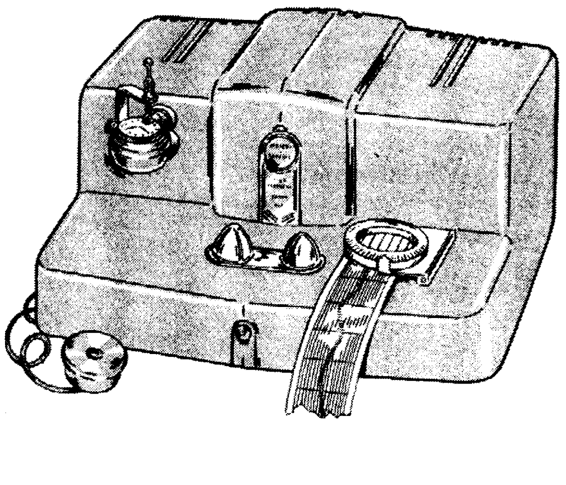
Master Watchmaking

MODERN SHOP METHODS



LESSON

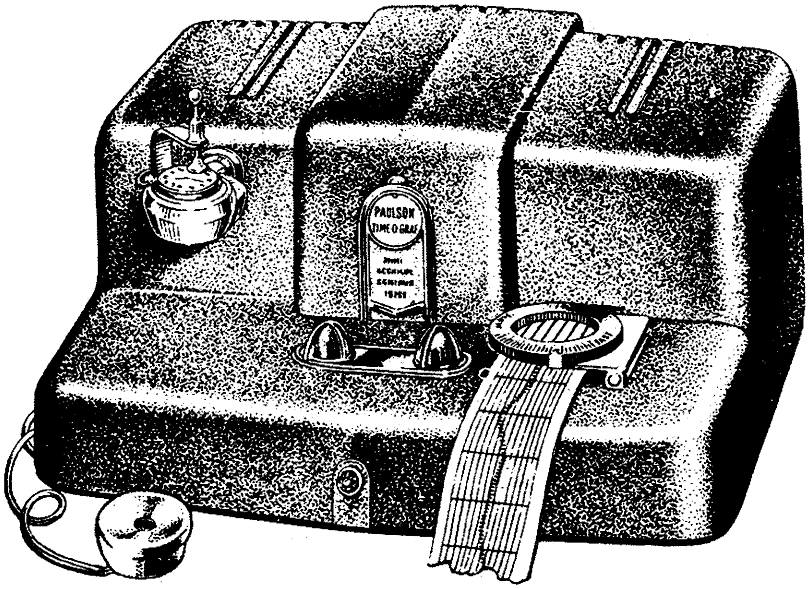
34

Electronic Timing Machines

(Time-O-Graph)

CHICAGO SCHOOL OF WATCHMAKING

Founded 1908 by THOMAS B. SWEAZEY



SEC. 585—Introduction

Every watchmaker, whether he be engaged in repair or manufacture, can do his work better and more efficiently if he has proper tools and uses them intelligently. The PAULSON TIME-O-GRAF is an electronic instrument which can be used to print on a paper tape a record of the performance of a watch; this record may be used to determine such factors as: rate, position errors, isochronal errors and faulty actions of the movement. TIME-O-GRAF cannot be used as a substitute for the skill and knowledge of watchmaking, but it can give a clear, accurate and rapidly obtained record of the actions of the watch under test and upon which watchmaker's skill and knowledge may apply.

In making this expertly designed machine only the finest of workmanship and materials have been used. Everything possible has been done to make it easy and convenient to set up and operate. But it is important to remember that this is a precision instrument and to take full advantage of its potentialities, you should know as much as possible about the machine.

You are urged, therefore, not only to make a thorough study of this lesson but to refer to it often.

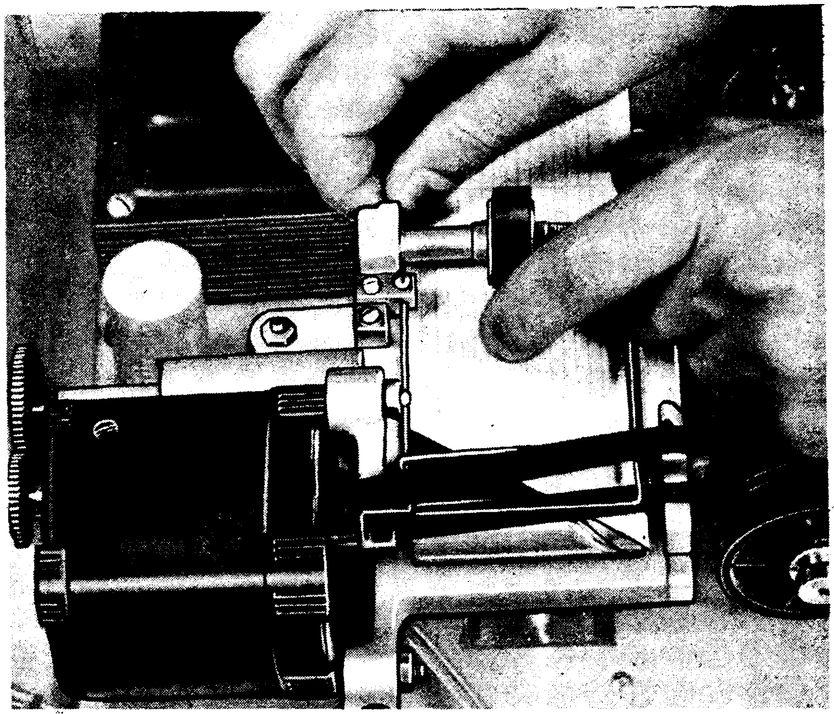


Fig. 34-1

SEC. 586—Threading the Printer Tape

Figure 34-1 shows the threading of the printer tape. Cut the end of the paper tape to about a 45 degree angle; place the roll on its roller in position and thread the end of the tape between the 3/32" diameter rod and the top surface of the cast aluminum printer frame.

DO NOT LIFT UP ON THE PRINTER BAR when threading the paper tape beneath the inked ribbon.

Connect the rubber covered cord to a source of 110-120 volt, 50-60 cycle alternating current and turn the right hand knob to the "ON" position and let the machine warm up for at least 30 seconds. Then, turn the knob to the "RECORD" position. As the machine then starts you will start the paper tape forward in between the rubber roller and the knurled driving roller. Let the motor feed it on through, and with a piece of pegwood guide the tip of the tape under the inked ribbon and over the spiral roller.

Let the machine run until the tip of the paper tape just extends beyond the inked ribbon, then turn the knob back to the "ON" position.

Remove the knob from its post and lower the cover of the machine into place.

Place both knobs on their respective posts.

Then, turn the right hand knob to the "RECORD" position, and as the paper tape feeds through, use a piece of pegwood and guide it through the window in the case and under the paper cutter bar.

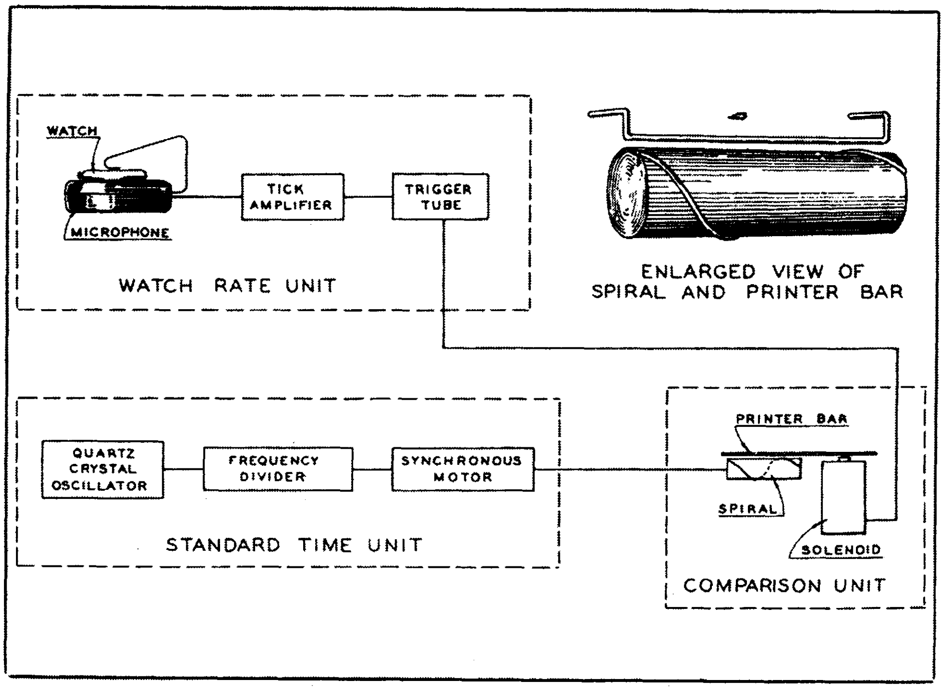
Place a watch under the clamp of the microphone with the watch crystal making contact with the metal button in the center of the microphone and with the right hand knob in the "Record" position, the printer tape should start to emerge. Turn the volume control about 2/3 of the way on and then the printer bar should pull down with an easily heard click with each tick of the watch.

SEC. 587—Construction and Theory

The TIME-O-GRAF is a time differentiating watch rate recorder. Its basic principle is the comparison of the rate of the watch under test with an accurately measured interval of time and the printing of this comparison on a paper tape so that the rate may be ascertained therefrom or may be obtained by reference to a calibrated dial.

IMPORTANT: It must be clearly understood by every watchmaker that any watch rate recorder will indicate the rate of the watch during the period of the test only, hence it is impossible to predict the full 24 hour rate of

Fig. 34-2



a watch from any test covering less than that amount.

The method by which the TIME-O-GRAF makes the comparison between the rate of the watch on test and the standard time is shown in Figure 34-2. The unit which furnishes the source of standard time consists of a quartz crystal controlled oscillator which generates a high-frequency voltage of exceptional stability and a frequency divider which divides this frequency to a value which permits it to be used to drive the synchronous motor of the comparison unit. The armature shaft of this motor, running at a speed of 2700 revolutions per minute or 45 revolutions per second, carries a metal drum which has a raised spiral on its surface.

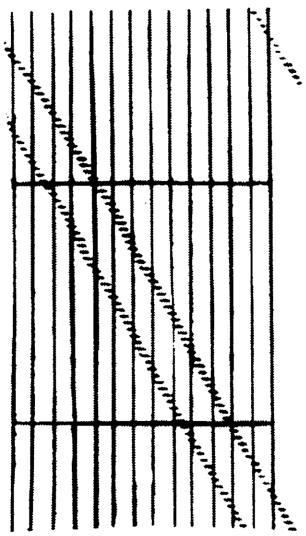
The watch rate unit consists of a microphone which picks up the tick of the watch under test, an amplifier which amplifies this tick, and a trigger tube which operates or "fires" once for each tick of the watch and energizes a solenoid in the comparison unit. This solenoid pulls a printer bar downward against an inked ribbon and a paper tape which rest lightly on the spiral previously mentioned. Inasmuch as the printer bar can strike the spiral at only one point, each stroke produces a dot on the tape, the location of the dot depending on which part of the spiral is under the printer bar at the moment of contact.

It can be seen that if the spiral is made to rotate at a constant rate of speed, the point at which the spiral and the printer bar make contact will move at a uniform rate across the tape. In the TIME-O-GRAF the spiral, which has a lead of two inches, is made to rotate at 45 revolutions per second which causes the point of contact to move from right to left across the tape at a rate of 90 inches per second. If each tick of the watch occurs EXACTLY one-fifth of a second later than the preceding one, the spiral will make exactly nine revolutions between ticks and each dot on the tape will fall on top of the last one. If, however, the watch is running slow, the spiral will turn slightly more than nine revolutions between ticks and each dot will fall to the left of the one preceding it. If the watch has a losing rate of 43 seconds per day, each tick will occur one ten-thousandth of a second later than it should, and consequently each dot on the tape will fall nine-thousandths of an inch to the left of the preceeding one. If provision is now made to advance the tape at a uniform rate, the dots will also progress along the long axis of the tape, forming a line thereon. In the TIME-O-GRAF this motion of the tape, which amounts to six inches per minute, is obtained by a reduction gear and friction roller driven by the same synchronous motor which drives the printed spiral.

Note that this line of dots may fall anywhere from the right side to the left side of the paper. Where it occurs depends entirely upon the time relationship between the motor spiral and the balance wheel in the watch. Thus, the location of the line (to the right or left side of the paper) is no indication of the rate of the watch.

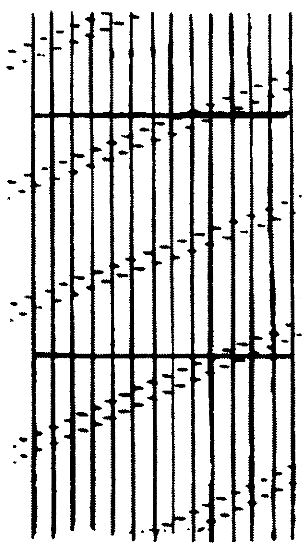
The rates of the watch and the actions of the escapement are determined by the slopes and variations in the line.

Hence, from the above, we see that if the watch is running slow the line of dots will slope to the left, as in figure 34-3, and if the watch is running fast the line of dots will slope to the right, as in figure 34-4.



Losing about 52" per day

Fig. 34-3



Gaining nearly 4' per day

Fig. 34-4

If one desires to calculate the rate of a watch directly from the line of dots on the tape, without using the Rotary Precision Dial, one may proceed as follows:—

Using the printed tape we find reference lines are printed on this tape, figure 34-5—one set spaced $1\frac{1}{2}$ inches apart and the other set spaced $\frac{1}{8}$ inch apart. The physical constants of the TIME-O-GRAF are so chosen that a rate of error of one second per day will cause the printed record to travel $\frac{1}{8}$ inch across the tape while traveling 12 inches along the tape. Thus a record which travels $\frac{1}{8}$ inch across the tape while traveling $1\frac{1}{2}$ inches along the tape indicates an error of 8 seconds per day. The rate may be calculated by the following formula:

$$R = \frac{A \times 96}{B}$$

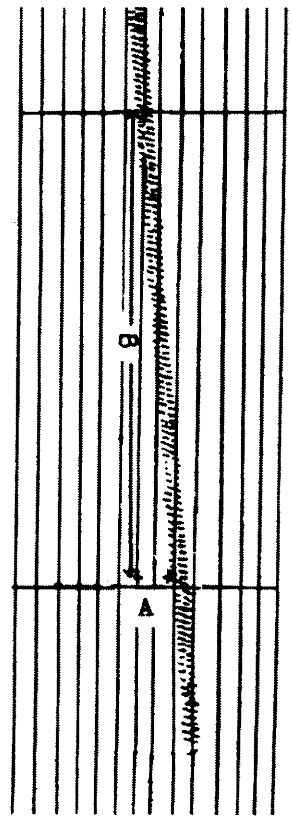


Fig. 34-5

Where **R** is the rate of the watch in seconds per day, **A** is the distance in inches which the record has travelled across the tape, while **B** is the distance in inches which the record has travelled along the tape.

SEC. 588—Crystal Control Assures Accuracy

Crystal Control: Nothing in the wide world has the accuracy of the quartz crystal control, your absolutely accurate, dependable time comparison. To depend upon anything but accurate time comparison is time wasted.

The U. S. Government uses crystal control for accuracy. The U. S. Bureau of Standards can tell you of the accuracy of crystal control. The world renowned clock at Greenwich, London, England, universally famous for continued accuracy, is under Crystal Control.

The Crystal Control is "natures own," scientifically ground and set; natures vibrations "like natures own" keeps in step with the stars for accuracy.

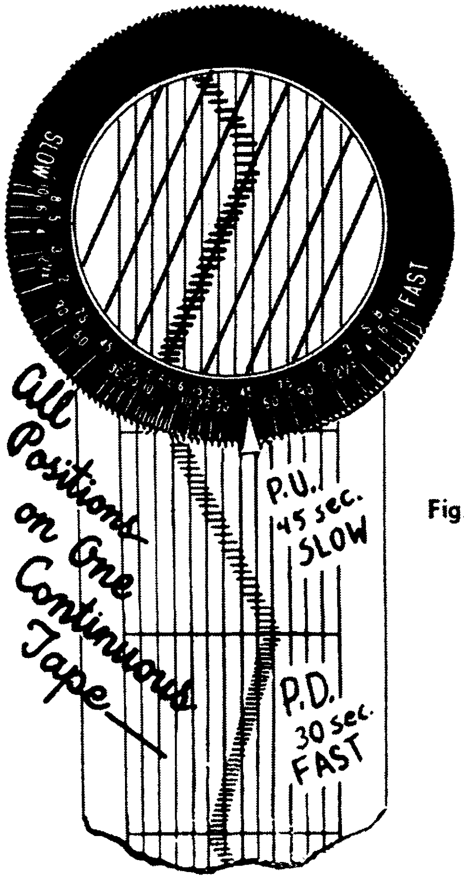


Fig. 34-6

SEC. 589—Instant Reading of Rates

The ROTARY PRECISION DIAL, under which the tape moves is calibrated in seconds per day, gain or loss, and enables the user to read the rate directly instead of having to measure the angle of the printed line and calculate the rate.

The rotary precision dial on the TIME-O-GRAF is illustrated in figure 34-6. It consists of seven parallel lines and is turned so that these parallel lines become parallel to the angle made by the line of dots issuing from the machine. Then the second marks on the dial show instantly the exact number of seconds per day, gain or loss. When using the rotary dial exclusively to ascertain the rates, it is not necessary to use the calibrated paper tape inasmuch as ordinary adding machine paper tape will suffice for the printed record under these circumstances.

SEC. 590—Operation

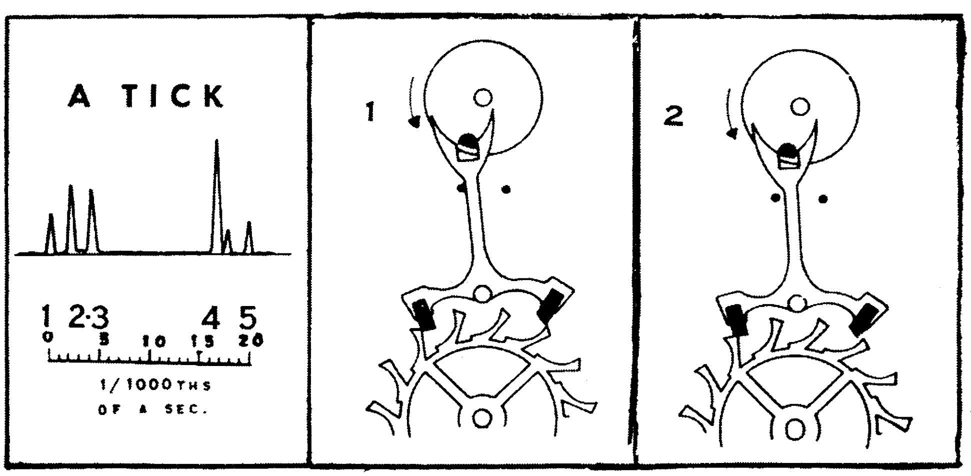
To use the TIME-O-GRAF intelligently it is first necessary to understand the sequence of sounds produced by the escapement in a watch. We know that the sounds in a watch which we call the "tick" and the "tock" occur as the result of the escapement action. These sounds are caused by the parts of the escapement striking or rubbing one another. An analysis of the escapement action will clearly show that not one but several sound impulses occur each time the escapement action ("tick" or "tock") occurs.

A watch "TICK" consists primarily of five major sounds. These sounds all occur within about 1/200th of a second. Figure 34-7 is a graph showing the sequence of these sounds, the height of the curve showing their comparative volumes.

The first sound, though not the loudest one, occurs when the roller jewel comes around and strikes the fork slot as in figure 34-7, No. 1.

The next sounds we hear are Nos. 2 & 3. When we have an escapement model and move the parts slowly, apparently the escape wheel tooth begins pushing on the pallet stone face

Fig. 34-7



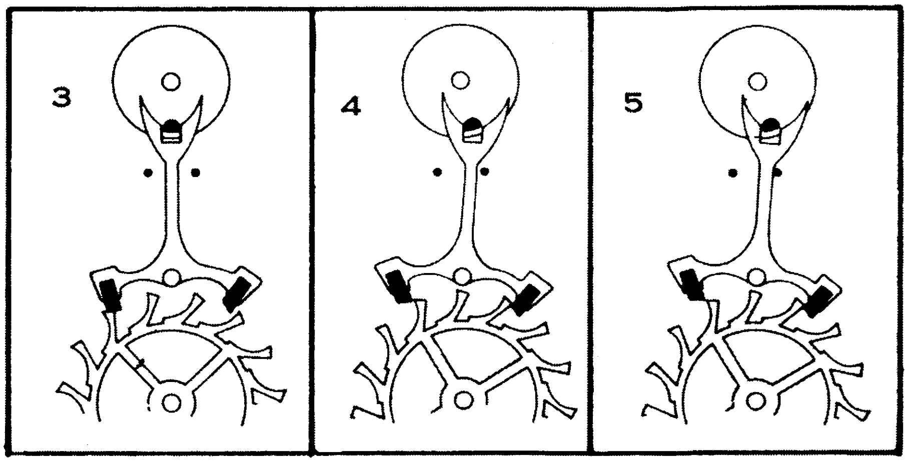


Fig. 34-7 (Cont.)

immediately after the unlocking action causing the fork slot to strike the roller jewel and push on it. But in actual practice it does not work that way because the pallet stone, having a certain amount of draw, forces the escape wheel to move backward a slight amount when it is withdrawn from the locking face of the tooth, and, inasmuch as the pallet stone is practically jerked out of that position (due to the speed at which the roller jewel is traveling at the time), it throws the escape wheel backwards slightly. Then, by the time the escape wheel overcomes its inertia and starts forward again the toe of the tooth may strike the pallet stone perhaps a third of the way down its impulse face, the impulse action actually beginning at that instant. The loudest sound is depicted in No. 4 when the escape wheel tooth drops onto the locking face of the other pallet stone. There is a slight rebound to that which is followed by the last sound as depicted in No. 5 when the lever falls against the banking pin.

For an accurate watch rate record it is necessary for the printed dot to come from a clearly defined part of the "Tick." The most exact point on a watch "Tick" and the most clearly defined point is the point designated in No. 1.

The trigger tube selects the part of the tick from which the dot is printed. The exact part of the tick that fires the trigger tube depends upon the loudness of the tick. If the trigger tube does not fire with the first (No. 1) part of the tick, then it will fire with the next part that is sufficiently loud to operate the tube. Since the ticks of different watches vary in loudness, it becomes necessary to adjust the volume control on the machine so that it will pick up the No. 1 sound at all times yet not have the volume on full enough to pick up unnecessary sounds as the picking up of unnecessary sounds only serves to confuse the action of the trigger tube, likewise the printed record. Therefore, if the machine is to be used for diagnostic purposes, the picking up of the No. 1 sound will give a continuous record from which a quite complete diagnosis may be made.

We then take this continuous record and by analysing the position of the dots, the lines they form, etc., consecutively and relatively, we are able to determine the condition of the escapement in detail and the rate of the watch throughout as long a run as we may desire.

SEC. 591—Diagnosis of the Printed Record

The methods of determining the overall rates of the watch under test have been described in Section 587 and Section 589.

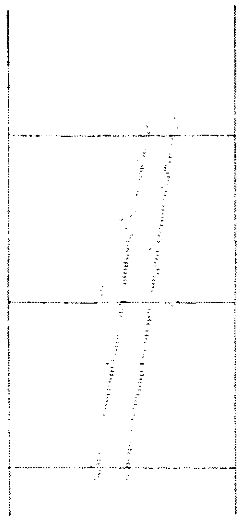
Now we present a few notations on the readings and diagnoses of irregularities found in the dots on the tape.

SEC. 592—Examples of Records

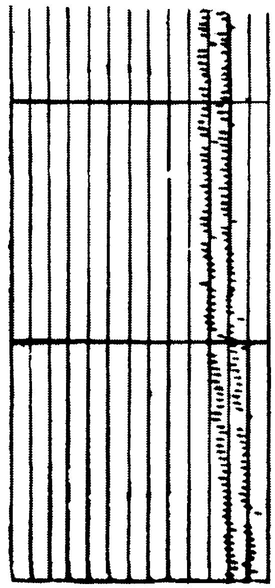
Before submitting any watch to the timing machine for analysis, the watchmaker should have made certain that the watch is in good mechanical order throughout.

Many defects may be heard in the ear phone and such should be corrected before any attempt is made to obtain a good printed record.

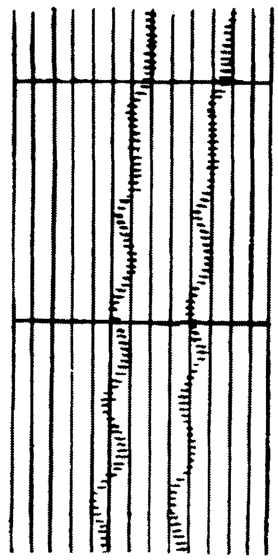
Pivots should be in good condition and jewels fitted correctly, otherwise the printed pattern will be irregular. The end-shake of the balance especially must be correct in the smaller wrist watches and the escapement



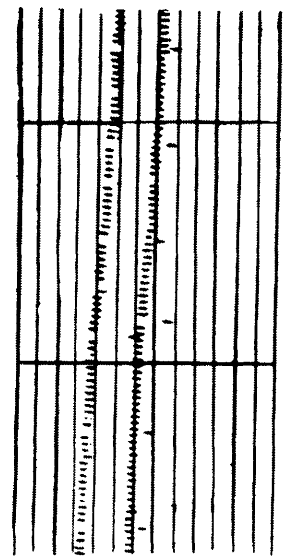
Loose Roller Jewel
Fig. 34-8



Loose Pallet Stones
Fig. 34-9



Escape Wheel Out of Round
Fig. 34-10



Bent Tooth in Escape Wheel
Fig. 34-11

PROPERLY oiled in order to obtain a readable record.

A loose roller jewel may be detected by visual inspection, but at times one may be so slightly loose as to have escaped notice.

Figure 34-8 is the record made by a 11¼ ligne watch with a roller jewel very slightly loose.

Loose pallet stones may also usually be detected by a visual inspection, yet one often finds that pallet stones which are apparently tight (visually) will show to be loose, giving a record similar to figure 34-9. A small amount of stone cement is the remedy.

Quite often we will find watches about 6¾ ligne in size that apparently keep time, but which refuse to make a legible record on the TIME-O-GRAF. An examination of many of these will disclose a hairspring which is out of flat and a balance staff which has too much endshake. The out of flat hairspring causes the balance staff to dance up and down or endwise in its pivot holes and the timing machine will pick up the sounds of that in preference to the sound of the roller jewel striking the fork slot (as in figure 34-7, No. 1). The obvious remedy is to true the hairspring and eliminate the surplus end-shake in the balance staff.

The left hand line of dots is usually the record of the action caused by the receiving pallet stone—likewise the right hand line of dots is usually the record of the action caused by the discharging pallet stone.

The escape wheel in the ordinary 18,000 beat watch makes one revolution in six seconds, or ten revolutions per minute. Hence, errors in the escape wheel may be easily recognized by the fact that they should repeat themselves every six seconds, or ten times per minute (ten times per six inches of paper travel). The line caused by an escape wheel which is out of round due to its either being bent itself or having a bent pivot will be curved, a complete cycle showing every six seconds. (Figure 34-10) A bent or damaged tooth in an escape wheel will show a single displaced marked similar to that shown in Figure 34-11, occurring every six seconds. A damaged leaf in the escape pinion will make a record showing an error of much longer duration, the duration of the error being nearly one second in length, and it also repeating every six seconds.

A bent fourth wheel or a fourth wheel out of round will show as an error every 60 seconds or every minute. This can be found only on a machine that runs for a full minute or more, such as the TIME-O-GRAF.

Presume now that we have a defect that occurs once in every 60 seconds. If it be curved, similar to that in figure 34-12, we would assume that the fourth wheel or one of its pivots was bent, as the record clearly shows it to be out of round. If, instead of the record showing a clearly cut curve, it shows defects of moderate time duration, spaced at intervals of 60 seconds apart, we may then examine further. When

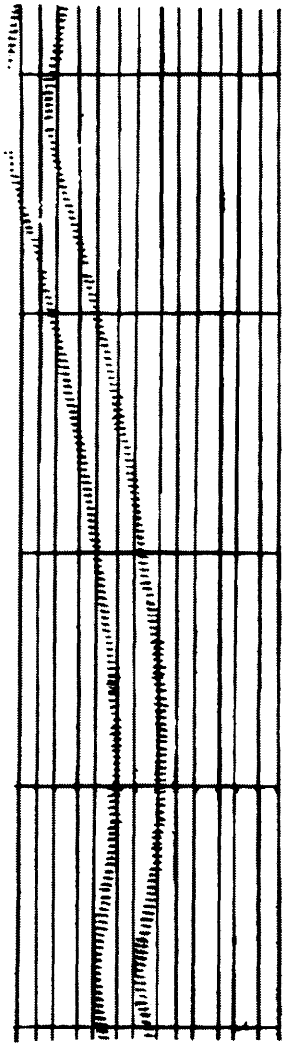


Fig. 34-12

Train Wheel
Out of Round

the length of the record of the defect in a fourth wheel is about $\frac{1}{2}$ inch of paper travel, we could assume that it was a defective tooth in the fourth wheel. If the length of the defect consumed about 10 seconds of travel of the paper, we would say that it was a defective leaf in the fourth wheel pinion. That is easily understood as the pinion leaf requires a longer time to pass than does a single wheel tooth.

Likewise, defects in the center seconds mechanism of chronographs are easily located with the TIME-O-GRAF. For example, we may take a chronograph and with the center seconds hand in its neutral or zero position, bring the watch movement to time. We then push the plunger which starts the center seconds hand into action and observe if the watch records any variation in rate. If so, we know there is some defect in the action of the center seconds hand mechanism when it is in action. We then may push the plunger which stops the center seconds hand, and any change in the rate of the watch at this point indicates a defect in the braking or locking mechanism of the center seconds hand.

MAGNETISM never affects two watches in the same manner. Hence, we cannot present any "typical" record showing magnetism. Watchmakers are supposed to look for magnetism in a watch with their compass.

PRESSURE applied to the movement, or to the train bridges of many of these thin watches will cause a noticeable variation in the rate of the watch.

We presume that the watchmaker has properly cleaned and oiled the mainspring, replacing it if necessary; but if he has not, he cannot be assured of a good rating of the watch. A dry mainspring will seize, then release, giving an uneven delivery of power to the train wheels. (See figure 34-13). CAUTION: A mainspring that is slightly too wide for the barrel will rub the barrel or the cap, and cause an irregular rating of the watch.

If the movement of the watch shows a record as keeping time, and the hands of the watch

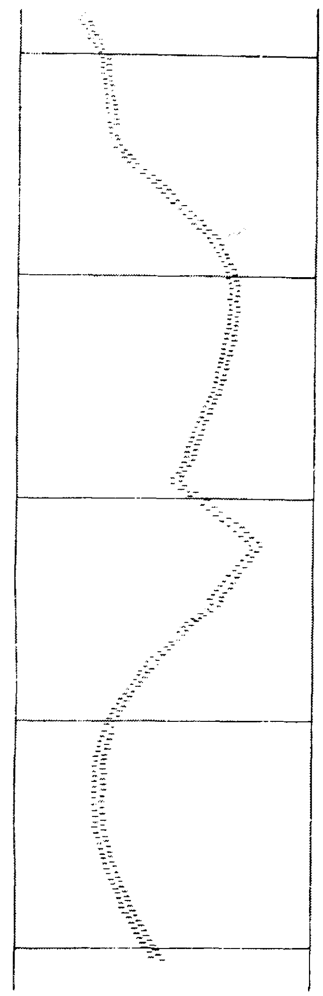


Fig. 34-13

Uneven Power
Caused By a
Dry Mainspring

indicate a loss of time,—look well to the canon pinion friction, and see that the setting bridges do not bind on either the minute wheel or other dial wheels. Also see that the minute hand does not bind onto the hour hand, and the pipes do not rub the holes in the dial in any position.

SEC. 593—Putting an Escapement in "Beat"

The general rule for putting an escapement "in beat" is to so place the hairspring collet that when the escapement is at rest, the roller jewel lies on the line of centers. See figures 34-14 and 34-15.

To be sure that we have it in beat, we release the power from the train, even to the extent of removing the ratchet wheel. Then we carefully adjust the position of the hairspring collet so that when the escape wheel is moved forward, the toe of the escape wheel tooth will drop onto the receiving pallet stone about the center of its impulse face, (See figure 34-14), and likewise, the toe of the escape wheel tooth will drop onto the discharging pallet about the center of its impulse face or a little beyond. See figure 34-15. When that condition exists the escapement may be said to be very closely "in beat." Thus, when the hairspring collet is adjusted to that position, if we "bank the escapement to drop," (the escapement being otherwise in mechanically good order), we will find that the TIME-O-GRAF will give us a record composed of apparently almost one line, the two lines being practically superimposed upon each other. See figure 34-16.

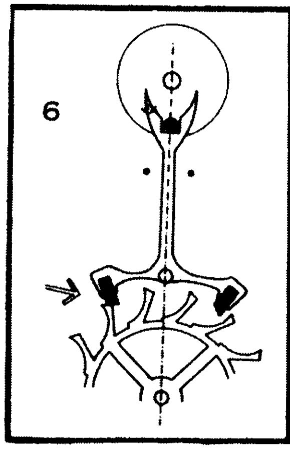


Fig. 34-14

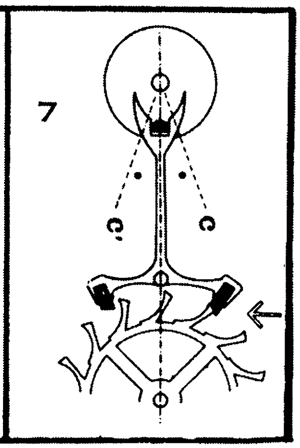


Fig. 34-15

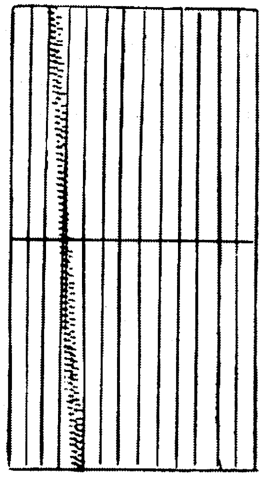


Fig. 34-16

SEC. 594—The "Double" Line

PLEASE NOTE: In practically all small Swiss watches and in many other watches due to variations in escapement design, it is practically impossible to obtain a reading of a "single line" as in figure 34-16.

The workman must be his own judge as to when the watch is in "passable" condition.

A double line on the record may be caused by numerous things, including the improper setting of a pallet stone, loosely fitting pivots in the members of the escapment, as well as the improper setting of the hairspring collet.

However in an escapement wherein the pallets are properly set, the roller jewel properly set and the escapement otherwise in good order, a double line indicates that the roller jewel is striking the fork slot on one side at a greater distance from the line of centers than on the other side. Turn to Escapement drawing No. 1, figure 34-7. If we move a banking pin out a little for example, the one on the left hand side of the figure, it will allow the lever to lay over a little farther to the left which means that the roller jewel will strike the fork slot on that side, which in this case is the receiving side, a little sooner or if you please, a little farther from the line of centers on that side which causes the machine to record the No. 1 sound on that side in a new position or sooner as shown by the appearance of the line of dots a bit away from their previous position. Following is an example of how this may apply:—

In figure 34-17 we have the record of a 16 size Elgin first with the escapement properly adjusted. At "A" we opened the banking pin which controls the slide on the receiving stone.

Here you will note the immediate appearance of the line of dots made by the receiving side moving over to a new position. Coincident with this you will note that the increment of the slide on the receiving stone of an escapement tends to slow down the rate of a watch slightly. Returning the banking pin to its proper position at "B," the line of dots produced by the receiving side return to their former position, and the watch resumes its former rate. Likewise, we may open the banking pin which controls the slide on the discharging pallet stone. This will cause the line of dots made by the discharging stone to assume a new position as at "C." Here we note that giving the discharge stone more slide, we tend to speed the rate of the watch slightly. Returning this banking pin again to its proper position, the line of dots controlled by the discharging side return to their former position, and the rate of the watch again returns to its former rate as at "D."

It is desirable to bring the two lines as closely together as possible with the slide adjusted to a minimum with safety on both sides.

SEC. 595—Poising and Adjusting

Much has been written in the past years on the matter of poising the balance wheel in a watch, and great theories have been expounded on the subject.

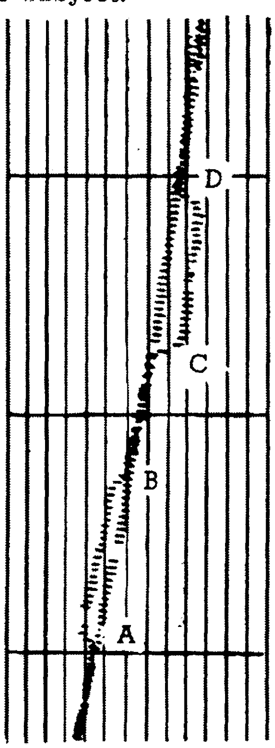


Fig. 34-17

The great majority of these are well founded, but one notable fact becomes increasingly evident: many textbooks, yes, even instructors in watchmaking, do not agree on even the fundamentals of hairspring work.

Not until the advent of the TIME-O-GRAF with its continuous tape with instant reading have we been able to solve these problems in a practical manner.

The RATE of a balance can only be changed by some force which gives an impulse tending to turn or retard its turning one way or the other.

When the balance is at rest and the hairspring idle, we may say that it is in the NEUTRAL POSITION.

The FUNDAMENTAL RULE on rates is: A push toward the neutral point speeds it up; a push away from the neutral point slows it down. This is true for either direction of the balance swing.

Let us see how this fundamental rule shows the effects of a balance which is out of poise. (See figure 34-18). If the heavy part of the balance is at the bottom in the neutral position, and the motion is less than one turn, the push of the heavy point is always toward the neutral point making the watch gain. Conversely, if the heavy part of the balance is at the top in a neutral position, and the motion is less than one turn, the push of the heavy point is always from the neutral point making the watch lose.

If the heavy point is at the side, the amount of gain and the amount of loss may counteract each other.

In figure 34-18 the balance is making a swing of over one full turn. The heavy point in going up from Z to the top on either side causes a gain, but in going beyond the top to X or Y the push of the weight is away from the neutral point and causes a loss. One might think that as in the figure, as the upswing from Z to the top of greater length than the swing from the top to either X or Y, the gain would be greater than the loss. It does not work out that way, for the travel from the top to either X or Y is nearer the end of the swing and errors which show that near the end of a swing of a balance are far more effective than errors near the middle of the swing. Mathematicians have shown that if the arc from the top to X and from the top to Y are each 40 degrees, and the heavy point being at Z, the loss from the top to X will offset the gain from Z to the top. Hence, for a swing of

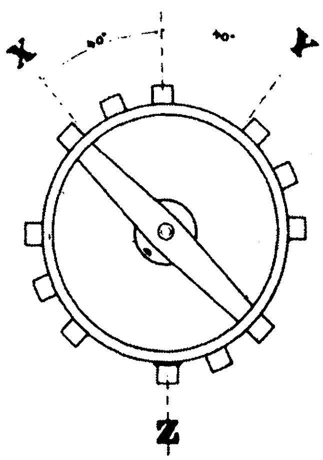


Fig. 34-18

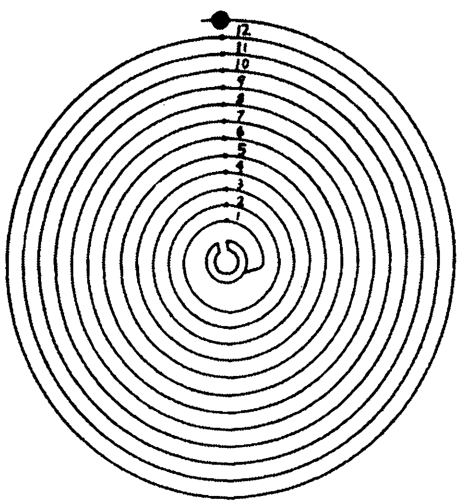


Fig. 34-19

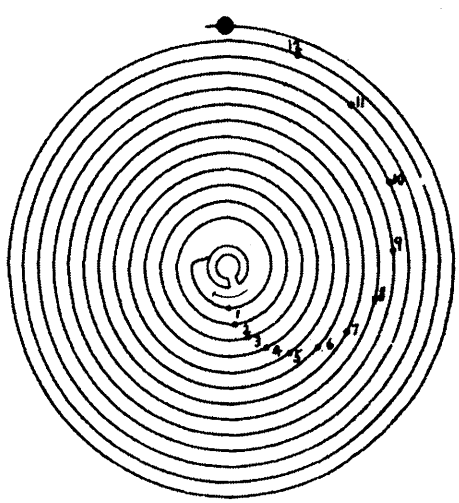


Fig. 34-20

220 degrees on a side, a poise error in the spot indicated will not affect the rate. However, should the arc of swing vary, either more or less, the poise error will show itself causing the rate to vary in turn.

Many watchmakers accept the statement that all watches, even those with an overcoil hairspring, have what they call a "natural error" of losing some 20 seconds per day, in some one of the vertical positions, which one it may be depends on the position of the pinning point of the hairspring to the collet.

There is nothing mysterious or occult about the workings of a watch or adjusting it. There is no such thing as an inexplainable "Natural Error." There is a definite reason for any and all errors and combinations of errors.

We may poise a balance wheel as carefully as we please on the poising tool and oft times we put it in the watch and the watch behaves as though it were out of poise. True, the fact that we have poised the wheel only, does not mean that we have poised the wheel with all its accessories, some of which move in whole or in part with the balance in the watch. We all know that we poise the wheel, and after that we apply the hairspring to it. In figure 34-19 we have a hairspring at rest with 12 little dots on the coils. Notice the dots are in a straight line. When that hairspring collet is turned a half turn, as it must when the balance carries it, notice the new position of the dots, and suppose the collet is turned a half turn in the opposite direction, the dots would arrange themselves in a similar pattern on the opposite side.

What occurs there, as you will notice, is that an unpoised mass, namely about half of the inner terminal of the hairspring plus certain portions of the succeeding hairspring coils, has been added to that balance staff. In other words, we have introduced and added to that balance an unpoised mass of material which is simply, as the balance moves to and fro, waggling back and forth.

In connection with this, please bear in mind that your hairspring must be true in the round and in the flat. The least error in the inner coil of the hairspring throws the entire timing of a watch into a condition where it is almost impossible to adjust. The hairspring must be

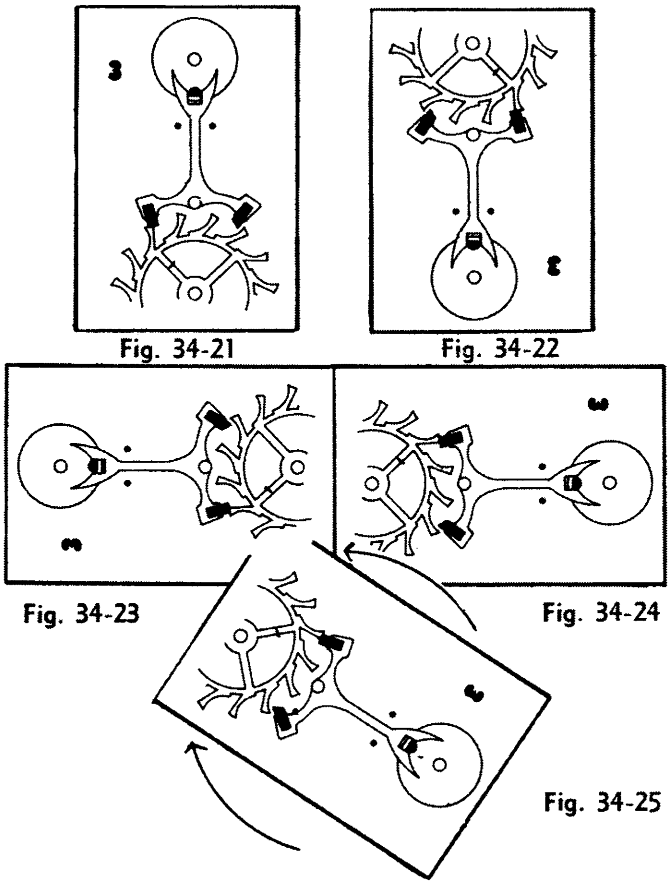


Fig. 34-21

Fig. 34-22

Fig. 34-23

Fig. 34-24

Fig. 34-25

true. Yes, the rates of a watch can be altered by tampering with the outer coil of the hairspring before or after it passes through the regulator pins, but inasmuch as the watch factories themselves do not agree on the proper shape for an overcoil, we shall not set forth any definite form that it should take. You can raise or lower the outer coil of a hairspring with the point of a tweezer, screw driver, tooth pick or anything else, call that operation anything you please, but if you adjust the outer coil of the hairspring in accordance with the well known rules of isochronism, it cannot be improved upon by any new tricks or methods.

Also theorists will tell us that the center of gravity of the hairspring shifts from side to side, up and down, or through any intervening angle, depending upon the position of the watch, and the shift of that center of gravity will affect the timekeeping, True, but it does so in an infinitesimal manner. Likewise the "sag" of a hairspring has but a very slight practical affect on the timekeeping. Even the unpoised pallet fork may introduce a slight position error.

The pallet fork may be considered as being practically "in poise" when the assembly finds itself in the positions depicted in figures 34-21 and 34-22. It is definitely out of poise in the positions depicted in figures 34-23 and 34-24. In the position shown in figure 34-23 the weight of the lever adds to or detracts from the power delivered to the roller jewel, depending on whether it is moving upwards (against the force of gravity) or downwards (being accelerated by the force of gravity). NOTE that when the watch is turned 180 degrees, so that we find the lever in the position as depicted in figure 34-24, the conditions described in figure 34-23, as to power delivered are exactly reversed. Concurrently, we must bear in mind that in practical usage, the lever finds itself in every conceivable angular position (figure 34-25) between the above described positions, hence, the "out of poise" element contributed by it, has every conceivable variation with positions.

Sometimes these small variations or errors will tend to offset each other, and sometimes they compound.

Thus we see that poising a balance wheel on the poising tool, while quite necessary, only suffices to place that one unit of the escapement in a condition which may be described as "static poise." That is quite insufficient—as it is imperative, for good timekeeping, that we consider the cumulative effects of the additional elements of the escapement. In other words, we must bring this entire "mobile unit," and by "mobile unit" we mean the completely assembled and running escapement, with its accumulated plus and minus errors—we must bring this entire "mobile unit" into a condition that shows it to be in poise WHILE RUNNING.

We can do this only with the use of the TIME-O-GRAF, as on it we can observe the entire accumulation, summation or whatever you wish to call it, continuously from one position to another, of all these infinitesimal errors, and correct them in one simple gesture.

First, we know that if we have a balance with a good motion, a motion with an arc of (See figure 34-18) over 220 degrees on a side, it will be very easy to detect the heavy side of the balance by locating the position of the watch when it has the greatest loss of time. We place the watch in the microphone of the TIME-O-GRAF pendant up, and rotate the watch slowly while the machine is running. The TIME-O-

GRAF immediately tells us on the continuous tape which position that watch is in when it has the slowest rate. We know that in that position, were the balance to be at rest, the heavy side of the balance assembly would be down. Your attention is called to the fact that when you rotate that running watch in the microphone of the timing machine, you have found the heavy side of the entire mobile unit, that is, of the balance, hairspring, all the other cumulative errors, some of which are very slight. However, you have absolutely and correctly located the heavy side of the mobile unit simply, effectively and without delay. This is the only method available today for the watchmaker to make a poise test on a running watch so that he may know at once where to make the necessary adjustments. Suggestion: If the watch has an over all losing rate, remove a little from the heavy side of the balance, or if it has an over all gaining rate, weight may be added to the lighter side. By these means in a very short time you can take a watch that is in good mechanical order and bring all of your vertical positions up to within a variation of less than 3 seconds in 24 hours in a good grade of pocket watch.

To summarize: The rates of a watch in the vertical positions can be adjusted very closely and rapidly by making use of the TIME-O-GRAF to determine the poise errors.

SEC. 596—Tapes from Odd Beat Movements

The watchmaker will occasionally encounter a watch beating other than 18,000 beats per hour (five beats per second).

Herewith is a list giving the beat of some of the currently found odd beat watches.

BEATS PER HOUR

Agassiz, 8PCV	20,222
Agassiz, PCV, AO, Z	20,944
Agassiz, 8AC	21,600
Audemars, 8'''	21,000
Concord 5½''', 7¾''', and "R. Cart"	19,800
Elgin, "Slow Train"	16,200
Elgin, 26/0	19,800
Gruen, some of the 124, 125, 176, 177	19,440
Gruen, 151	19,332
Gruen, 455, 457, 459, 465, 467, 469	19,800
Gruen, 106, 107, 109, 130, 133, 137, 139, 155, 159, 161, 169, 181, 183, 306, 307, 327, 328, 329, 331, 520	20,160
Gruen, 105, 333, 840, 841, 845, 857	20,222
Gruen, 305, 837, 839, 847, 863	20,940
Haas, 8''' round	20,222
Huguenin, 5½'''	20,160
Meylan, 7''' and 8'''	20,944
Meylan, 8'''	20,222
Nardin, 7'''	20,944
Omega, 11.5	21,300
Omega, 13.5 and 17.8	21,600
Omega, 30.10	19,800
Patek-Phillippe, 4'''	21,000
Touchon, 4'''	21,000
Vacheron & Constantin, 7''' oval	20,944
Waltham, 18 size, old models	14,400
Waltham, 18 and 16 and 14 size, "Slow Train"	16,200
Waltham, "400"	21,600

All of these odd beat watches can be rated on the TIME-O-GRAF, although in most cases the record for a watch with a zero rate will not consist of a single line, nor will it run straight down the tape.

In determining the pattern made by any odd beat watch, two constants of the machine must be known. These are the scanning speed and the rate of paper feed. The motor in the TIME-O-GRAF runs at EXACTLY 2700 revolutions per minute or, 45 revolutions per second. The lead on the printing spiral is exactly 2 inches. Thus, the scanning speed is exactly 45 r.p.sec. x 2" which equals 90 inches per second. The paper speed is exactly 6" per minute.

Some of the very early Roxbury made Walthams were 14,400 beats per hour, or 4 beats per second.

In this case the revolutions of the spiral per beat are 45/4, or 11¼ revolutions.

As ¼ revolution of the spiral equals one half an inch of scanning speed, this watch when running on time will print four lines of dots one half an inch apart, straight down the tape. Figure 34-26.

If the escapement is slightly out of beat, the record will appear somewhat like figure 34-27, the lines being "paired off."

Some of the early "Slow Train" Elgins and Walthams employed a 63 tooth fourth wheel and a 7 leaf escape wheel pinion, giving these watches a beat of 16,200 per hour, or 4½ beats per second.

In this case the revolutions of the spiral per beat are 45/4½, or 10 revolutions.

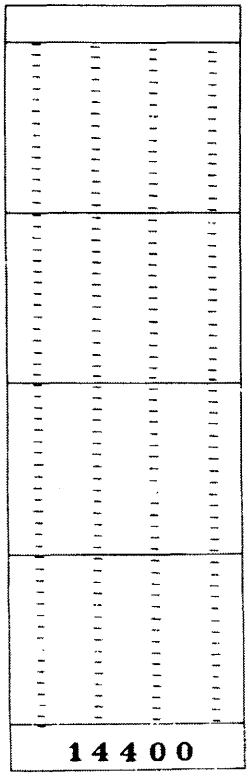


Fig. 34-26
A 14,400 Beat

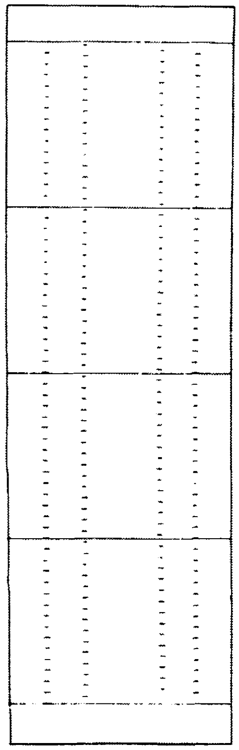
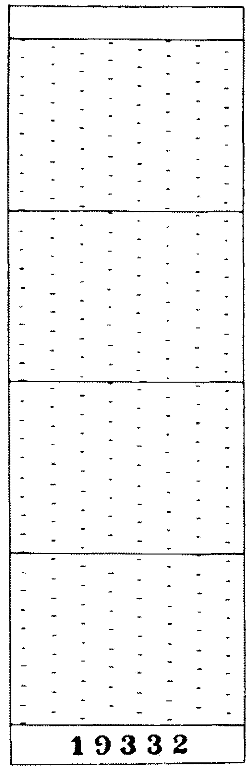
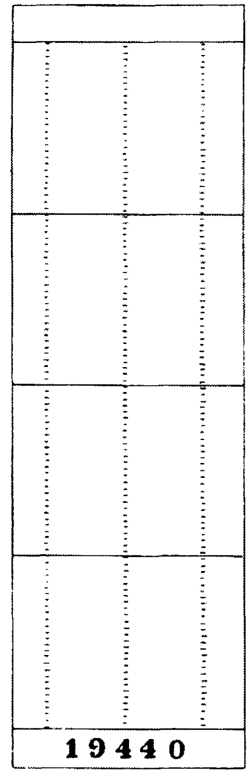


Fig. 34-27
A 14,000 Beat, when "Out of Beat"



A 19,332 Beat
Fig. 34-28



A 19,440 Beat
Fig. 34-29

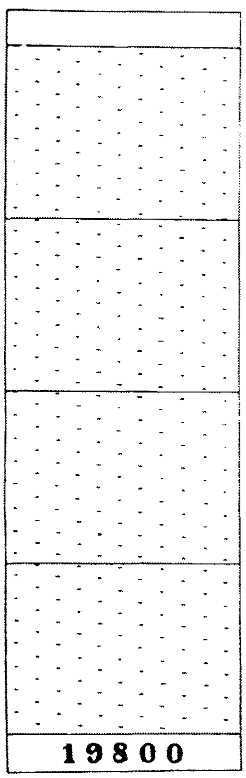


Fig. 34-30
A 19,800 Beat

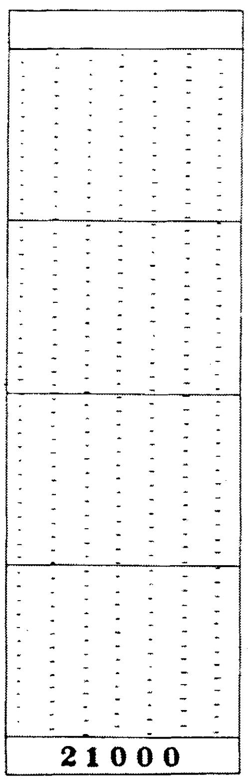


Fig. 34-31
A 21,000 Beat

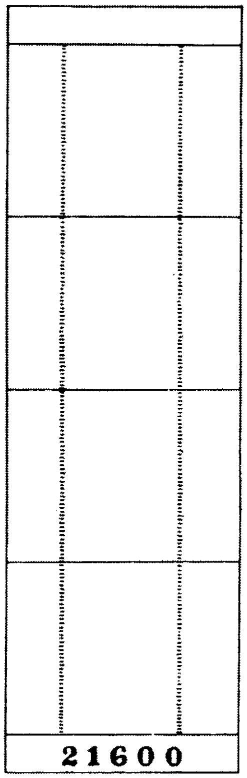
Thus, this 16,200 beat watch when running on time will print exactly in line straight down the tape very similar to the line made by an 18,000 beat.

Similarly, we find that the watches having 19,332 beats per hour, allow the spiral to make 8⅜ revolutions per beat, thus, these 19,332 beat watches when running on time will print 8 lines of dots straight down the tape, the lines being ¼ inch apart, figure 34-28.

The 19,440 beat watches allow the spiral to make 8-1/3 turns per beat, thus, the 19,440 beat watches when running on time will print three lines of dots straight down the tape 2/3 of an inch apart, figure 34-29.

The 19,800 beat watch will allow the spiral to make 8-2/11 turns per beat, thus the 19,800 beat watches when running on time will print 11 lines straight down the tape 2/11 of an inch apart, but it is rather difficult, on account of the scattered position of the dots comprising these lines, to arrive at a quick diagnosis of the watch, unless the watch is almost on time. The appearance of the correct record made by one of these watches is shown in figure 34-30.

The 21,000 beat watches, similarly, when running on time, will make a record of 7 lines straight down the tape, figure 34-31.

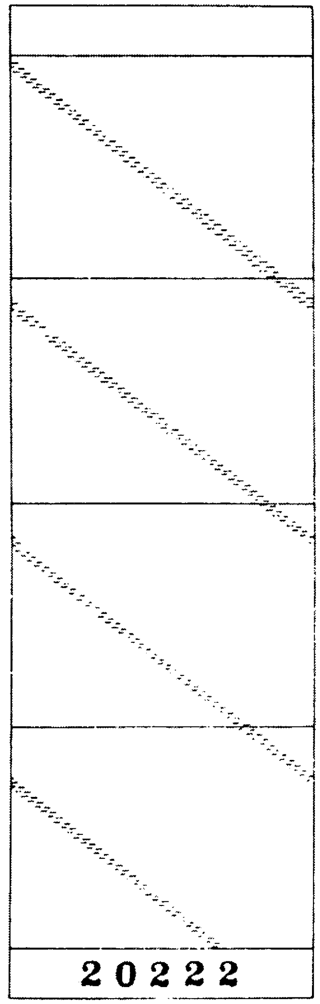


A 21,600 Beat

Fig. 34-32

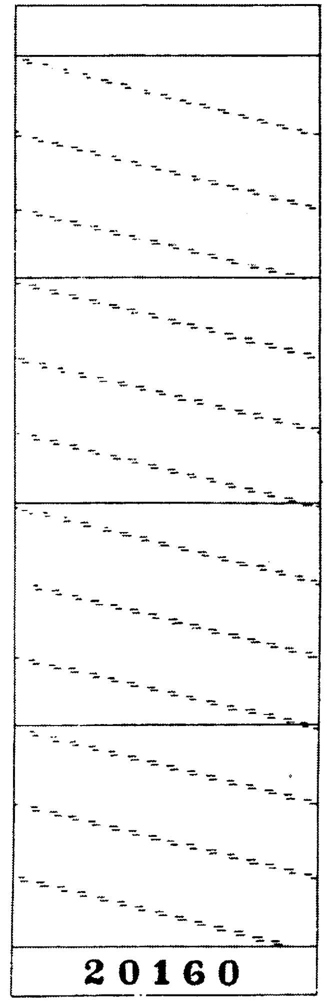
The 21,600 beat watches, similarly, when running on time, will make a record of two lines one inch apart, straight down the tape, figure 34-32.

Now, for those who like mathematics, let us look at a watch having 20,222 beats per hour, which is 5.61720555 per second. We see immediately that this watch will not print a straight line. $\frac{45}{5.61720555}$ equals approximately 8 and 1/100 revolutions of the spiral per tick. Now we can see that this one will print like a normal 5 beat watch **except** that since the spiral will make slightly more than an even number of turns between ticks, the line will slope to the left. Let us determine to what extent the line slopes. The time between ticks is 3600/20222 or .178024 seconds. Then .178024 x 90" per second (the speed of the spiral) equals a travel of 16.02216" per tick. As 8 turns equals 16" scanning, then 16.02216 minus 16 equals 0.02216" that each dot is displaced to the left of the previous dot. So, dividing the 2" of travel by this .02216 we get 90.25 ticks for the printed line to travel once across the 2" width of the paper. In time, this is equal to 90.25 x .178024 which equals 16.06666 seconds.



A 20,222 Beat

Fig. 34-33



A 20,160 Beat

Fig. 34-34

And $\frac{16.06666 \times 6''}{60\ (\text{sec.})}$ equals 1.606" of paper travel while the dots move two inches to the left. We take a piece of paper and with a scale measure carefully 2" across the paper from a point and then up the paper 1.6" and make another point, then draw a line connecting these two points, giving us a pattern of what the record of this 20,222 watch should look like when the watch is running on time, figure 34-33.

With the paper travel of 1.6" while the line of dots crosses the 2" width of the paper, we may also lay out the position of the line by obtaining its angle by trigonometric functions.

The 20,160 beat watches, when running on time will make a record resembling that in figure 34-34.

note:

(No job sheets are associated with Lesson 32, Part 2)