. It is also claimed, justly, that in case the fork is thrown against the roller edge, less resistance is offered to the motion of the balance, owing both to the respective sizes of the rollers and the difference in the angles at which they contact, as shown by the lines **GG** and **HH.**

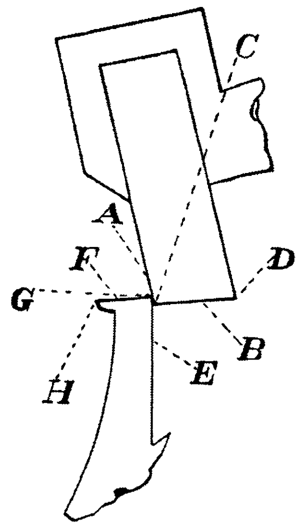


Fig. 21-5

SEC. 399—Loss of Power

Before considering the important subject of loss of power, it might be well to give the terms used to designate the acting parts of the pallet stones and the escape wheel teeth.

The parts of the pallet stone, figure 21-5, are: **A,** the locking face; **B,** the impulse face; **C,** the locking corner; **D,** the releasing corner.

The parts of the escape tooth are: **E,** the locking face; **F,** the impulse face; **G,** the locking corner; **H,** the releasing corner.

There is a great loss of power from the lever escapement even under the most favorable conditions. There is more loss of power entailed in conveying the motion from the escape to the balance than in all other losses of power combined. Of the force conveyed from the mainspring through the train up to the escape wheel teeth, upwards of one-third of the power is lost before it reaches the balance. This will no doubt seem surprising, but it will be explained by figure 21-6 and the specifications connected therewith. In order to avoid confusion, the guard pin and passing hollow, which constitute the safety action, have been omitted from this figure as they have nothing to do with the conveyance of power.

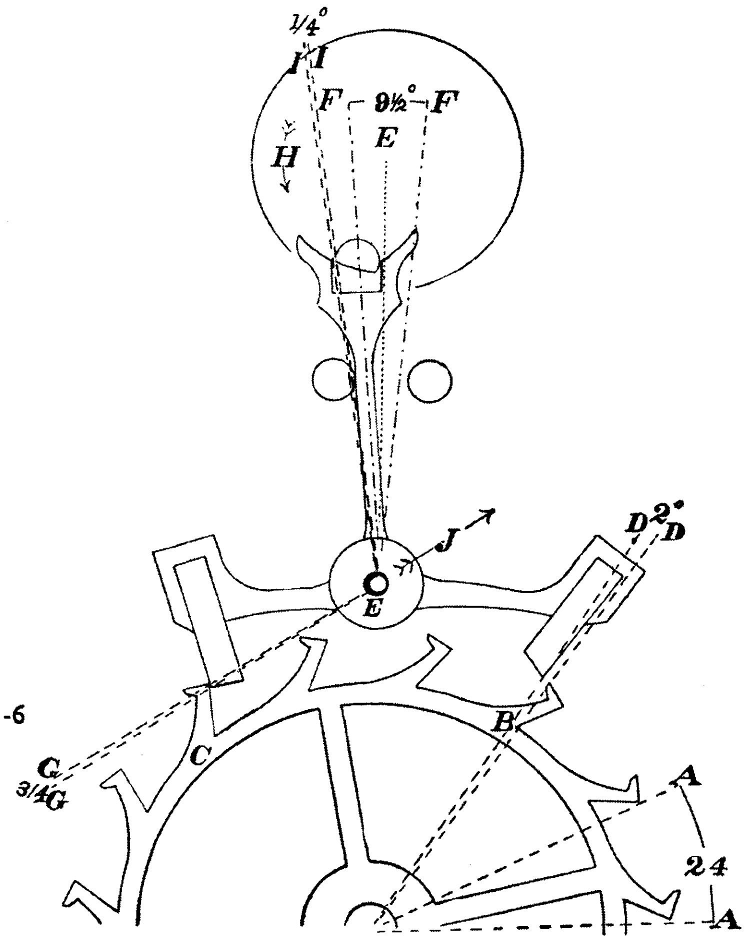


Fig. 21-6

The escape wheel has 15 teeth; the quotient of 360 degrees divided by 15 is 24 degrees; therefore, the angular distance between similar points of adjacent teeth is 24 degrees as shown by lines **AA**. One revolution of the escape wheel causes each tooth to deliver two impulses to the pallets, or thirty impulses in all—one impulse on the receiving stone and one on the discharging stone. This gives 12 degrees of angular motion for each impulse. The entire 12 degrees, however, cannot be used for impulse as a certain amount is necessary for freedom. This freedom is called the drop. In the drawing, tooth **B** has just been released from the discharging stone and tooth **C** arrested by the receiving stone. The angular distance between the releasing corners of the discharging stone and tooth **B** is the amount of the drop; the drop is just that much lost power. The wheel passes through that portion of each revolution without doing any effective work, its force being lost in the impact when it is stopped by the pallet. The amount of drop is usually 2 degrees, as shown by the lines **DD**. This involves a loss of 16-2/3 per cent, exclusive of that in the impact.

In figure 21-6 the arc of impulse of the fork from banking to banking is 9½ degrees as shown by lines **FF**. In the drawing **EE** is the line of centers; the lines **FF** include the arc of vibration. Of this 9½ degrees of vibration, ¾ of a degree must be deducted for lock, as shown by lines **GG** which pass through the locking corners of tooth **C** and the receiving stone. This leaves 8¾ degrees of actual impulse which is a loss of more than 7 per cent; and bear in mind that this 7 per cent loss is 7 per cent of the power left after deducting the loss from drop.

The roller jewel must be allowed some freedom in the fork slot. This freedom is called roller jewel shake, and can be readily understood by referring to the drawing, which shows the fork held against the left banking, the tooth locked on the receiving stone. Let us assume that the roller is making an excursion in the direction indicated by the arrow **H.** In making this excursion, the roller jewel enters the fork slot, and, coming in contact with its right side, moves the fork to the right, thereby unlocking the wheel tooth. When the tooth passes to the impulse face of the stone the fork immediately moves to the right until the left side of the slot makes contact with the roller jewel. This is referred to as roller jewel shake. Its amount is usually ¼ degree, as shown by lines **II.** A loss of 3 per cent is thus incurred. The losses thus far given bring the aggregate up to about 27 per cent, for we must bear in mind that each deduction for loss is the given percentage of the amount remaining after the previous deduction. There remain other losses, such as friction, impact and side shake, the exact amount of which cannot be readily calculated. Perhaps the side shake in the pallet arbor jewels is the most serious of these.

As the various impulses are applied and resistance is encountered by the members of the escapement, their pivots are forced against their bearings in different directions. This may readily be detected through a double eye-glass by looking directly down on the pallet arbor pivot while the balance is in motion. The side shake will show more plainly when the jewel and pivot are clean and unoiled. When the parts are in contact under the conditions shown in figure 21-6 the pallet arbor is pressed against the side of the jewel hole in the direction indicated by the arrow **J.** As the impulses are delivered alternately to the stones, and the resistance of the roller jewel is encountered, the pivot will be seen to rock from side to side in the jewel, thus incurring a loss of power. Hence it is important that the side shake in these jewels be as close as possible.

Another loss of power to which attention is called is the result of the impacts of the escape teeth with the pallet stones, and the roller jewel with the fork. To fully appreciate this, the fact must be kept in mind that the fork is started up from a dead rest at each vibration and that it comes to a sudden stop at the end of each vibration.

Another condition existing in the fork and roller action is that the movement of the fork is practically uniform, while that of the balance varies. A balance having a motion of one turn must necessarily travel at a higher rate of speed than if the vibration were half a turn. When the roller jewel is in contact with the fork, the balance is at its maximum velocity. As the roller jewel first contacts the fork, it releases the escape wheel by unlocking and immediately the resistance of the fork is reversed. It begins to exercise force to accelerate the motion of the balance. but the balance is moving at a higher rate of speed and consequently has a tendency to recede from its pressure—to get away from it, so to speak. The result is that as the motion of the balance increases, the efficiency of the force of the fork decreases.

It will be seen from the foregoing that placing the loss of power at one-third is a very conservative estimate.

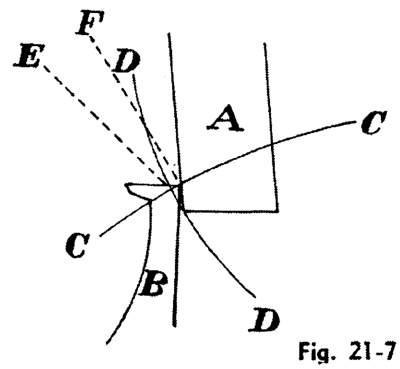


Fig. 21-7

The recoil in unlocking is a source of error that sometimes makes itself felt in adjustment. Figure 21-7 illustrates what is meant. The drawing is made to exaggerate the condition for the purpose of making the point clear.

A is a pallet stone, **B** an escape wheel tooth. The circular line **CC** is the path of the locking corner of the tooth. The circular line **DD** is the path of the locking corner of the stone. In unlocking, the stone passes along the arc **DD** and the tooth along the arc **CC.** The unlocking takes place at **E,** where the lines **CC** and **DD** intersect. It follows then that the tooth must be forced backwards from the point **F,** where it is shown on the drawing, to the point **E,** where it unlocks. This backward motion is known as the recoil. In forcing the escape wheel backwards, the fourth, third, center, and barrel are all in their turn reversed. This actually winds up the mainspring 300 times a minute. True, it is an infinitesimal amount, but let it be understood that the entire impulse delivered by the escape wheel is but a minute fraction of the rotation of the barrel.

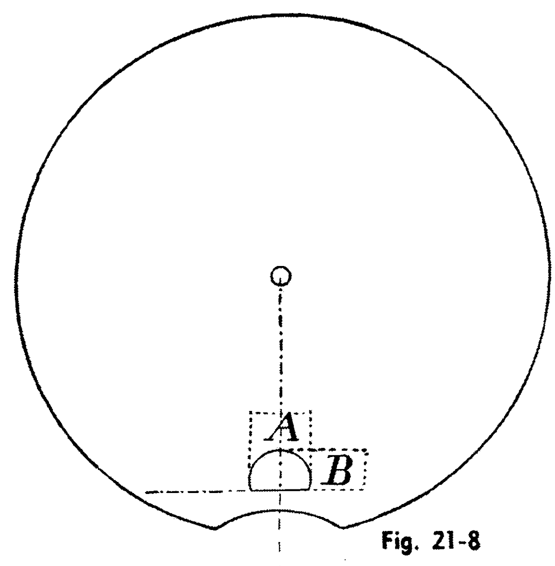


Fig. 21-8

SEC. 400—The Fork and Roller Action

An improperly fitted or incorrectly located roller jewel is perhaps the most common error found in escapements. A roller jewel should have 1½ to 2 hundredths of a millimeter shake in the fork slot. The roller jewel should be set firmly in the roller. It should be perfectly upright, its face square to the front, that is, at right angles with a radial line from the center of the roller, as shown in the broken lines in figures 21-8.

A D-shaped roller jewel should be flattened to about two-thirds of its diameter. The diameter **B** should be two-thirds that of **A.**

Figure 21-9 shows the effect of a roller jewel tilted sidewise. In this figure **A** shows a jewel set upright while **B** shows a jewel set out of upright. Referring to **A,** it will be seen that the roller jewel **c** has a certain amount of sideshake, as indicated by the black portion at the right of the jewel; referring to **B,** the roller jewel **c** being tilted, takes up all the sideshake.

Figure 21-10 shows the effect of tilting a roller jewel forward. In this figure, **A** is a roller, **B** a fork, **C** a roller jewel. The point where the section lining ceases at the lines **dd** is the bottom of the fork slot. The perpendicular dotted lines **ee** represent the front end of the slot, where the curve of the horn **f** begins. The fork is shown in two relative positions to the roller jewel. It is evident that owing to the necessary endshakes of the balance and fork, the fork will vary with regard to longitudinal position on the roller jewel. In the uppermost position, the roller jewel penetrates a greater distance into the fork slot than in the lower. This variation (being liable to constant change) is detrimental to regularity of rate. Its effect on escapement adjustment will be more fully explained as we proceed.

Fig. 21-10

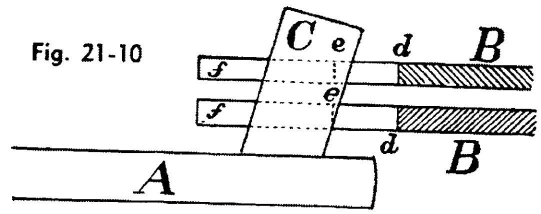


Figure 21-11 illustrates the proper position of the roller jewel when entering or leaving the fork slot. The bankings are set correctly for lock and slide; the escape wheel and pallet are not shown. It will be observed that the face of the roller jewel clears the curve of the fork horn. The fork is against the left banking, but if at this instant it should be moved to the right, the left corner of the slot would come in contact with the face of the roller jewel, thus preventing overbanking.

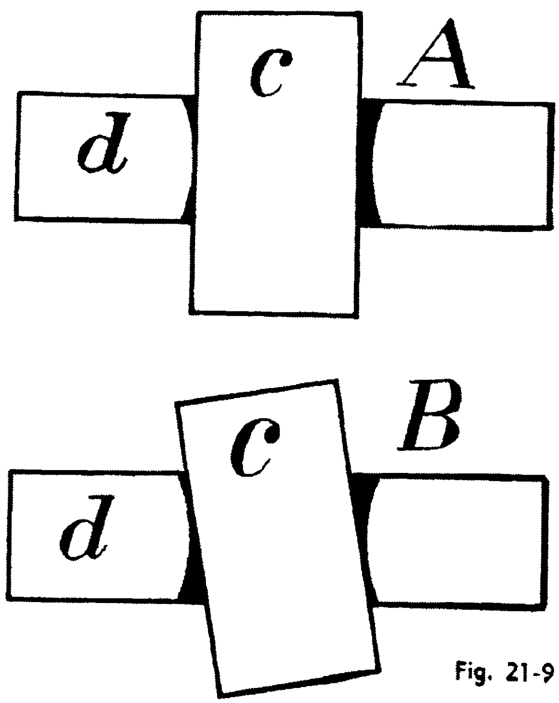


Fig. 21-9

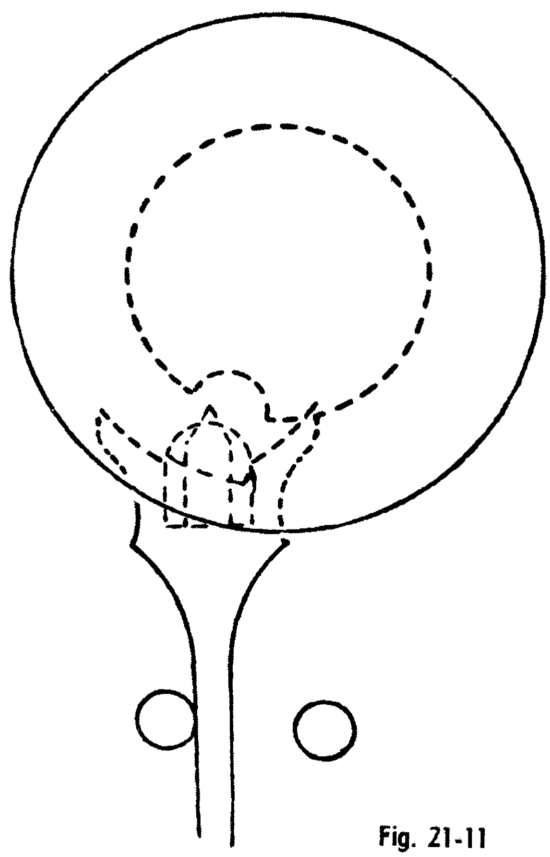


Fig. 21-11

Figure 21-12 below, shows this condition. In this figure the roller jewel is in the same position as in figure 21-11, but the fork is moved to the right, away from the banking pin. The guard pin is not shown, as it is not involved in this action. It will be noticed that further movement of the fork to the right is prevented by the roller jewel and that this also prevents unlocking the escape tooth.

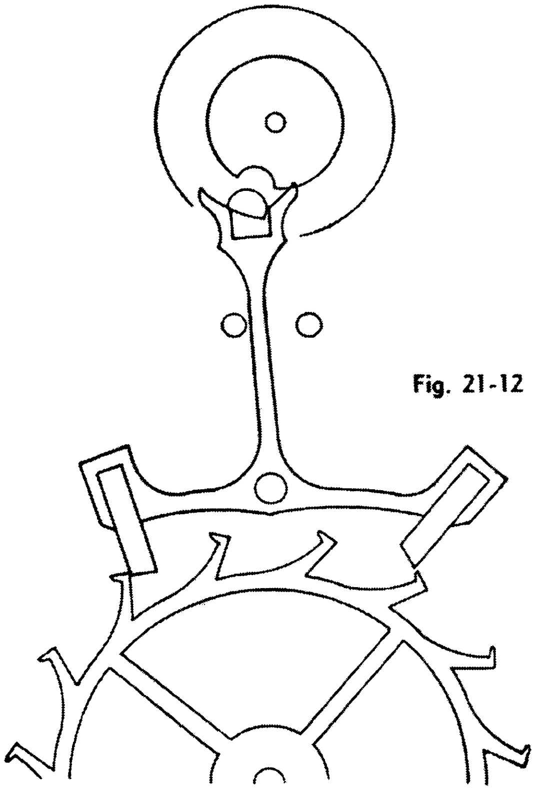


Fig. 21-12

SEC. 401—Correct Position for Roller Jewel

The fork and roller jewel actions can not be readily seen in the watch; the student is therefore compelled to rely to some extent on the sense of touch. How this may be done will now be explained.

Prepare a piece of tissue paper as follows: Take a piece of watch paper, fold it over the top of the index finger of the right hand, securing it with a light rubber band, as shown in figure 21-13. The purpose of this paper is to act as a shield. It permits the finger to be placed upon the balance without danger of smearing it. Placing the finger lightly on the balance, bring the escapement to the position shown in figure 21-14. Now move it in the direction indicated by the arrow until the escape tooth is released by the discharging stone and a tooth drops on

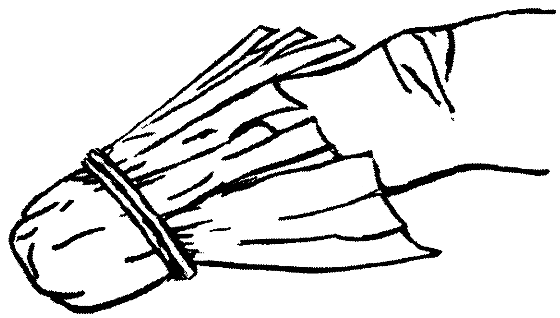


Fig. 21-13

the receiving stone. Stop instantly at this point. Press the fork lightly to the right. If the escape tooth unlocks with this action, the roller jewel is too far back and should be brought forward. Figure 21-15 shows this condition. The fork is shown pressed away from the left banking until it is arrested by the left horn coming in contact with the face of the roller jewel; but before this has taken place the escape tooth has been unlocked and passes on to the impulse face of the pallet stone.

There are two methods by which it may be determined whether or not the roller jewel is too far forward. The balance may be taken out and the escapment banked to drop; that

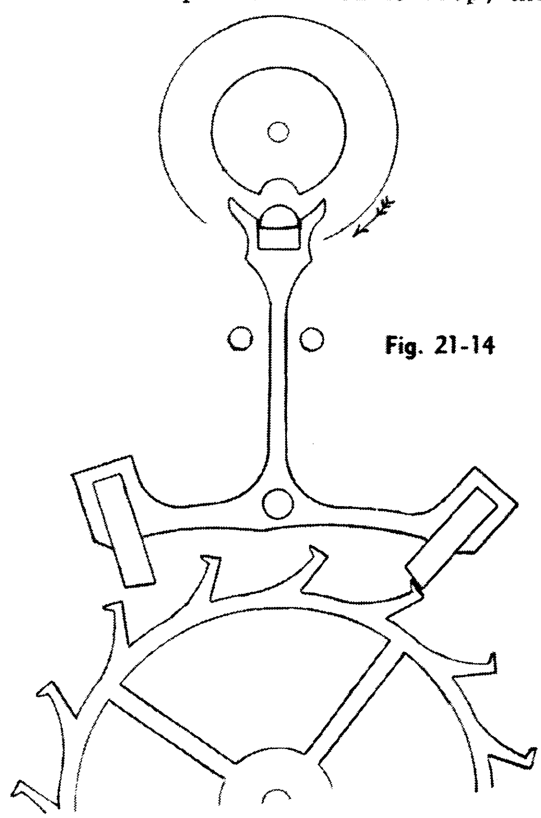


Fig. 21-14

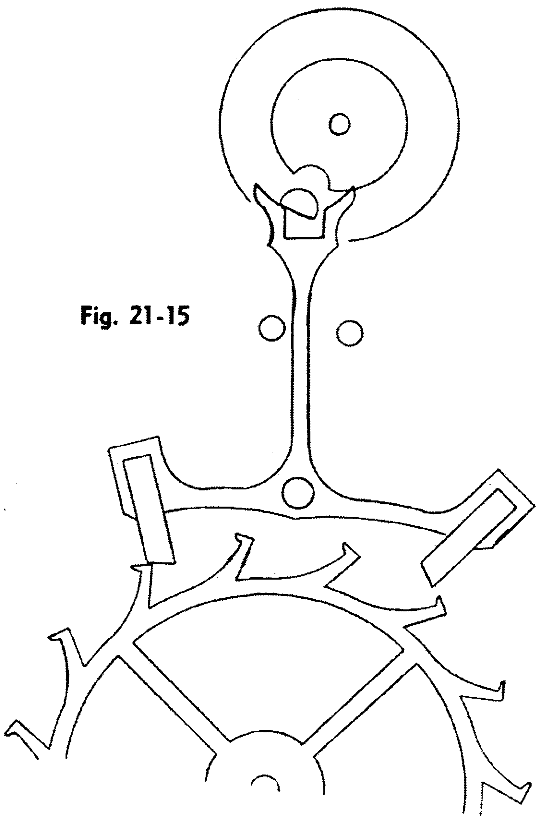


Fig. 21-15

This is frequently done but is entirely wrong, for it gives too much slide. At the locking point, the roller jewel should just pass out of the fork slot without shake. The necessary freedom is given by opening the bankings slightly. Any opening of the bankings beyond this imposes unnecessary work on the balance.

When a banking pin is opened in an escapement banked to drop, it allows the locking face of the pallet stone to slide along the locking corner of the wheel tooth. This is slide—sometimes called run. A perfect understanding of the difference between the terms lock and slide should be acquired.

Lock is the amount that the locking corner of a pallet stone projects beyond the locking corner of an escape tooth at the instant the drop takes place. Lock can only be changed by drawing out or pushing in one or both of the pallet stones. Opening or closing the bankings produces no change in the lock.

When a properly adjusted escapement is in action, a tooth drops on the locking face of a stone. At this moment the fork is a slight distance from one of the banking pins. In its further movement the locking face of the stone slides along the escape tooth until the fork is arrested by the banking pin. This is the slide.

is, the bankings closed up so that the escape wheel will not be released at either side. Now open them until the wheel will be barely released. Leaving them in this condition, replace the balance in such a position that the roller jewel is away from the fork. If on rotating the balance the roller jewel will not enter the fork slot, this is evidence that it is too far forward.

Another way of testing this is by banking to drop while the roller jewel is in the fork slot. If after doing this the roller jewel will not be released by the fork slot, it is evidence that the pin is too far forward.

Figure 21-16 illustrates the first method. The escapement is banked to drop; the roller is assumed to be moving in the direction indicated by the arrow, but the roller jewel is arrested in its motion by the end of the fork horn. It is quite evident that if the roller jewel should be moved back so as to clear the horn, the roller might continue its rotation. Figure 21-17 shows the escape wheel, pallets and fork in the same position as in figure 21-16. The roller jewel here is prevented from leaving the fork slot for the same reason that it is prevented from entering it in figure 21-16.

In either case, opening the bankings would allow the roller jewel to enter or leave the slot.

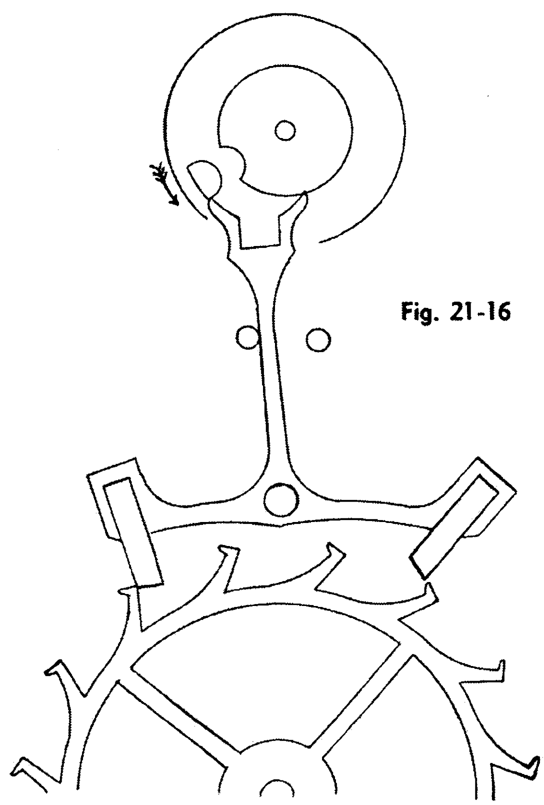


Fig. 21-16

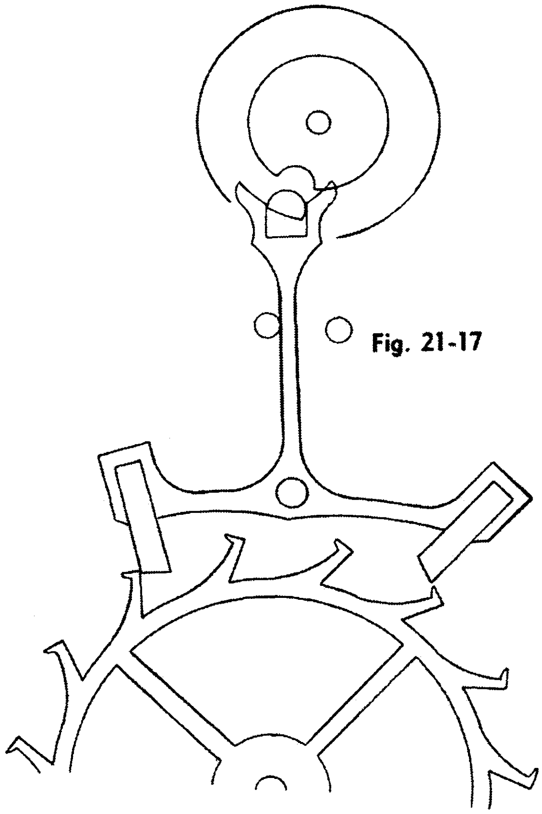
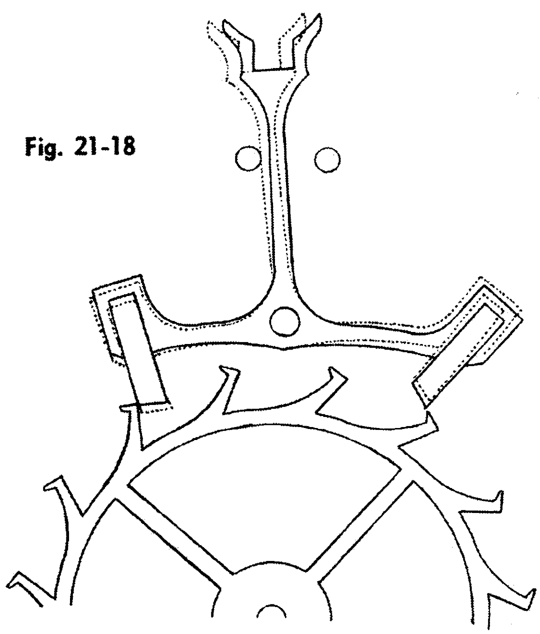


Fig. 21-17

Fig. 21-18



The slide may be increased by opening a banking pin or decreased by closing it, but these operations produce no effect whatever upon the lock.

Figure 21-18 will serve to illustrate the difference between the lock and slide. In this figure the amount of slide is exaggerated for the purpose of making it more readily distinguishable from the lock. The fork and pallets in full lines show the escapement at the lock; the broken lines show it after the slide has taken place.

SEC. 402—The Safety Action

The guard pin in a lever escapement is purely a safety device. It could be dispensed with without impairing the timekeeping quality of a watch, provided the watch was not subjected to any sudden or rapid motion. In order that it may be perfectly reliable as a time-piece a guard pin becomes a necessity. During the free excursion of the balance in the interval between two impulses, the combined action of the guard pin and roller edge prevents the fork going out of position to receive the roller jewel. Without this safety provision a sudden motion given the watch would be liable to cause what is generally called overbanking, or more properly speaking, going out of action.

When the roller jewel leaves the fork slot, the first part of the safety action is secured by the roller jewel and the fork horn. This is due to the fact that the passing hollow cuts away a part of the roller edge and while that cutaway part stands in the path of the guard pin some other means must be provided to prevent going out of action.

Figure 21-19 illustrates the above condition. In this figure the roller is moving in the direction indicated by the arrow. The guard pin, I, is just about to leave the roller edge and enter the passing hollow. Almost immediately the roller jewel will strike the right side of the fork slot, moving the fork and unlocking the escapement. The roller jewel will then be embraced by the fork slot.

In this drawing the passing hollow is not in position to release the roller jewel until it has been embraced by the fork slot. The passing hollow, however, is rarely as narrow as represented in full lines. As a matter of fact, it would not be practical to make it so. It will be seen that if the passing hollow were as wide as represented by the broken lines, the safety action at the point shown in figure 21-19 would be between the fork horn and the roller jewel. If the fork horn should be cut off entirely, as represented by the broken lines, **3, 3,** the safety action would still be perfect. The passing hollow

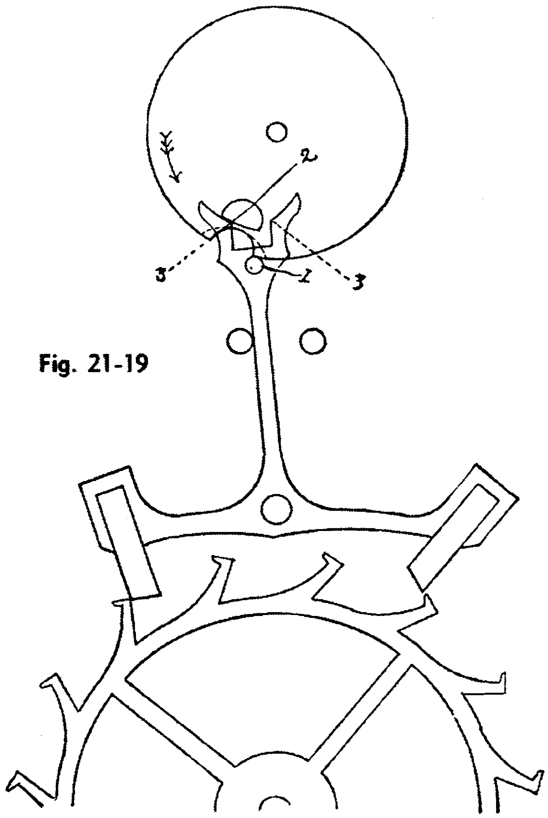


Fig. 21-19

in figure 21-19 represented by broken lines, is wider than is necessary. A passing hollow of a medium width would answer the purpose quite as well. When the roller jewel is made with a circular face as shown, the passing hollow may be left wider without impairing the action, but when the face is flat and the passing hollow wide, the action can not be so nicely adjusted. A double roller should always have an impulse pin with circular face. This condition will become apparent when we reach the description of the double roller escapement. In view of the above, long horns on a single roller escapement are more ornamental than useful.

Figure 21-20 shows how the safety action takes place in the double roller escapement under conditions similar to those prevailing in the single roller shown in figure 21-19. In figure 21-20 the roller is moving in the direction indicated by the arrow and the passing hollow is approaching the guard pin. It will be seen that the roller jewel is still some distance from the fork slot and that before it can enter, the safety action between the guard pin and roller will have ceased. Therefore, a fork horn to provide this safety action is necessary, or else it would go out of action.

When the guard pin in figure 21-20 first comes opposite the passing hollow, the roller jewel will still have a considerable distance to travel before contacting the fork. It is therefore evident that a much greater proportion of the safety action occurs between the roller jewel and fork horn in the double roller than in the single roller escapement.

The curves of the fork horn faces in figures 21-19 and 21-20 are arcs of circles having the same radius, but the centers from which they are described are not in the same location. These arcs are so described that when the fork lies against either banking the curve of the fork horn at that side coincides with the circle described by the face of the impulse pin in its path. In the single roller escapement this is of little importance, but in the double roller it is a great advantage owing to the fact that a greater portion of the safety action must be provided for by the fork horn.

It is a common practice for manufacturers to form fork horn hollows from a common center, in which case the radius must be greater than when two centers are used. These curves are apt to be so wide and to vary so widely from the path of the roller jewel that, especially in a double roller escapement, the safety action may be somewhat uncertain. Add to this a wide passing hollow and we have a combination liable to make trouble and be extremely puzzling to the student.

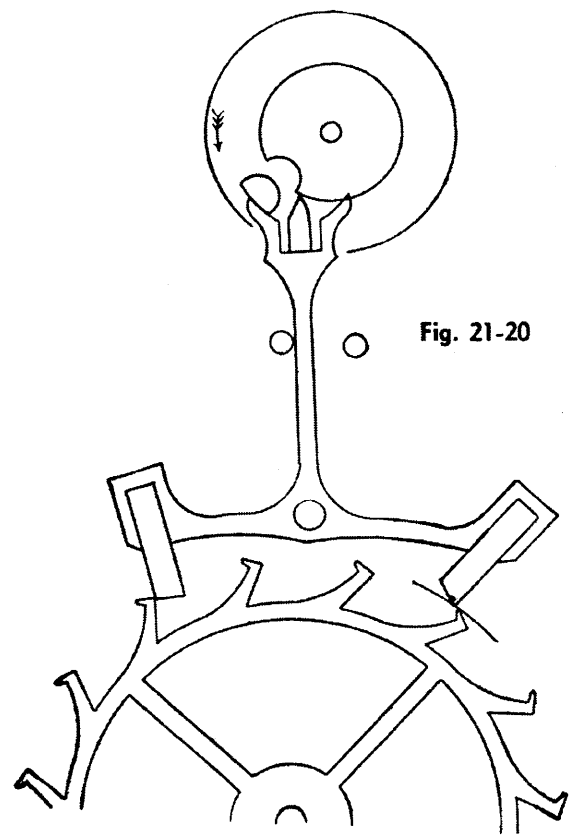


Fig. 21-20

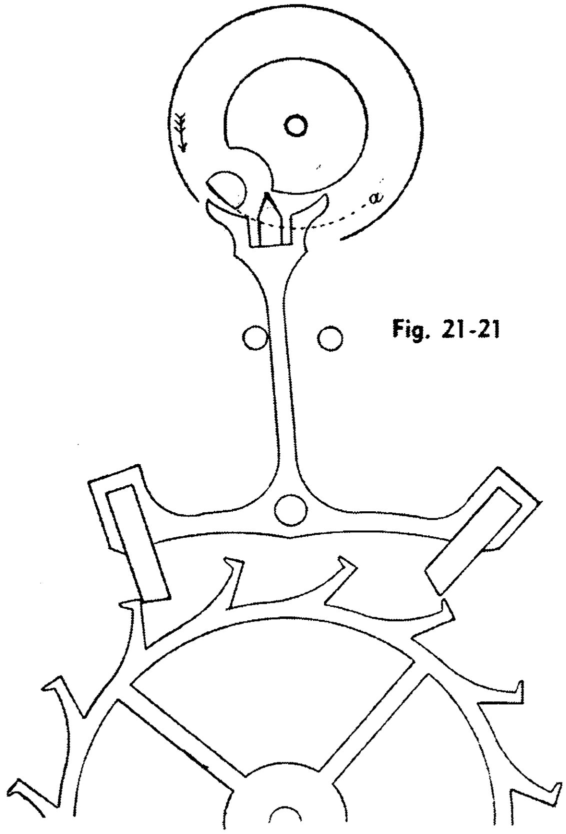


Fig. 21-21

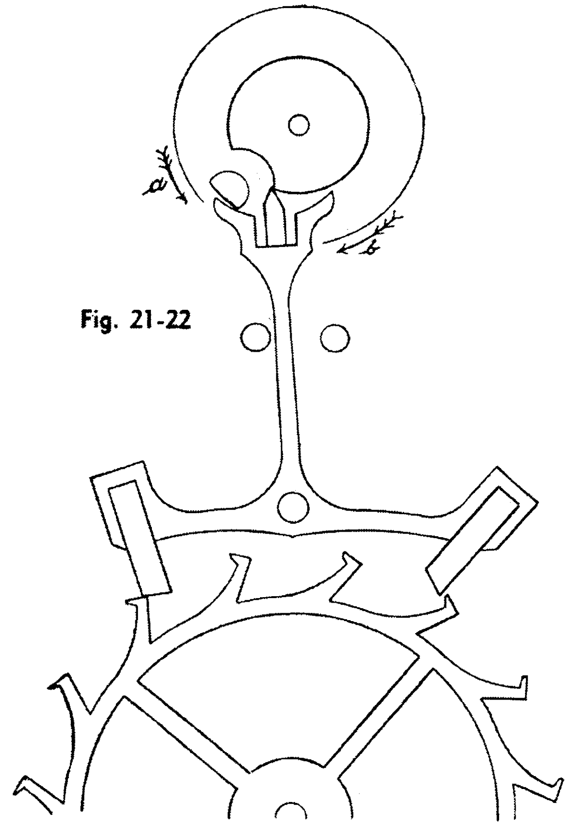


Fig. 21-22

Figure 21-21 illustrates the evil to be apprehended from the condition above described. In this sketch the escapement is shown in the same position as in figure 21-20. The particulars in which escapements differ are: In figure 21-21 the fork horns are curved from a common center, and the passing hollow is wider than in figure 21-20. It will be observed that the curve of the left fork horn does not coincide with the path of the roller jewel, which is the broken line, **a.** The corner of the fork slot is tangent to that line while the extreme end of the fork horn is some distance from it. Under these conditions any sudden jar might throw the fork to the right, thereby wedging the guard pin against the edge of the passing hollow, unlocking the escapement and stopping the watch. This is made clear in figure 21-22.

Figure 21-22 shows the roller in the same position as in figure 21-20. The fork is assumed to have been thrown to the right by a sudden jar. It will be seen that the escapement is now unlocked, an escaped tooth having passed down for a slight distance on the impulse face of the receiving stone. When this occurs and the roller is moving in the direction of the arrow, **a,** it will cause a wedging of the parts that must stop the watch and possibly break the roller jewel, or else bend or break the balance pivot. If it is moving in the direction of the arrow, **b,** it may only trip-check the motion—and pass on, but in that case the escapement must unlock momentarily, causing the watch to lose time to a greater or lesser extent according to the frequency of its occurrence.

It is not intended to imply that every fork in which the curve of the horns is developed from a common center will produce the condition described above. It is only intended to show what may ensue, and to caution the student against neglect in observing this particular feature.

This condition may readily be detected by following the directions below. Turn the balance slowly in either direction until an escape wheel tooth drops on a pallet stone. Then press the fork lightly toward the center position—away from the banking—continuing to turn the balance for about ¼ revolution. If the condition described prevails the escapement will unlock. Now make the same trial on the other stone.

SEC. 403—Guard Pin and Roller Action

In a single roller escapement the guard pin should be upright. Bending it forward, backward, or sideways to adjust the roller shake is not recommended. The evil of this practice will be demonstrated further on.

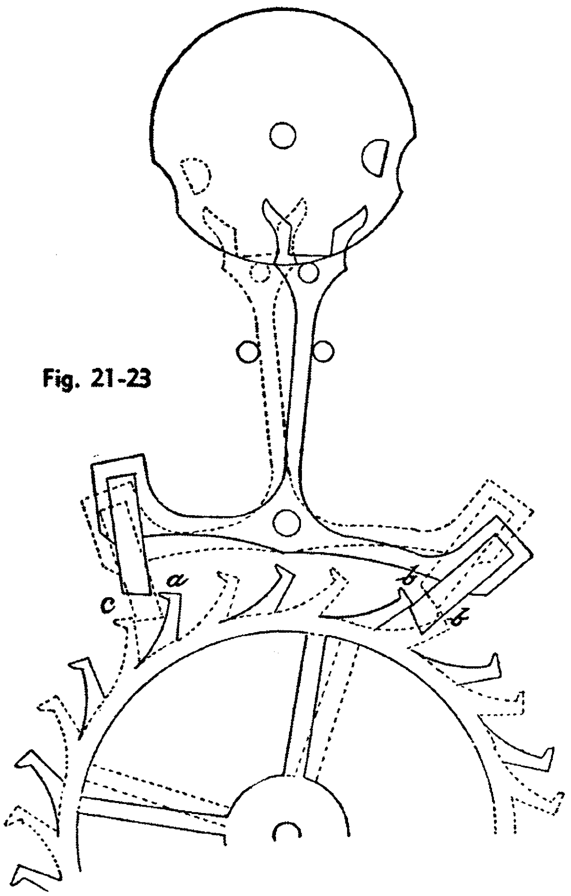


Fig. 21-23

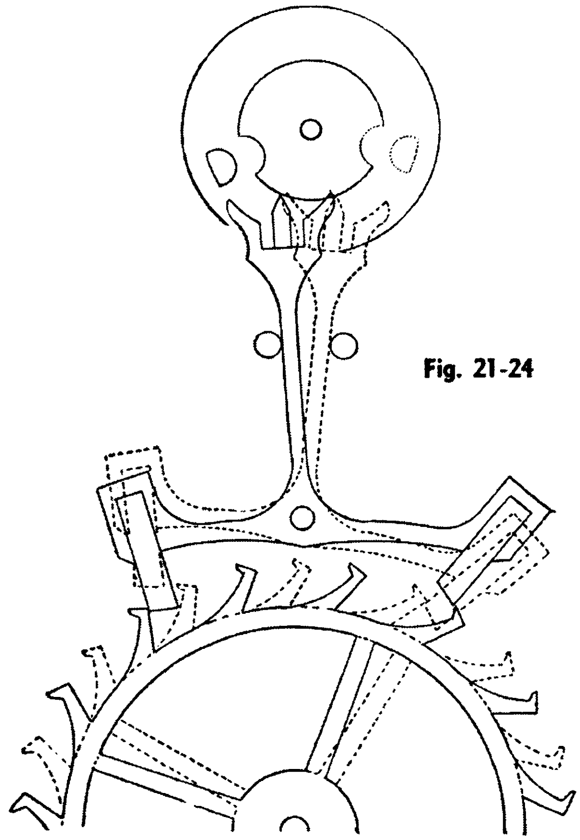


Fig. 21-24

Figure 21-23 shows a single roller escapement banked to drop. In the escape wheel, the full lines show tooth, **a**, of the escape wheel released from the receiving stone. The broken lines show tooth, **b**, after it has passed across the impulse face of the discharging stone, and tooth, **c**, has locked on the receiving stone. It will be observed that the fork lies against the bankings at both sides and that the guard pin contacts the roller at both sides also. This is called "Banked to Drop—No Shake—No Slide," which means that it is banked without either shake between the roller edge and guard pin or slide on either pallet stone.

Figure 21-24 shows the double roller escapement in the same condition as the single roller in figure 21-23. These last two figures show both fork and roller in two positions. Now turn to figure 21-25 which shows the fork in two positions and the roller in one. In this figure the fork, in full lines, is just about to embrace the roller jewel. The safety action which has been, until this instant, between the fork horn and the face of the roller jewel now ceases. In the fork, shown in dotted lines, the safety action is between the edge of the safety roller and guard pin.

Figure 21-26 shows a single roller and figure 21-27 a double roller. By comparing the two it will readily be seen why the single roller is more liable to allow the fork to go out of action than is the double roller. By comparing, in figure 21-26, the broken line **aa** which indicates the path of the guard pin with the broken line **bb**, which is the path it should take, it will be seen that it only requires a slight difference such as might arise from a pallet arbor with too much side shake, to allow the fork to go out of action. The roller is moving in the direction of the arrow and the fork should be at the right with its slot in position to receive the roller jewel. But in going out of action it has passed to the left. The roller jewel is arrested by coming in contact with the outside of the fork horn, and the watch immediately stops.

Now turn to figure 21-27. The two broken lines, **aa** and **bb** are in the same relation to the guard pin as they are in figure 21-26. Although the fork in figure 21-27 is thrown against the roller edge, it can not pass and the escapement is not unlocked. It therefore follows that a slight error which might cause a single roller escapement to go out of action might not seriously affect a double roller.

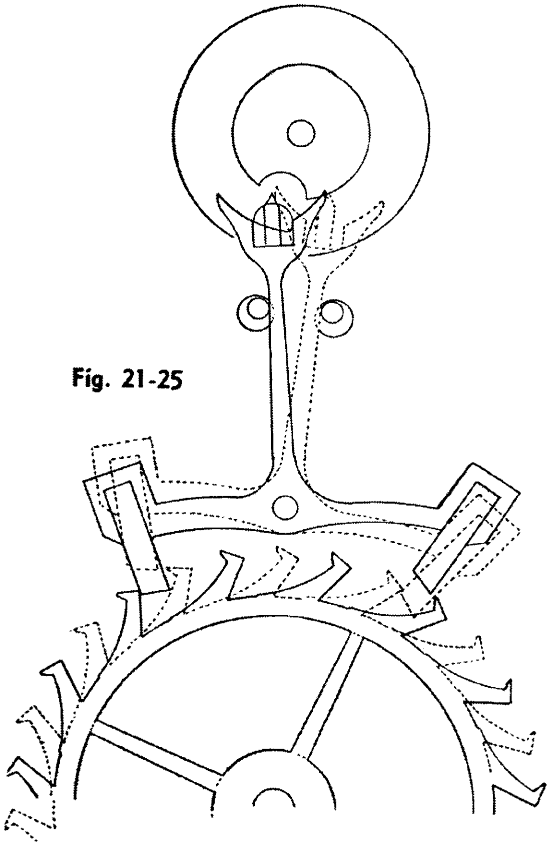


Fig. 21-25

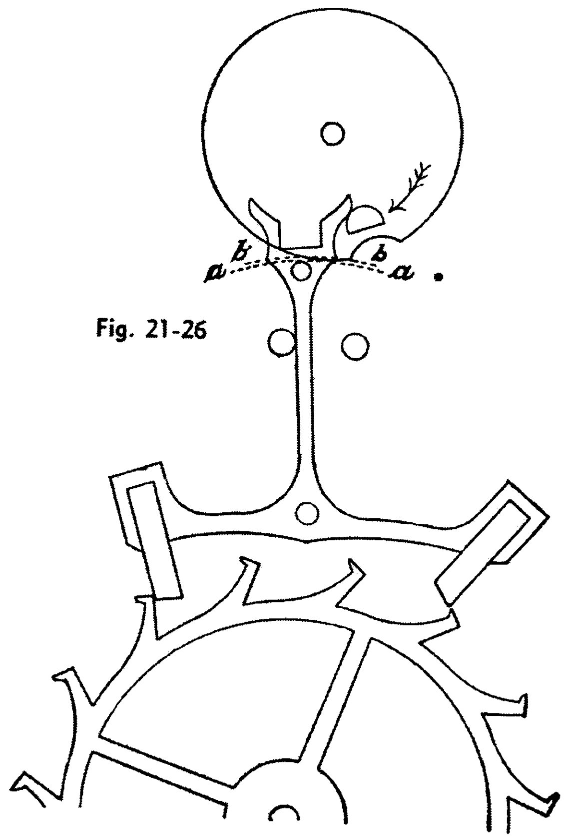


Fig. 21-26

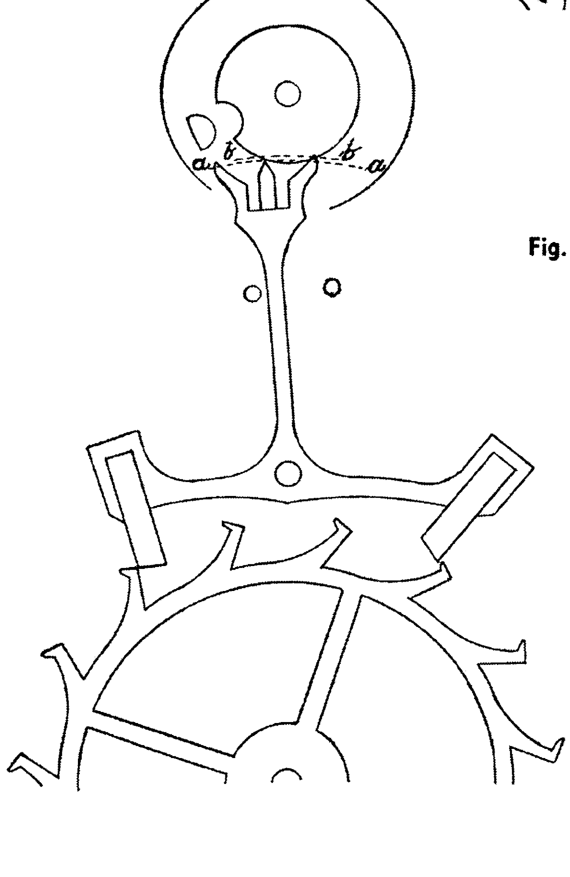


Fig. 21-27