The Watch Master

Watch-rate Recorder

HAND BOOK

Revised Edition

AMERICAN TIME PRODUCTS, INC.

580 FIFTH AVENUE • NEW YORK 19, N. Y.

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A brief summary
of typical WatchMaster charts
and analyses of watch conditions
which they interpret.

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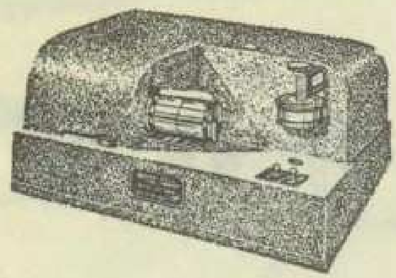

Introduction

This booklet has been prepared for the purpose of assisting the Watchmaker in utilizing the WatchMaster Watch-Rate Recorder to its best advantage. The relationship between the record and the watch is explained in some detail as a means of simplifying the interpretation of unusual records. No attempt has been made to reproduce exact records which are entirely indicative of a specific watch but rather the principles of diagnosis are illustrated.

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General Description

The WatchMaster Watch-Rate Recorder is a device which has been designed to record every tick of a watch or clock on calibrated chart paper in a manner which will give the maximum information in the shortest practical time. The calibration of the chart paper and the speed of its movement have been chosen to make an error of one second per twenty-four hour day, the minimum which can be distinguished in a period of thirty seconds, and at the same time, keep the recorded indication of instantaneous variations, due to watch irregularities, to a readable extent.

These principles take practical form in the WatchMaster by wrapping the chart paper around a drum which is rotated exactly five times per second by a motor controlled by a very accurate constant frequency. Since the escapement in a normal watch operates exactly five times per second when keeping correct time, a mark made on the chart paper every time the watch escapement operates would fall in exactly the same place for successive ticks. In order to distinguish between successive marks and hence successive ticks, the recording mechanism is advanced from left to right approximately the width of a mark every revolution of the drum. Therefore these conditions produce a line of marks on the paper which develop from left to right on the drum and exactly parallel to its axis when the rate of the escapement action and the rate at which the drum rotates are identical. A watch which is gaining produces marks which come slightly in advance of a complete revolution of the drum *between successive ticks* and hence produce a line of dots which slant in the direction of drum rotation as the recording is produced. This produces a line of dots which slopes upward from left to right as the record is viewed. Conversely, a watch which is losing produces marks which come slightly behind a complete revolution of the drum *between successive ticks* and hence produce a line of dots which slopes downward from left to right. The chart paper is calibrated directly in seconds error per twenty-four hour day, and the departure of the watch rate from correct time is read directly from the chart paper.

The Record and How to Read It

The size of the recorded marks has been chosen to be approximately the minimum which can be readily seen by the unaided eye and still be positive in its production. A line of such marks immediately adjacent to each other requires about thirty seconds of recording time to be dependably readable to one second in twenty-four hours when the instantaneous errors which exist in many watches are to be recorded.

The chart is ruled horizontally with parallel lines which are the equivalent of five seconds in twenty-four hours apart when the full width of the two inch recording represents a twenty-four hour day. When the record slopes the distance of one space between any two of these lines while covering the full two inch width of the paper, the watch is indicated to be five seconds in twenty-four hours off time. When the record slopes the distance between two divisions, the error is indicated to be ten seconds in twenty-four hours, and so on in units of five seconds for each space covered. When the watch is very nearly correct, errors of one second can readily be distinguished.

For convenience in reading large errors, every sixth line has been made of double width and the distance between the double width lines is hence read as an error of thirty seconds or one half minute per twenty-four hour day. For further assistance in reading large errors, the chart is also ruled lengthwise to divide it in two equal parts. This divides the observation time by two and errors observed in either half represent the twelve-hour performance and must be doubled to obtain the twenty-four hour rate.

Figure I shows samples of typical records illustrating the method of reading charts. Record A represents a watch which is in exact agreement within the frequency standard. The record is exactly parallel with the lines on the chart. Record B represents a watch which is gaining at the rate of twenty seconds in twenty-four hours. Four five-second spaces are covered in the full width of the chart. Record C represents a watch which is losing at the rate of thirty seconds in twenty-four hours. Six five-second spaces, or the space between two heavy lines, are covered in the full width of the chart. Record D represents the use of the lengthwise ruling. The left half of the chart covers three five-second spaces but since the half chart is a twelve hour indication, the error must be doubled making this error thirty seconds in twenty-four hours. By extending this record to the full chart width as indicated by the dashed line, the similarity with Record C is shown. The errors indicated by records C and D are identical.

Watches will occasionally be found which are running very fast or very slow in one or more positions. Records which indicate such rates may make one or more complete spirals around the drum. The size of the drum has been chosen to include exactly one hundred twenty five-second spaces, hence a record which made one complete spiral in the full width of the chart would indicate an error of ten minutes per day. Two spirals would represent twenty minutes per day and so on. Any incomplete spirals are read on the basis of five seconds for each division in the usual way and added to the error represented by the number of complete

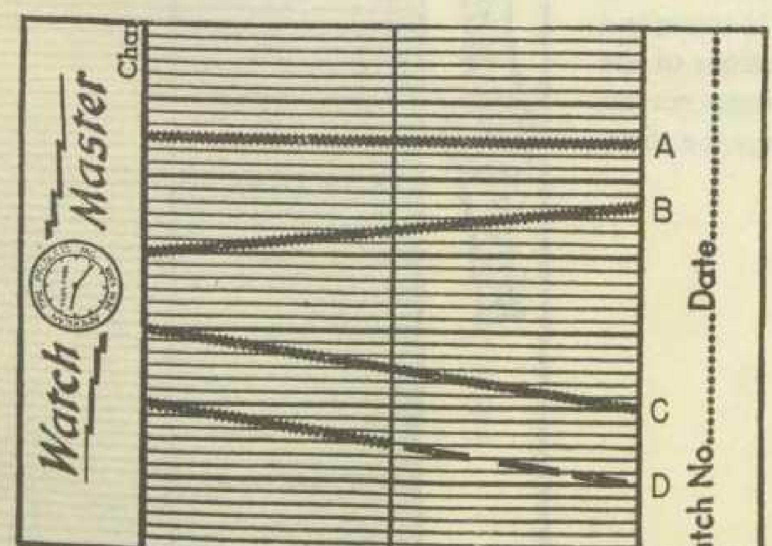


FIG. 1

spirals in the record. For example, Figure 2 represents a watch which is gaining at the rate of twenty-six minutes per day. The record makes two complete spirals plus twelve large (or seventy-two small) divisions.

There are also many watches made which do not operate five times per second when keeping correct time. Many inexpensive watches and most clocks operate only four times per second while many small ladies' watches operate up to six times per second. While the WatchMaster is primarily designed to record the action of watches which operate five times per second, it will produce usable records from these other so-called "odd beat" movements as well.

For example, a watch or clock which operates only four times per second will make only four marks for every five complete revolutions of the drum. This means that one and one-quarter revolutions of the drum occurs between successive ticks. Hence, the first,

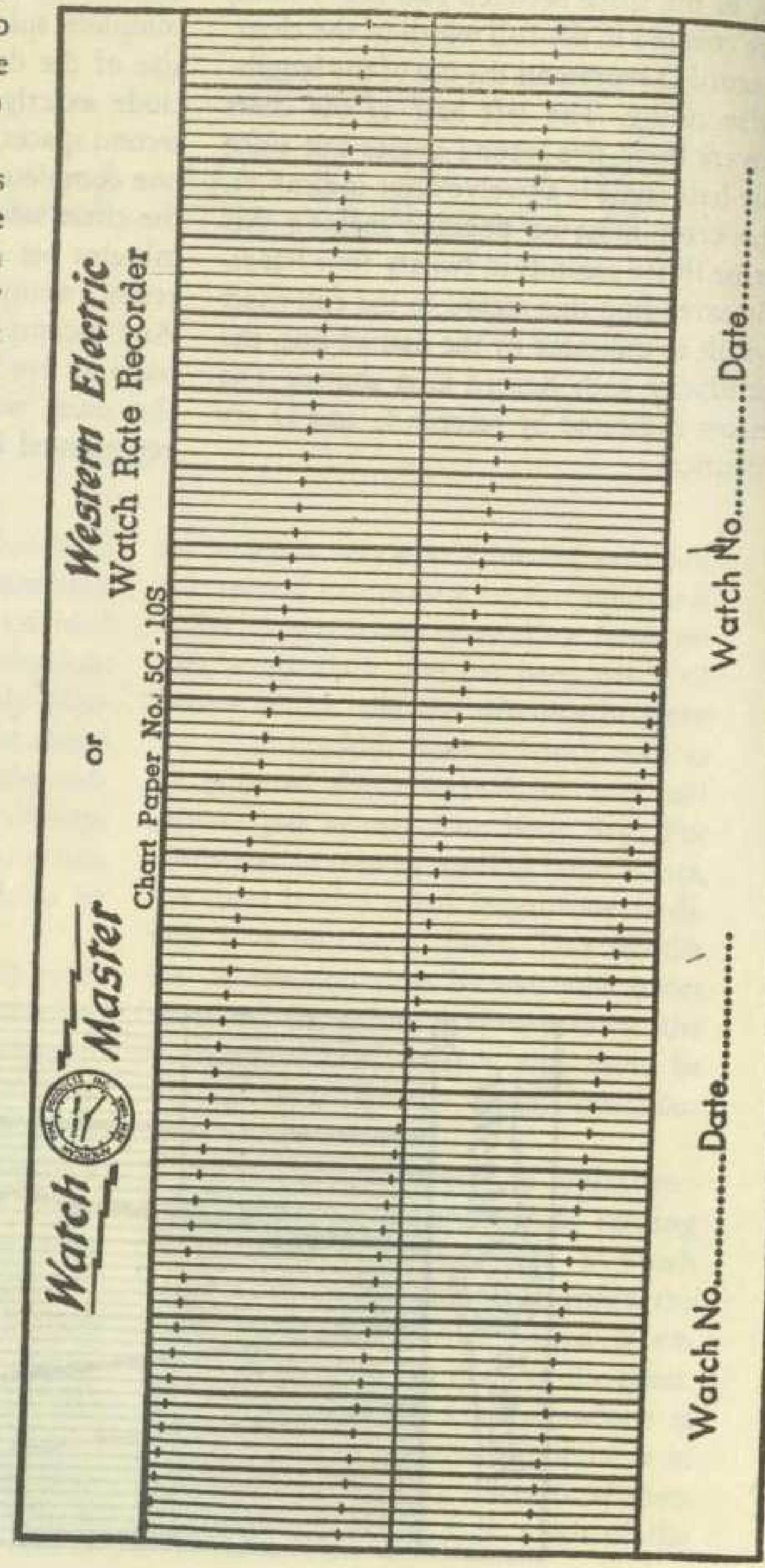


FIG. 2

fifth, ninth, thirteenth, etc., ticks will produce marks at the same position on the drum. The second, sixth, tenth, etc., ticks will produce marks in the same position and one-quarter revolution behind the first. The third, seventh, eleventh, etc., will produce marks on the other side of the drum and the fourth, eighth, twelfth, etc., will be three-quarters of a revolution behind the first. The effect of this condition will be to record four separate lines of dots on the drum. They will all be parallel and any one of them may be used to read the rate in the same manner as the complete line is used for five-beat watches. Figure 3 represents a four-beat movement which is keeping correct time.

The manner in which the record from a six-beat movement is produced is similar except that six marks are produced for every five revolutions of the drum. In this case five sixths of a revolution occurs between successive ticks. This results in six separate lines of dots any one of which

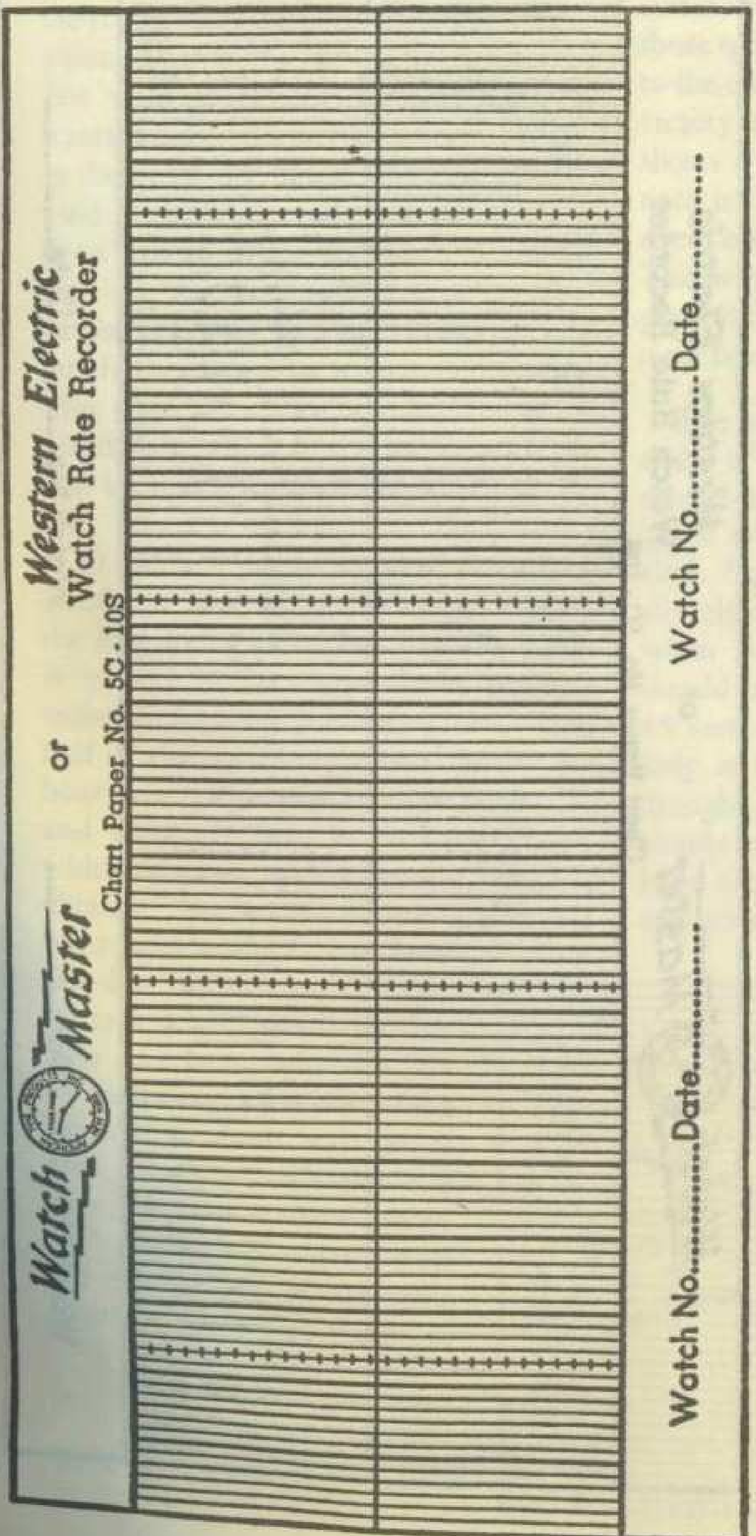


FIG. 3

is usable in the regular manner. Figure 4 represents a six beat movement which is keeping correct time.

There are a number of other odd beats frequently encountered. Records from these movements are produced in a similar manner and all are usable in the same way. Typical records for most of the odd beat movements are shown at the rear of this booklet, together with a list of most common makes and sizes using each beat.

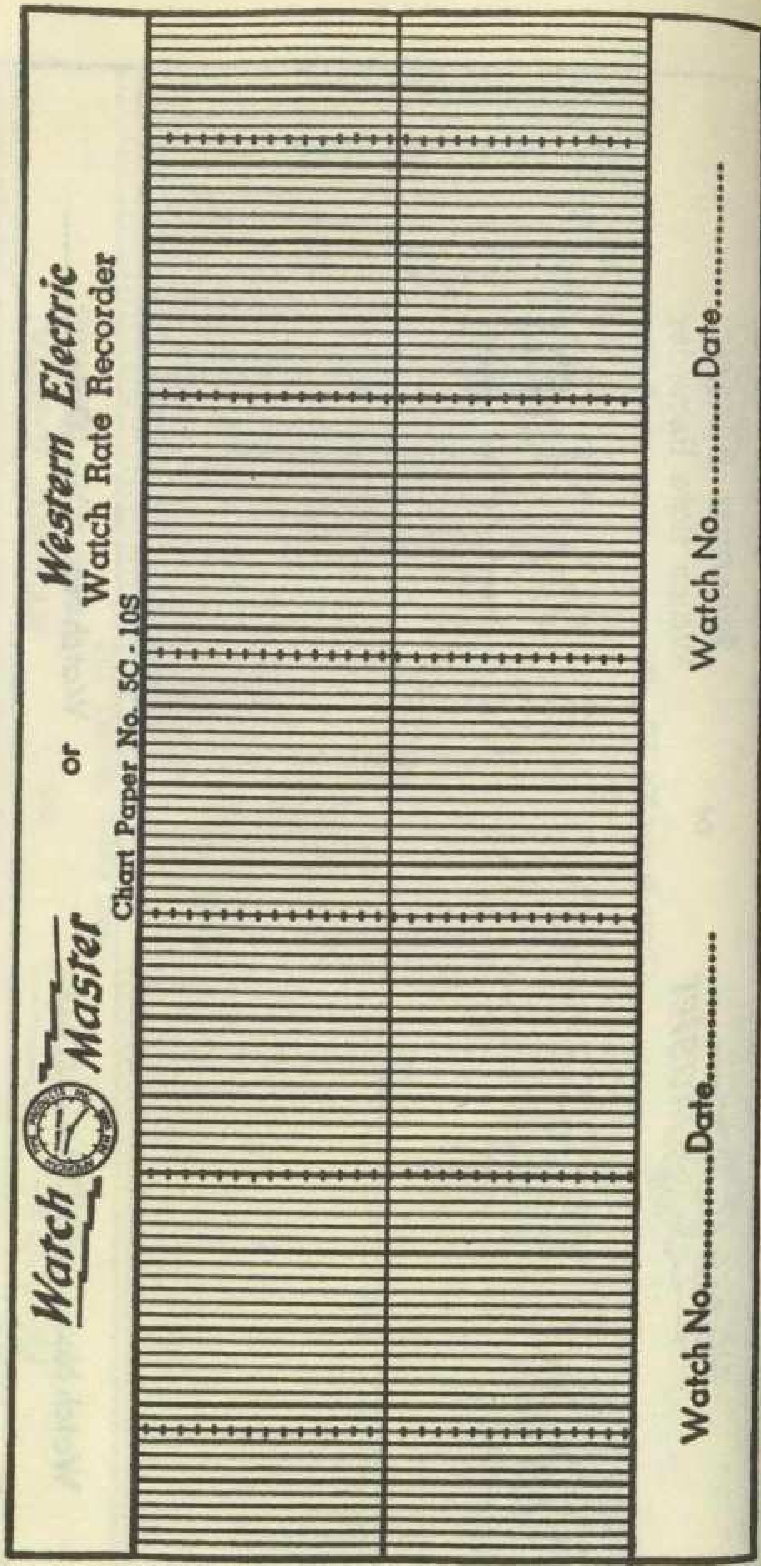


FIG. 4

WRIST WATCHES

When the WatchMaster is used for timing wrist watches of average commercial grade, it is generally unnecessary to make the complete 30-second record in each position. This is due to the fact that very few wrist watches will repeat their instantaneous rates exactly from one minute to the next and the average rate must be used. The dial-up and crown-down positions control the performance of a wrist watch when worn and the average between the rates in these positions is a satisfactory basis for wrist watch timing. This two-position average is obtained by placing the watch in the holder with the dial up and the crown either to right or left.

The WatchMaster is started in the usual manner and when the record reaches the longitudinal dividing line, the watch is turned to the crown-down position without stopping the instrument. Each half of the record represents the twelve-hour rate in the respective positions used and when the chart is read for its full width, the twenty-four hour average is obtained. Record A, Figure 5, shows a wrist watch which has been timed in this manner. The dial-up rate is 10 seconds per day slow and the crown-down rate 80 seconds per day slow. The twenty-four hour average is read as 45 seconds per day slow. In order to make certain that a serious rate error does not exist in one of the other positions, it is desirable to quickly check the crown-right and crown-left positions before bringing the watch to time. Record B, Figure 5, shows the crown-right-and-left rates for same watch and illustrates the method used in making these quick checks. The rates are similar to the crown-down rate indicating a satisfactory condition. Record C, Figure 5, shows a similar watch in which the balance is out of poise in a manner which does not affect the crown-down rate. This watch could not be expected to keep good time when worn and the error must be corrected before bringing to time.

The watch represented by Records A and B of Figure 5 is in satisfactory adjustment for timing and the dial-up, crown-down average rate is 45 seconds per day slow. Since wrist watches generally run slightly slower when worn than they do when perfectly stationary, this watch should be adjusted somewhat more than 45 seconds per day faster. One position only is necessary for this operation although quick position checks are desirable to make certain that other errors have not been introduced by the timing operation.

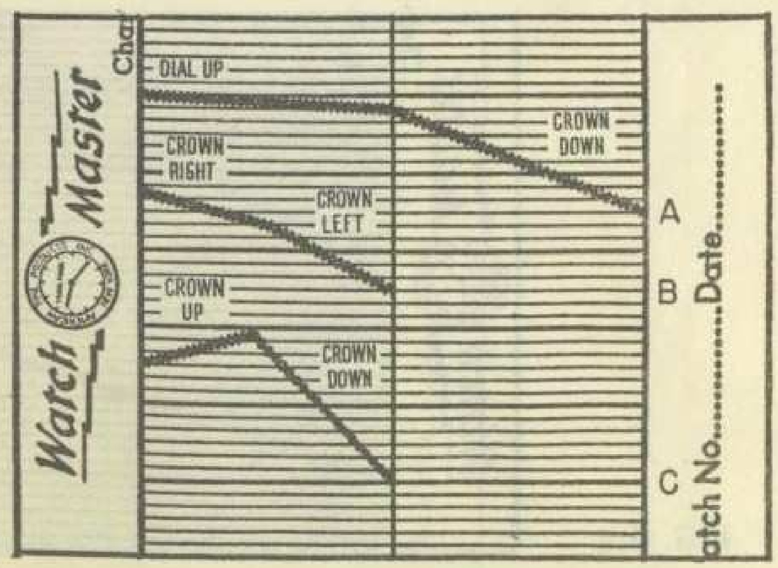


FIG. 5

Figure 6 shows the steps followed in regulating the watch and the use of short records to obtain an indication of the extent of the adjustment. Record A shows the result of the first attempt. This record represents a rate approximately two minutes fast. Record B represents the next attempt—about 90 seconds fast. After a further adjustment the full record is made and the watch found to be one minute fast in the dial-up position. This should be about right for this particular watch as the average would then be about 30 seconds fast which allows for the amount the watch will run slow when worn and still have it gain slightly. This is the desirable condition to achieve as a slightly slow watch is unsatisfactory.

All of the records shown up to this point are representative of watches in good mechanical adjustment where the time from "tick" to "tock" is exactly the same as the time from "tock" to "tick" and hence are in perfect beat. Any departure from this time relationship is evidenced by a double line of dots as shown in Fig. 7. The separation between the two lines is a direct measure of this "time" difference and hence the amount the watch is out of beat dynamically (when it is running).

When the watch has been placed in beat statically, by visual inspection of the roller jewel with respect to the line of centers of the balance staff, pallet, and escape wheel arbors, there are at least two more factors which contribute to the dynamic beat condition. The first of these is the relative amount of angular travel the pallet makes on either side of center, (pallet travel is determined by the banking pin adjustment), and should be exactly the same on both sides of center in order that the time of balance

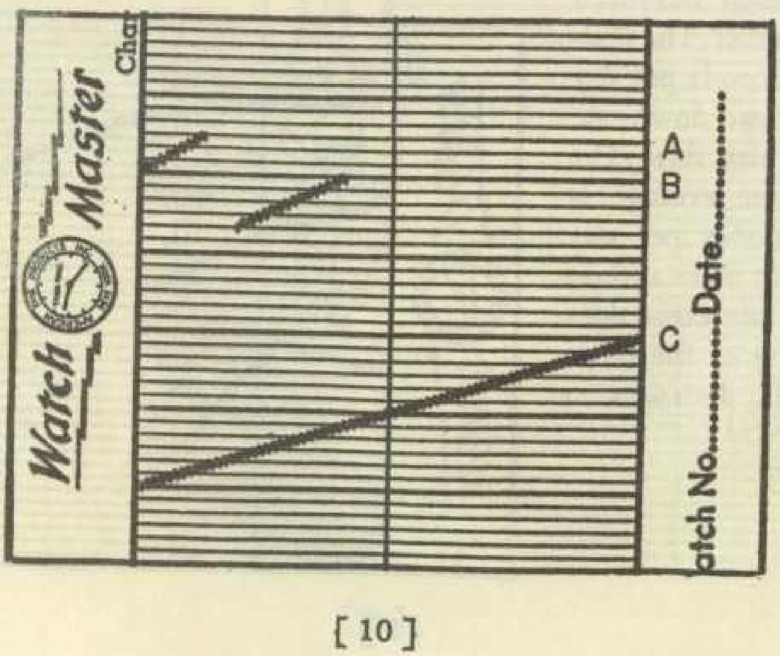


FIG. 6

swing on each side should be the same. The second contributing factor is the relationship between the hairspring and the regulator pins. It is vitally important that the spring be centered between the pins at rest and that both pins have the same restricting value on the spring at all motions normally encountered.

When all of these conditions have been met, the balance and hairspring combination are in the best condition to oscillate freely and be least affected by variable mechanical influences. The existence of this state of adjustment is evidenced by a single line record which is clean and does not show changes of time between succeeding ticks or ticks and tocks. In wrist watches of ordinary commercial grade, it may be impractical to attain this true state of dynamic beat due to the miscellaneous mechanical imperfections normally present. With watches of this type a compromise adjustment which will produce a double line record with a clear separation not to exceed one small chart division may be assumed to be acceptable. Record B, Fig. 7, is representative of such a compromise which may be assumed to be satisfactory although obviously not perfect.

Most watches have balance and hairspring assemblies which are out of true dynamic poise even though the balance wheel itself has been carefully poised before adding the spring. Part of this effect is due simply to lack of symmetry of the collet and inner spring termination and it can be reduced by counterpoise. A further contribution to the apparent out-of-poise condition is made by the tendency of the spring to sag when improperly supported.

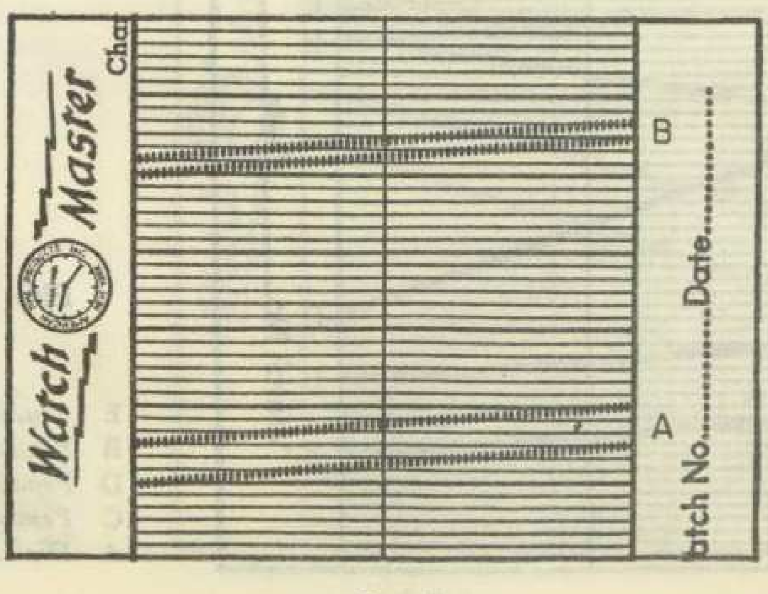


FIG. 7

OUT-OF-POISE

In a carefully designed watch, the hairspring pinning points have been chosen to provide the most support to the spring in the positions which are most important. Most support is given in the pendant-up position and the least in the pendant-down. A sagging spring has the same general effect as an out-of-poise balance and the position which is affected the most is located in the same manner. When all other conditions are normal, this will generally be found in the pendant-down position. A slight movement of the inner regulator pin in the direction of the spring body away from the stud will be found effective in affording more support in the pendant-down position with a slight improvement in the pendant-right and left rates.

The principles involved in locating the effective heavy side are as follows: Figure 8 shows the rates in one horizontal and four vertical positions in a watch which has the balance somewhat out-of-poise but is otherwise in good condition. The heavy spot on this balance is directly down with the pendant-up and the balance at rest in dead center. This is the position with respect to the out-of-poise condition of the balance which produces the fastest rate and the slowest rate is found directly opposite, in this case with the pendant-down. The pendant-right and left positions are not appreciably affected by this out-of-poise condition and remain close to the rate of the watch in the horizontal position.

Figure 9 shows the rate of the same watch in the same positions as in Figure 8 with the heavy spot on the balance moved half way between the six and the nine on the dial with the pendant-up and the pendant-left rates are now fast and the pendant-right and pendant-down rates are slow, the errors in each case being less than the maximum errors indicated in Figure 8.

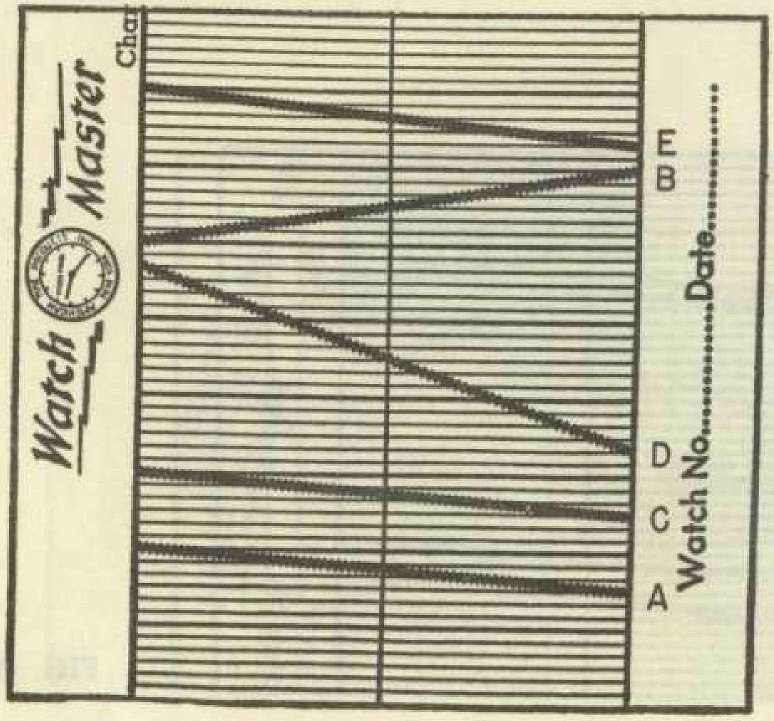


FIG. 8

E *Pendant right*
B *Pendant up*
D *Pendant down*
C *Pendant left*
A *Dial up*

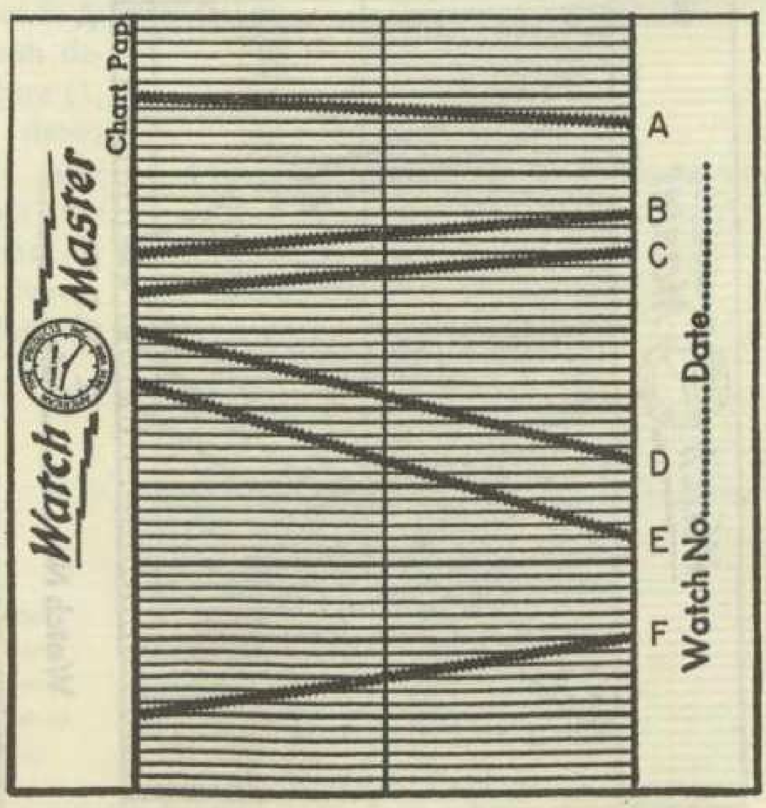
A comparison between Figure 8 and 9 indicates that the fastest rate on the watch in the condition of Figure 9 would be expected with the pendant moved half-way left, (in other words, the position corresponding to the 1½ on the dial uppermost). Figure 9, Record F, shows the rate in this position and this rate checks exactly with the pendant-up rate with the watch in the condition as shown in Figure 8.

Figures 8 and 9 indicate the method to be followed in determining the balance poise error in any watch and offer a ready means of making a correction which will bring the watch within acceptable limits for its particular grade in a minimum of time. For example, the watch used in obtaining Records in Figures 8 and 9 has its balance arbitrarily thrown out of poise by the addition of a single timing washer under one balance screw.

The effects of lack of poise are the same regardless of the cause. When the obvious mechanical conditions of wheel poise and collet center poise and pin support have been fulfilled and an out-of-poise condition is still apparent, the trouble will generally be found in the manner in which the spring develops. This is corrected by slightly altering the spring so that it develops in a direction away from the apparent heavy spot as located above.

Many watches, particularly of the cheaper grades, will be found with the regulator pins spread too far apart in order to correct the horizontal rate while leaving the regulator in the center of its scale. The most serious error caused by this manipulation appears to be the increased position error encountered.

FIG. 9



A *Dial up*
B *Pendant up*
C *Pendant left*
D *Pendant down*
E *Pendant right*
F *Pend. Half left*

Most of the error encountered through this condition is truly isochronous in that a difference in rate accompanies a change in motion. In this case the effect of the pins is reduced as the motion falls off in the vertical position, thereby making the full length of the spring to the stud effective for a greater part of the time and thus making the watch very much slower at the reduced motion encountered in the vertical positions.

Figure 10, Records A, B and C, show three positions of a watch having regulator pins excessively far apart. The horizontal rate is approximately correct, the pendant-down-and-up rates are very slow.

Figure 10, Records A′, B′ and C′, shows the same three positions after the regulator pins had been closed to the point where the action of the hairspring between them was proper. This, of course, has the effect of making the watch run faster in all positions but the change in the vertical position rates is greater than the change in the horizontal rate. This has had the effect of bringing the position error for this watch within acceptable limits.

ISOCHRONISM

Isochronism in a watch may be roughly defined as the relationship between the rate and the arc of balance motion in any position. The isochronous error may then be defined as the difference between the rate of the watch full wound and the rate at the end of the normal period between windings. This is generally 24 hours. This is most easily measured by taking the rate with the main-spring wound an amount equivalent to that after 24 hours of running and then measuring the rate in the same position with the mainspring fully wound. The difference between these two rates is the isochronous error of a watch in the position tested.

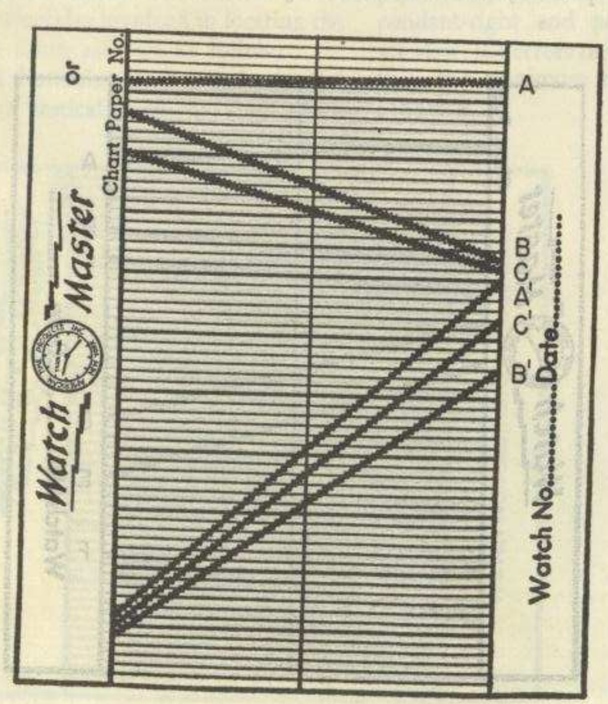


FIG. 10

A *Dial up*
B *Pendant up*
C *Pendant down*
A¹ *Dial up*
C¹ *Pendant down*
B¹ *Pendant up*

Figure 11, Records A and B, shows the full-wound and 24-hour down rates of a watch with a flat hairspring which, of course, has no isochronal correction and always runs slower as the motion decreases. Figure 11, Record C and D, shows a comparable watch having a hairspring with an over-coil which does not fully compensate the rate with decreased motion and Figure 11, Records E and F, shows another watch in this same classification in which the over-coil over-compensates for decreased motion, thereby making the watch run faster as it runs down.

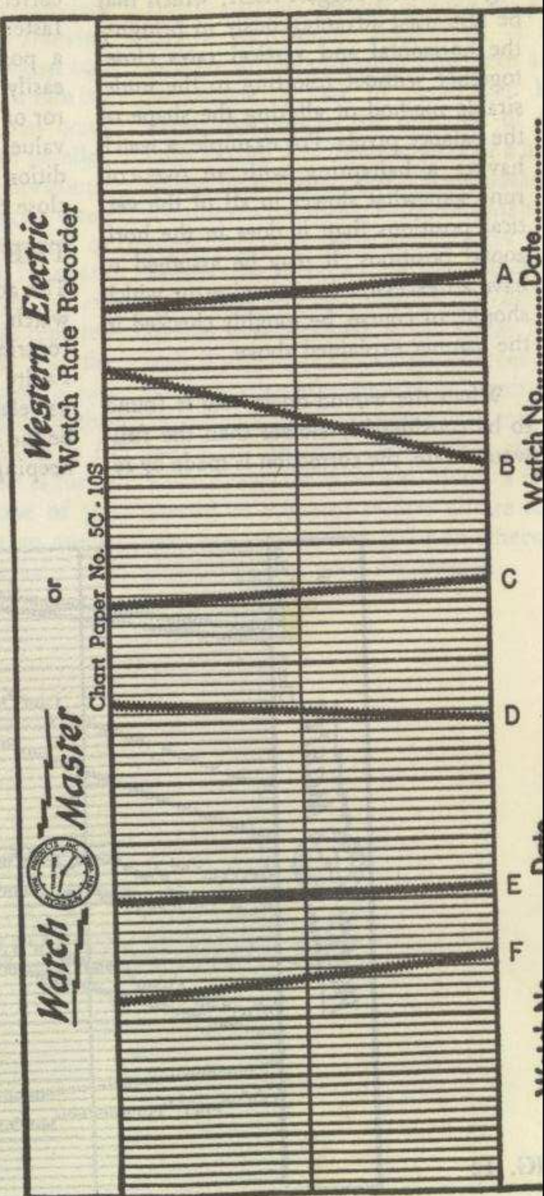


FIG. 11

A *Dial up—full wound*
B *Dial up—24 hrs down*
C *Dial up—full wound*
D *Dial up—24 hrs down*
E *Dial up—full wound*
F *Dial up—24 hrs down*

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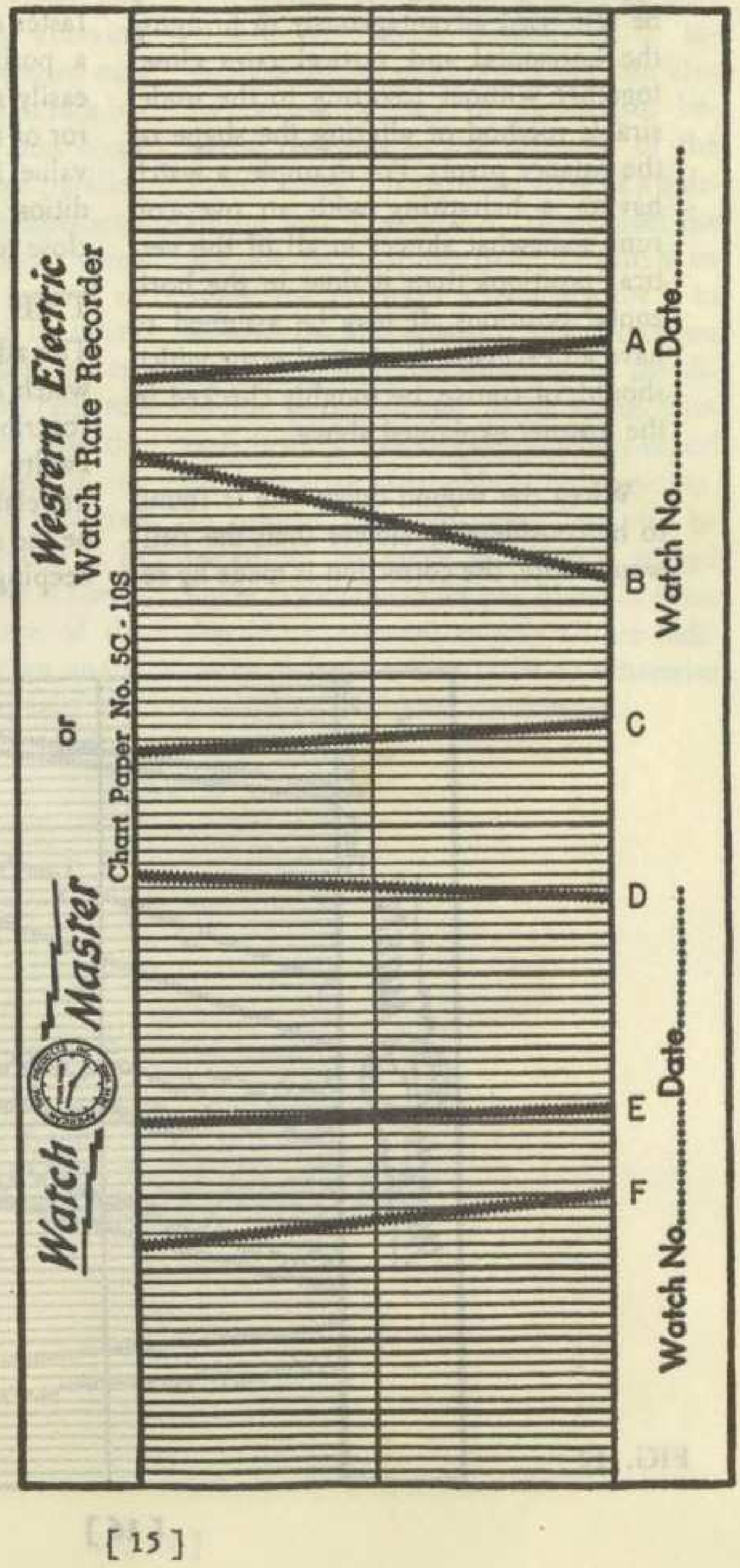


FIG. 11

A *Dial up—full wound*
B *Dial up—24 hrs down*
C *Dial up—full wound*
D *Dial up—24 hrs down*
E *Dial up—full wound*
F *Dial up—24 hrs down*

From an inspection of these three records, a quick method for correcting excessive isochronal errors in watches having over-coils suggest itself, which may be also used advantageously in bringing the horizontal and vertical rates closer together without resorting to the undesirable method of altering the shape of the balance pivots. For example, a watch having a hairspring with an over-coil runs somewhat slower in all of the vertical positions than it does in the horizontal positions. It may be assumed to have an excessive isochronal error which should, of course, be roughly checked in the manner explained above.

When the wound-down rate is found to be considerably slower than the full-wound rate, the correction is made by reshaping the over-coil slightly to have the straight part in the center section of the coil slightly closer to the staff. If this correction is over-done the watch will run faster as the motion decreases. However, a position for this over-coil section is easily reached where the isochronous error of the watch is reduced to a tolerable value, in which case a watch in good condition will have vertical rates extremely close to the horizontal rate.

THE HAIRSPRING

The adjustment of the hairspring in the watch is the greatest single factor which contributes to the watch performance. Faulty adjustment of the hairspring and its relationship to the regulator pins can be the source of most of the erratic timekeeping which a watch in otherwise ex-

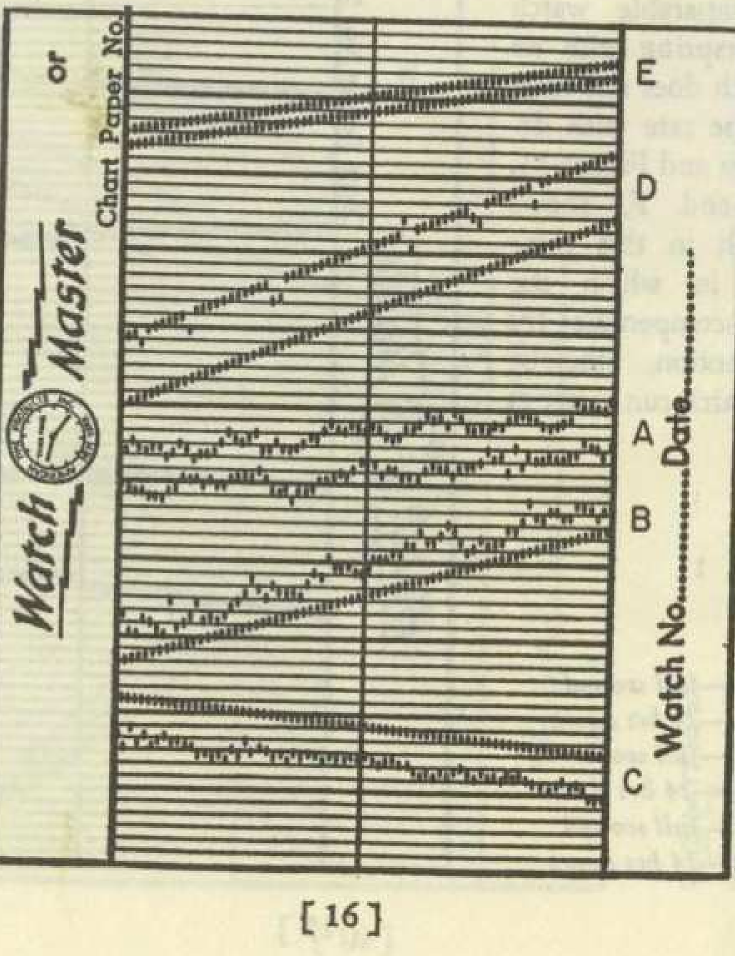


FIG. 12

cellent mechanical condition will exhibit. Variations in rate in the vertical positions may occur when the spring is improperly centered or when it is given insufficient support in one position, thus allowing it to sag and producing an apparent out-of-poise condition. Variations in rate between dial-up and dial-down may occur when the regulator pins are not parallel. Variations in rate between the horizontal and vertical positions may occur when the over-coil is improperly formed or when the regulator pins are too far apart. Generally erratic behavior may be experienced when the spring is not centered between the regulator pins so that the restrictive effect of the two pins is unequal. Record E, Figure 12, is indicative of this condition when the watch is in perfect beat statically. The effect is further exaggerated by bending one of the pins away from the spring at an angle. In addition to indicating a greater departure from perfect beat, one line of the record exhibits a slightly ragged tendency, due to spring hitting the pin at an angle and sliding an unequal amount on successive oscillations. Record D, is indicative of this condition which can also be caused by lack of parallelism between the pins in the direction of the staff. Record A is representative of a hairspring which is not flat. This causes the flat sides of the spring to hit the pins at an angle and produces a tendency for it to slide on the pins unevenly and also causes the spring to move unevenly in the direction perpendicular to its plane. Records B and C are very common types and are indicative of trouble at only one pin. In general, a ragged upper line may be traced to the outer pin and a ragged lower line to the inner pin. None of these should be tolerated as they all are indicative of faults which make an otherwise good watch, a poor timekeeper.

Watch Master

MECHANICAL FAULTS

Many of the common mechanical faults produce characteristic records on the WatchMaster. Some of these are occasioned by the fact that most watches have some isochronal error and hence the rate changes as the power delivered to the balance-changes. For instance, Figure 13 shows two consecutive records for a watch having a defective fourth wheel. The fourth wheel revolves once per minute and as a consequence, when it is out of round, or has a bent arbor, the power delivered to the escape wheel will vary over the period of one minute and will be accompanied by a rate change as the power varies. A second hand which binds or drags on the dial on one side and not on the other is a common cause of this trouble.

Similarly, an escape wheel which is out-of-round or has any mar or bur on its pinion will cause a change ten times per minute (15-tooth escape wheel). Figure 14, Records A, B and C, shows the typical records for these conditions. When the wheel, itself, is out-of-round or not exactly centered on the arbor, the locking of the escapement will vary as the wheel rotates and, while there may be slight changes in rate, the characteristic pattern consists of a periodic widening and narrowing of the space between the two recorded lines. This may also take the form of a single line which widens to a double line and returns to the single line at the rate of ten times per minute or five full cycles in the full 30 seconds of the WATCHMASTER Record. Figure 14, Record A, shows this condition.

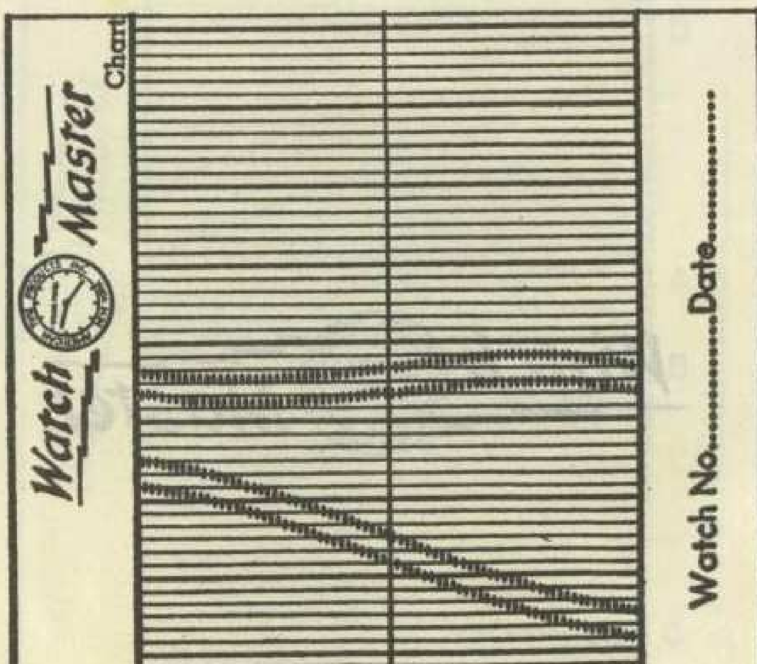


FIG. 13

When the pinion alone is defective, the power changes as the wheel rotates but the escapement is not affected. The record then shows a change of rate without change of pattern. Figure 14, Record B, shows this condition. When the pivot or arbor is at fault, the power transmitted usually varies and the escapement locking changes as the wheel rotates. This condition produces a record which changes rate and pattern both as shown on Figure 14, Record C.

In addition to these escape wheel faults, occasionally watches are found with a mutilated escape wheel tooth. This may result in the failure of the escapement to lock on one or both sides as this tooth presents itself to the pallet. Figure 14, Record D, shows the effect of this condition in a watch which is well adjusted in all other respects.

Occasionally, watches will produce records which indicate one or more of these escape wheel faults and upon examination, the fault cannot be found. This trouble will then be generally traced to a magnetized escape wheel. This is particularly true of a so-called non-magnetic watch which nevertheless has a steel escape wheel. When this condition exists the magnetism exerts a variable influence on the hairspring and the watch records a pattern which is similar to the escape wheel fault records of Figure 14.

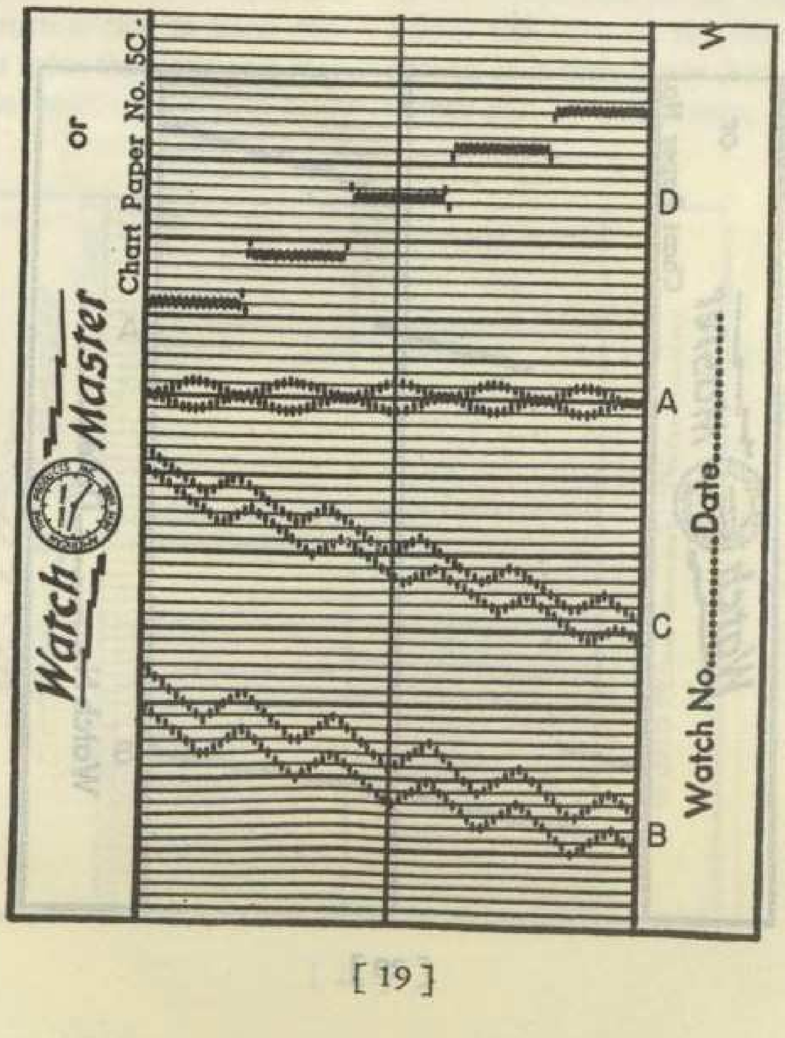


FIG. 14

Figure 15A is representative of watches in which the balance motion is excessive. This usually occurs after the watch has been put in first-class condition with the majority of its errors eliminated or greatly reduced. The trouble is ordinarily called "over-banking" and is caused by the roller jewel unlocking the escapement by hitting the pallet on its back side. The proper correction for this trouble consists in reducing the strength of the mainspring rather than by increasing the friction, by flattening the balance pivot ends. Figure 15B shows the same watch after the mainspring had been replaced.

Watches which have low motion of the balance wheel are generally unsatisfactory timepieces and are apt to be very troublesome in service. While the eye is a fairly good judge of the extent of the balance arc, the WATCHMASTER record gives a definite indication of the effect of the particular motion in question on the performance of the watch. In general, low motion which affects watch performance produces records which are unsteady in direction and are very characteristic of this condition. Figure 16 shows a record of this type. Watches which produce records having these characteristics are almost certain to be troublesome and should never be delivered until the condition is corrected.

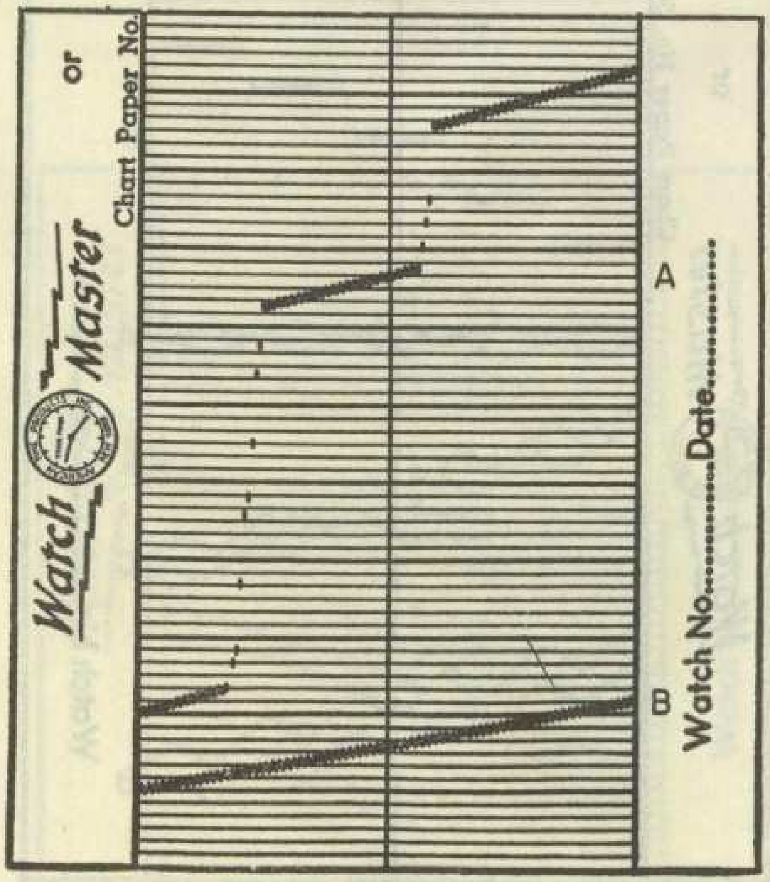


FIG. 15

All of the foregoing charts are indicative of watch faults which are correctable by adjustment and manipulation. These corrections are part of the finishing and timing procedure after the watch has been repaired.

There are, however, a certain number of specific faults which might be overlooked in the repairing process which produce records indicative of their existence. Such things as loose or cracked jewels, loose banking pins and loose or improperly set roller jewels produce ragged records which in some cases are similar to records produced by certain types of hairspring faults, but in general they will not vary between positions as the hairspring records do. In any event ragged, double records represent watch faults which should not be tolerated and the records furnish a clue to their correction although more than one part may contribute to the fault.

In addition to these specific faults excessive slide in the escapement has the effect of producing a ragged record when it begins to cause trouble in the watch. This may exist in one or both lines of the record and is an indication of which side to reduce the slide on. In many older watches in which the balance pivots have become slightly worn the separation between the lines vary as the watch is moved through the vertical positions. The lines will be closest together, in general, in that position where the balance is over the pallet and escape wheel, and the separation will be greatest in the position directly opposite that point with the records in the horizontal positions somewhere in between. When this condition exists, it is well to make all adjustments to the escapement in the position which brings the lines on the chart closest together. It is then likely that all other positions will be satisfactory.

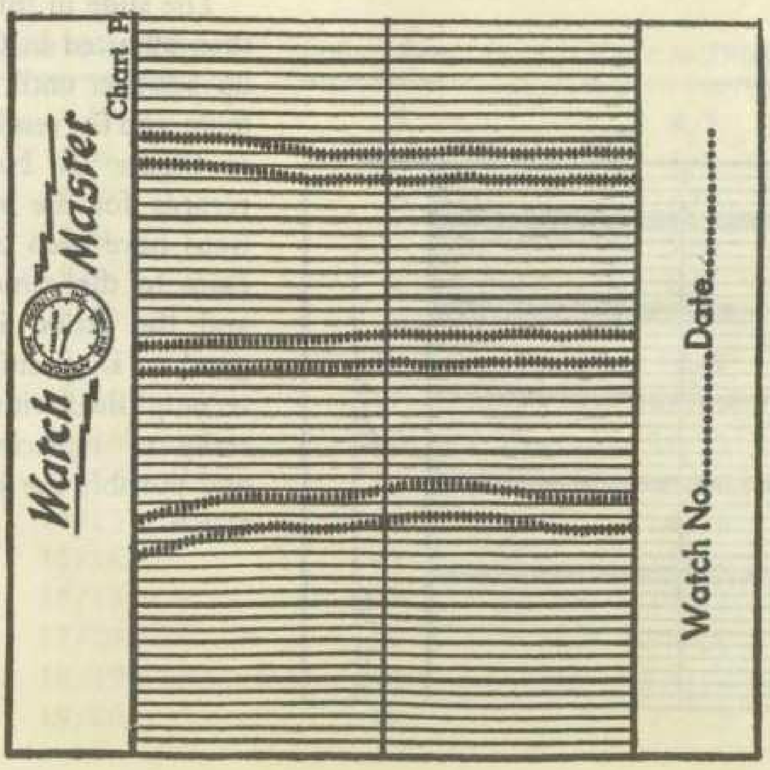
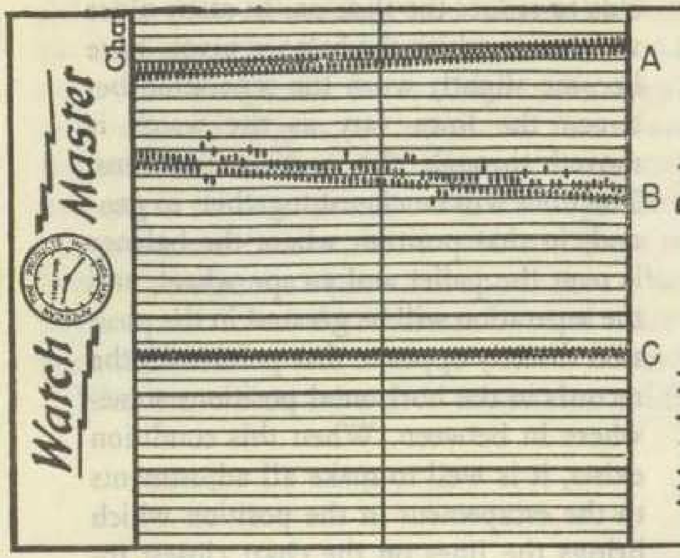


FIG. 16

FIG. 17



In order to compensate for the wear existing in the balance pivots, it is sometimes possible to reduce the slide on one side of the escapement and increase it on the other and thus arrive at a compromise which will produce a satisfactory operating condition in all positions without interference. Figure 17, Records B and A, represents pendant-up and pendant-down for a watch having somewhat worn balance pivots and which has been adjusted to have a good escapement action in a horizontal position. It is noted that interference is encountered in the pendant-up position which makes an extremely erratic record and in the pendant-down position the lines have separated considerably.

The slide in this watch was then adjusted in the pendant-up position until it was optimum, and the results are shown in Figure 18. Note that the records for the various positions have been brought very close to the same separation and the action is extremely good in all positions. This is accomplished without the necessity of replacing the staff and possibly the jewels in the watch.

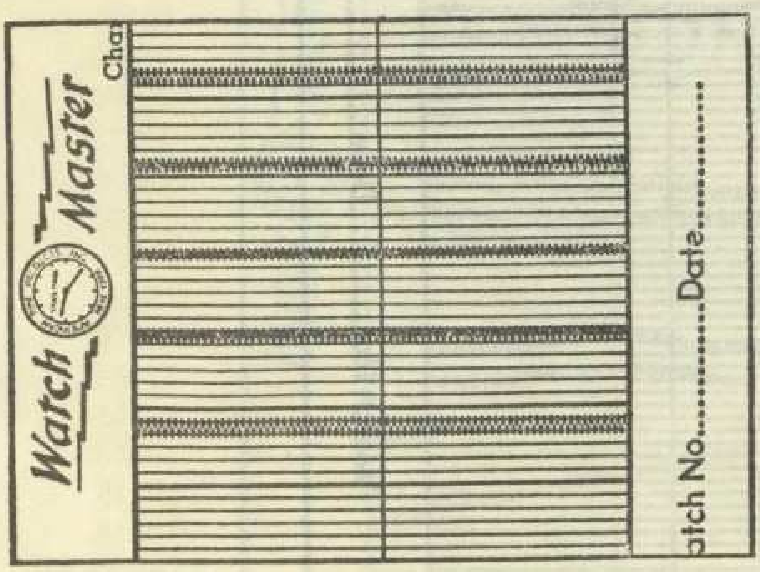


FIG. 18

Odd Beat Movements

The WatchMaster is primarily designed to record the action of watches having 18000 beat per hour trains. This means that the drum turns at exactly 18000 revolutions per hour and the comparison between the watch rate and the machine rate is read directly from the chart. However, the very nature of the WatchMaster design insures an adequately readable record for any other beat up to at least double the normal rate, or 36000 per hour. Most of these so-called odd beats record multiple line records around the drum, any of which are usable in the regular manner. This condition exists for all beat rates that are reducible to a small common fraction of the drum speed. For example, a watch which beats only four times per second will make four dots in five revolutions of the drum. This means that one and one quarter revolutions of the drum will be made between beats and every fifth beat will record at the same position on the drum. The intervening beats will record at evenly spaced intervals around the drum, one-quarter revolution apart. Thus, a four beat movement will record a pattern of four lines all equally spaced and parallel to the drum when on time. From this fact, it may be shown that any beat which bears a common fraction relationship to the rate of the drum with a difference of one between the numerator and denominator will record a multiple record parallel to the drum. The following table lists these odd beats which will produce lines parallel to the drum when on time.

Beat	*Ratio to 18000*	*No. of Lines*	*Ratio to 18000*	*Beat*
14400	4/5	4	4/3	24000
15000	5/6	5	5/4	22500
15428	6/7	6	6/5	21600
15750	7/8	7	7/6	21000
16000	8/9	8	8/7	20571
16200	9/10	9	9/8	20250
16363	10/11	10	10/9	20000
16500	11/12	11	11/10	19800
16615	12/13	12	12/11	19636
16714	13/14	13	13/12	19500
16800	14/15	14	14/13	19384
16875	15/16	15	15/14	19285
16941	16/17	16	16/15	19200
17000	17/18	17	17/16	19125
17052	18/19	18	18/17	19058
17100	19/20	19	19/18	19000

The maximum number of lines which can be read is nineteen. Any beat which is closer to 18000 than the beats which produce nineteen lines is read as one line with an off-time slope. Any beats which are other than the exact ones shown on the above chart produce the number of lines shown for the nearest exact beat but will have a slope which is representative of the difference between the beat of the watch and the nearest beat shown. The amount of this slope is determined by substracting the value of the nearest beat shown from the beat of the watch, dividing this difference by the exact beat shown and multiplying by 86400, the number of seconds in one day. This product will represent the slope of the record for the beat in question when keeping correct time. The sign of the answer will determine whether the indicated record is gaining or losing. Plus represents a gain and minus a loss. For example, 20222 is a relatively common beat for medium small size Swiss ladies' watches. The nearest exact beat shown is 20250, which produces nine lines. The correct time slope is determined as follows:

$$\frac{\text{Beat of watch under test (20222)} - \text{Nearest exact beat (20250)}}{\text{Nearest exact beat (20250)}} \text{ X } \begin{matrix}\text{No. of}\\ \text{seconds per}\\ \text{day}\end{matrix}$$

$$\frac{20222 - 20250}{20250} \text{ X } 86400 = \frac{28}{20250} \text{ X } 86400 = - 120 \text{ seconds per day}$$

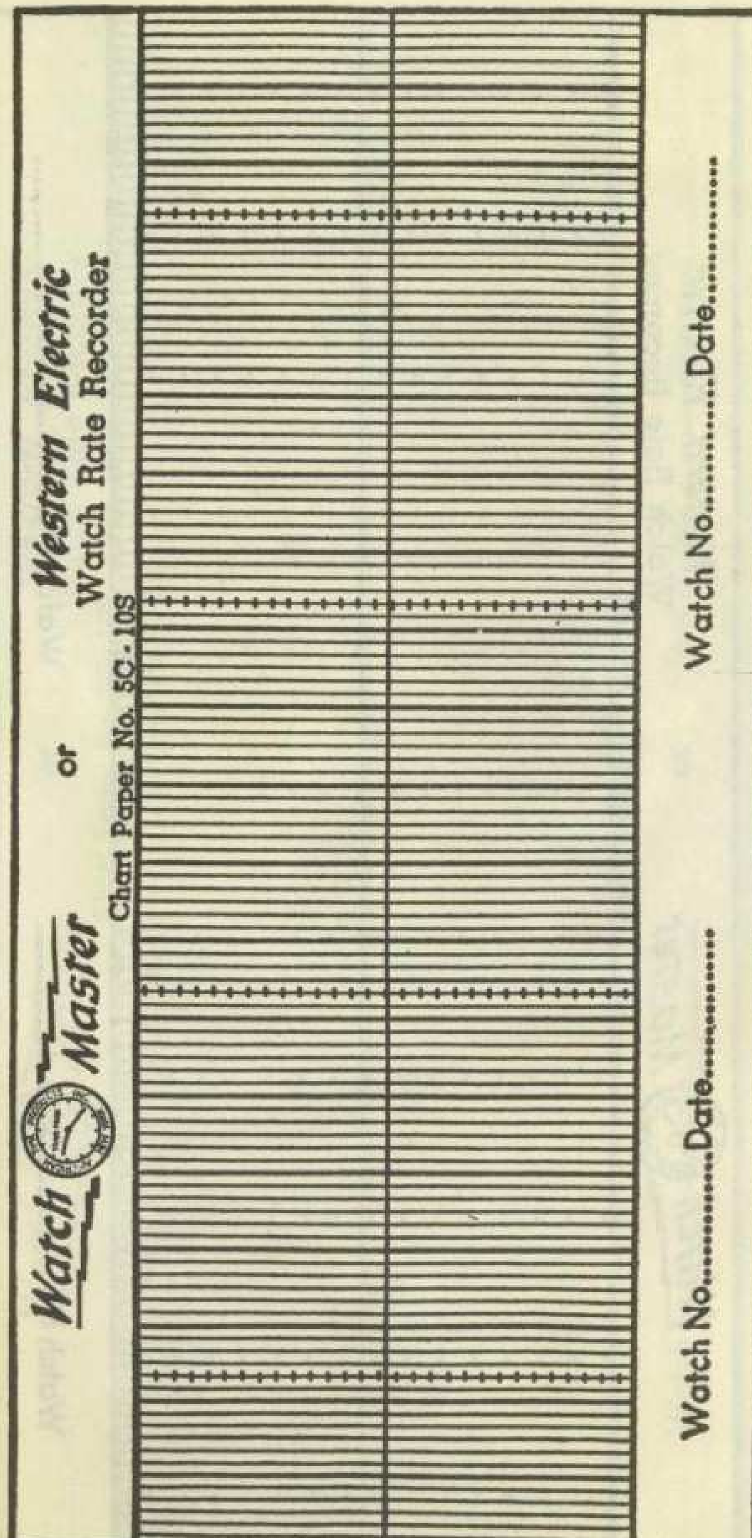
The correct record for a watch which is designed to beat at the rate of 20222 per hour is therefore nine lines evenly spaced around the drum at a slope of 120 seconds or 2 minutes per day slow.

Typical Odd-Beat Charts

The following charts have been included to show the on-time record for most of the common types of odd beat movements. In reading a watch rate of this type only one line is used and the watch is fast or slow by the amount the record departs from the on-time record shown. Any watches having beats other than those shown may be checked by referring to the method outlined above.

FIG. 19

Perfect Record
14,400
Beats Per Hour



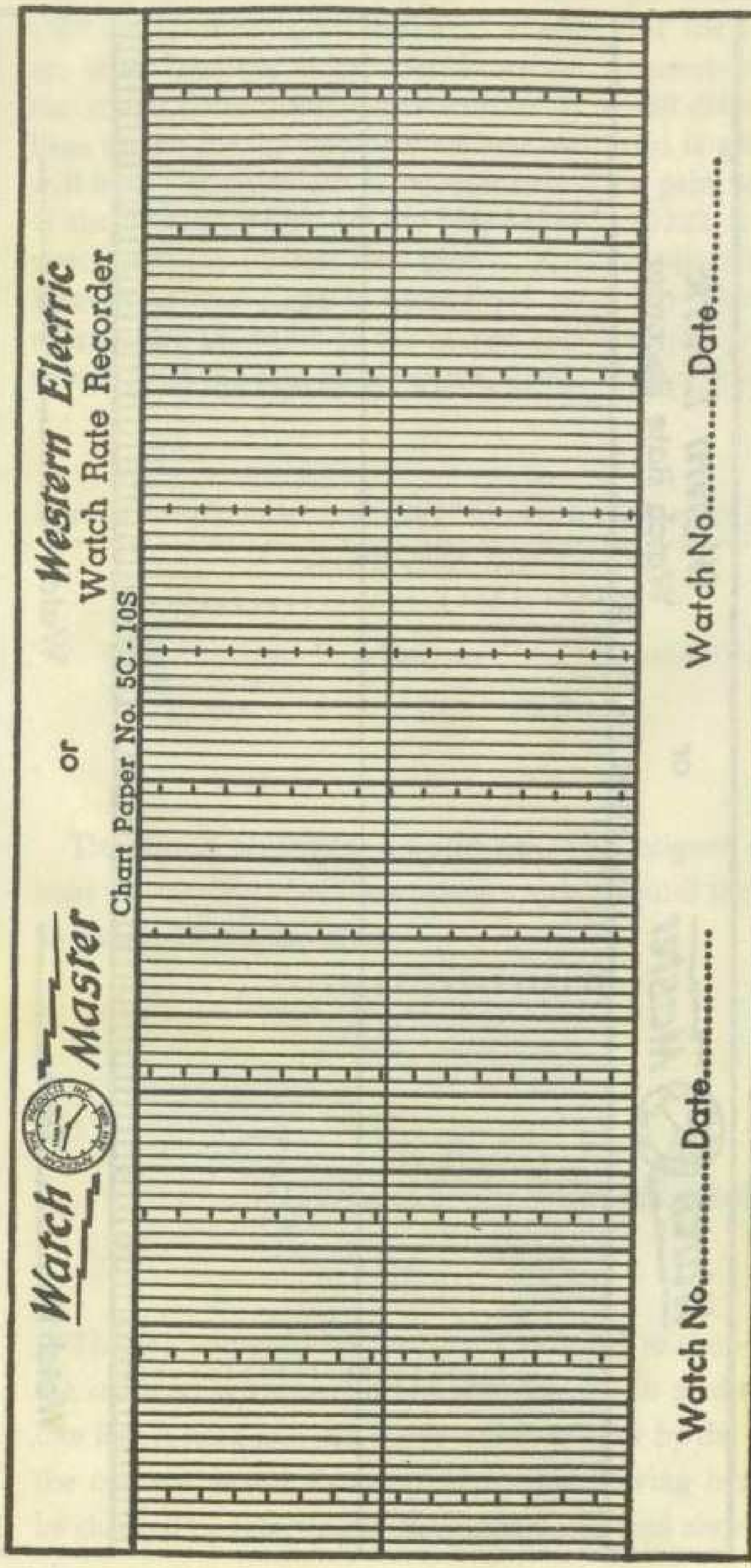
4 lines — Horizontal

The rate can be easily determined in the manner described in the introduction to this section.

This beat is common in cheaper watches and alarm clocks.

FIG. 20

Perfect Record
19,800
Beats Per Hour



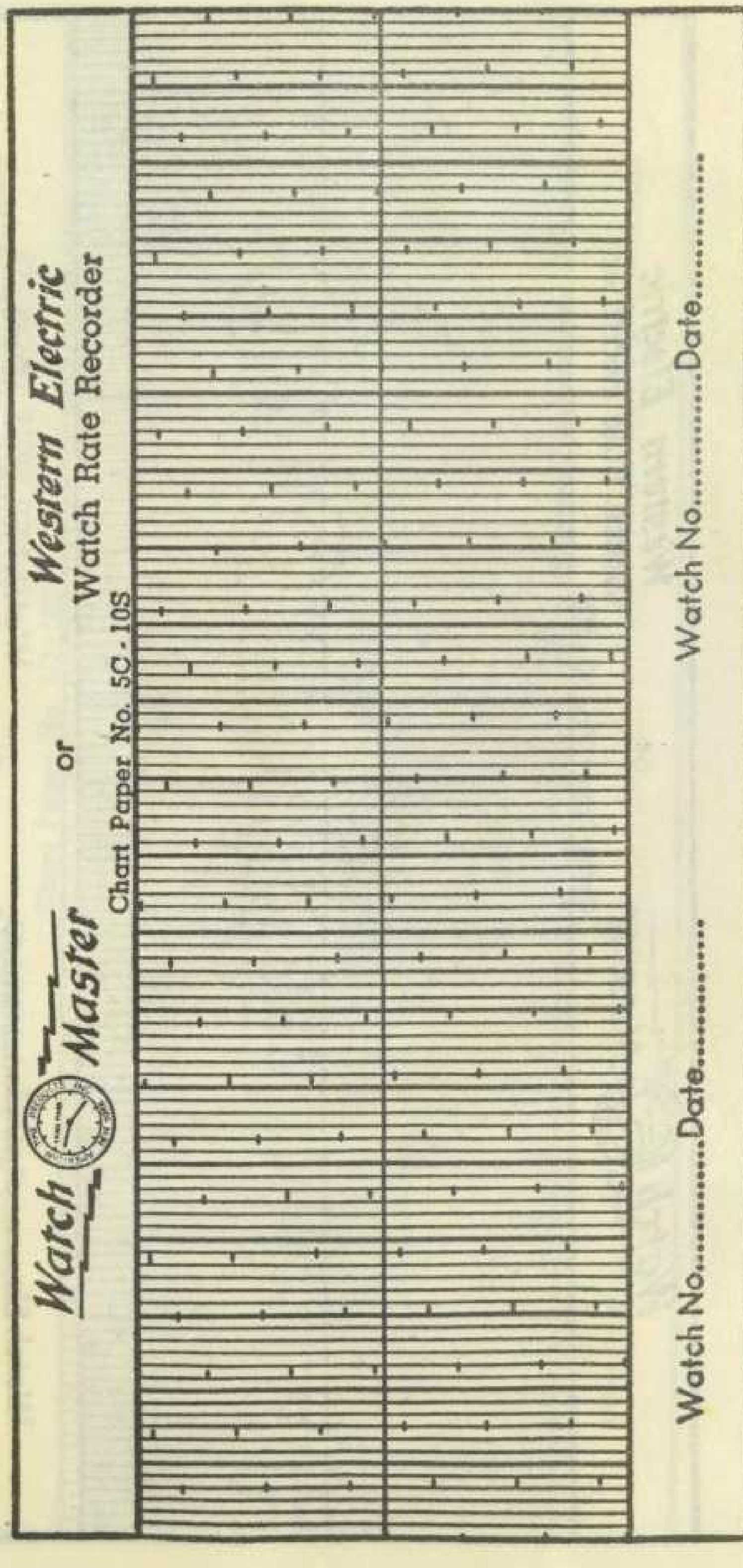
11 lines — horizontal — indicates a correct rate.

If the lines slope upward, the rate is fast—if the slope is downward, the rate is slow. (The same as for 18,000 beat per hour movements.)

Manufacturer	*Model or Size*
Elgin	*Baguette*
Omega	*5½ ligne oval*
Concord	*5½, 7¾ ligne and "R. Cart"*

FIG. 21

Perfect Record
20,160
Beats Per Hour



9 lines — 6 min. 24 sec. "SLOW" — indicates a correct rate.

If the lines do not slope downward as much as this, or if they slope upward, the rate is fast—also if the slope downward is more than this, the rate is slow.

The rate can be easily determined in the manner described in the introduction to this section.

Manufacturer	*Model or Size*
Huguenin	*5½ ligne*
Gruen	*Most small Models*

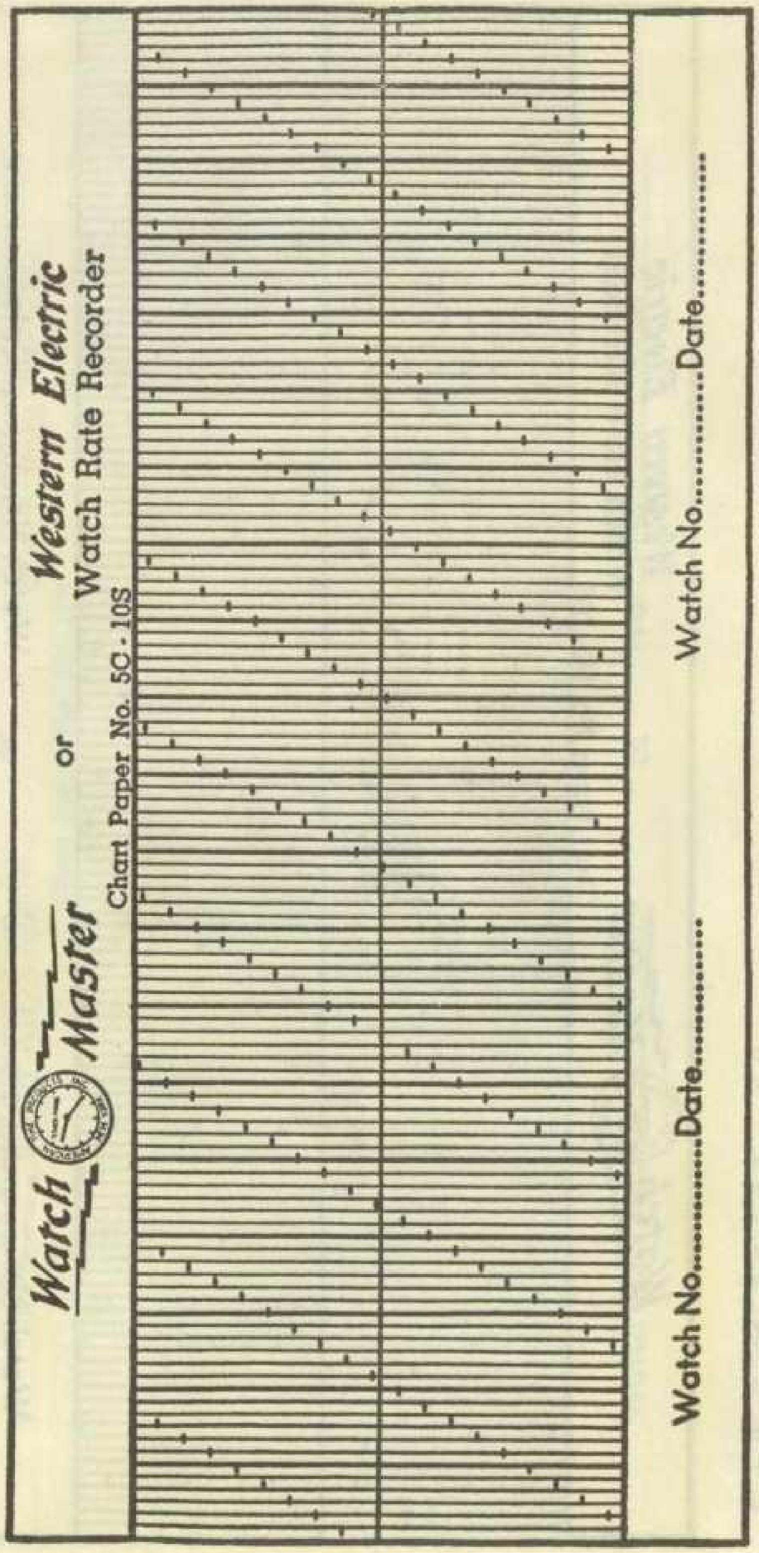


FIG. 22

Perfect Record
20,222
Beats Per Hour

9 lines—2 min. "SLOW"—indicates a correct rate.

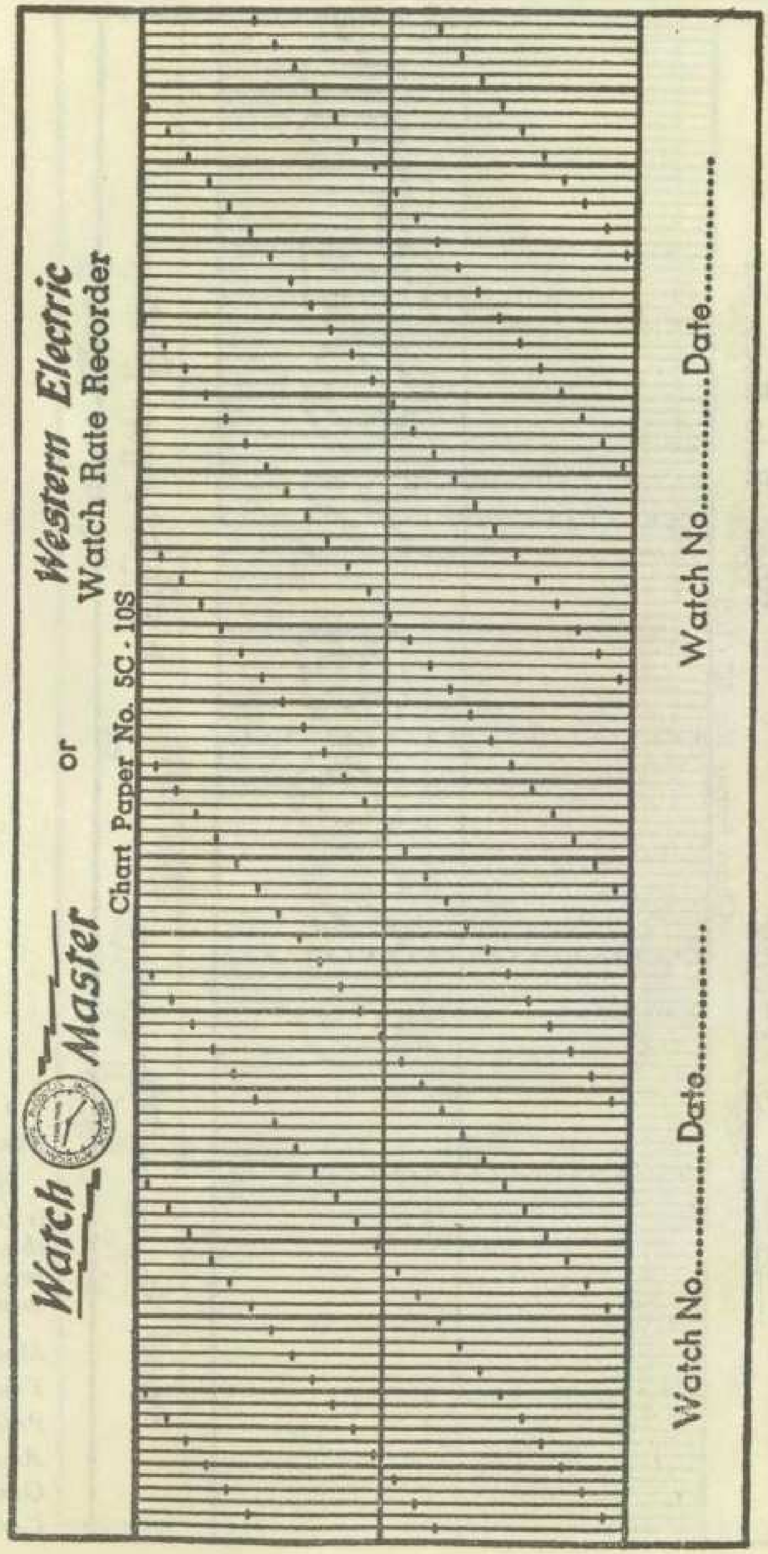
If the lines do not slope downward as much as this, or if they slope upward, the rate is fast—also if the slope downward is more than this, the rate is slow.

The rate can be easily determined in the manner described in the introduction to this section.

Manufacturer	*Model or Size*
Agassiz	*8 ligne (8PCV)*
Meylan	*7 and 8 ligne*
Haas	*8 ligne round*
Gruen (old)	*105, 840, 845*

FIG. 23

Perfect Record
20,944
Beats Per Hour



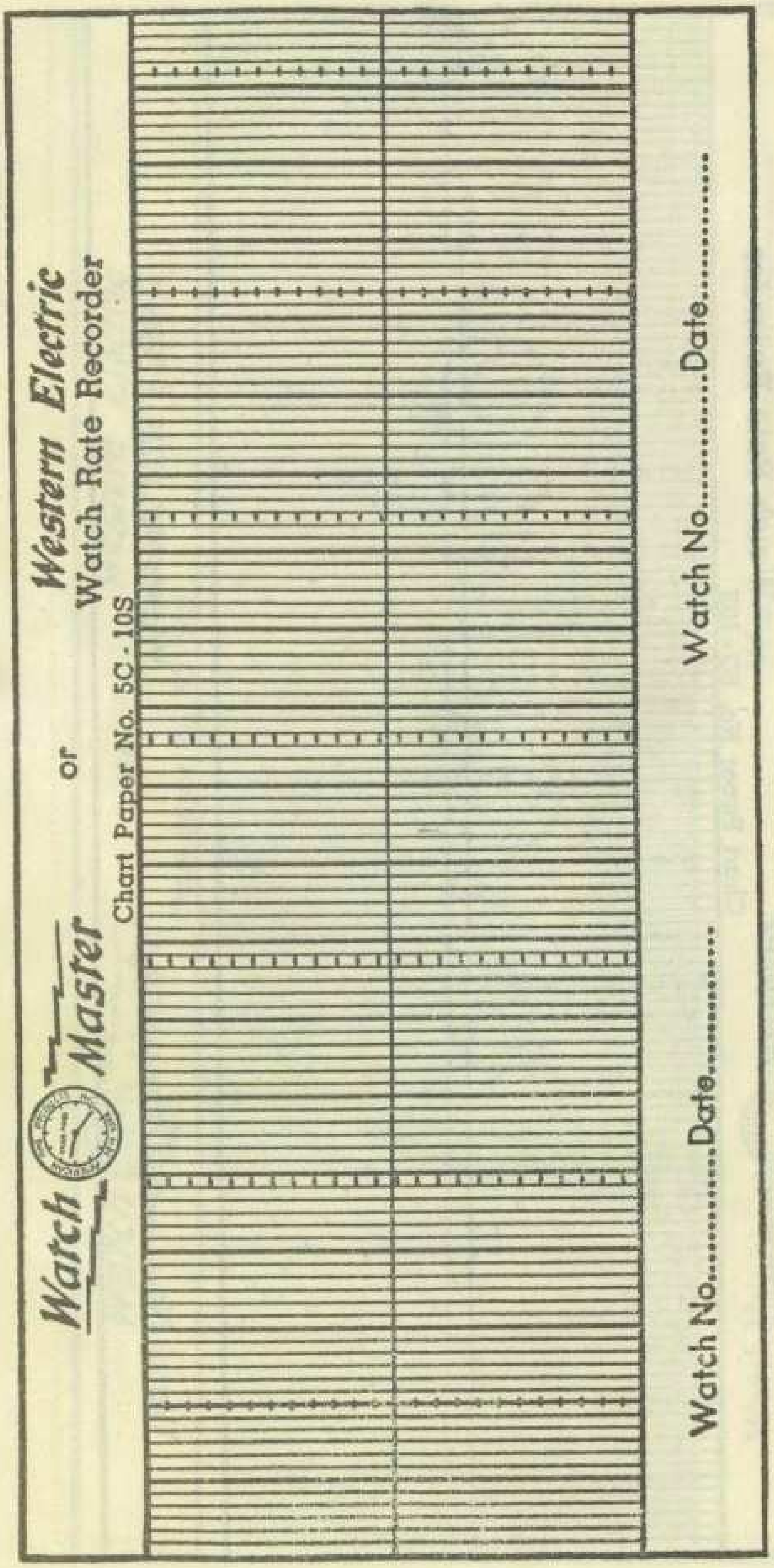
7 lines — 3 min. 50 sec. "SLOW" indicates a correct rate.

If the lines do not slope downward as much as this, or if they slope upward, the rate is fast—also if the slope downward is more than this, the rate is slow.

Manufacturer	*Model or Size*
Vacheron and Constantine	*7 ligne oval*
Agassiz	*7 ligne (PCV, AO, Z)*
Meylan	*7 and 8 ligne*
Nardin	*7 ligne round*
Merrimont	*7 ligne oval*
Gruen (old)	*839, 847*

FIG. 24

Perfect Record
21,000
Beats Per Hour



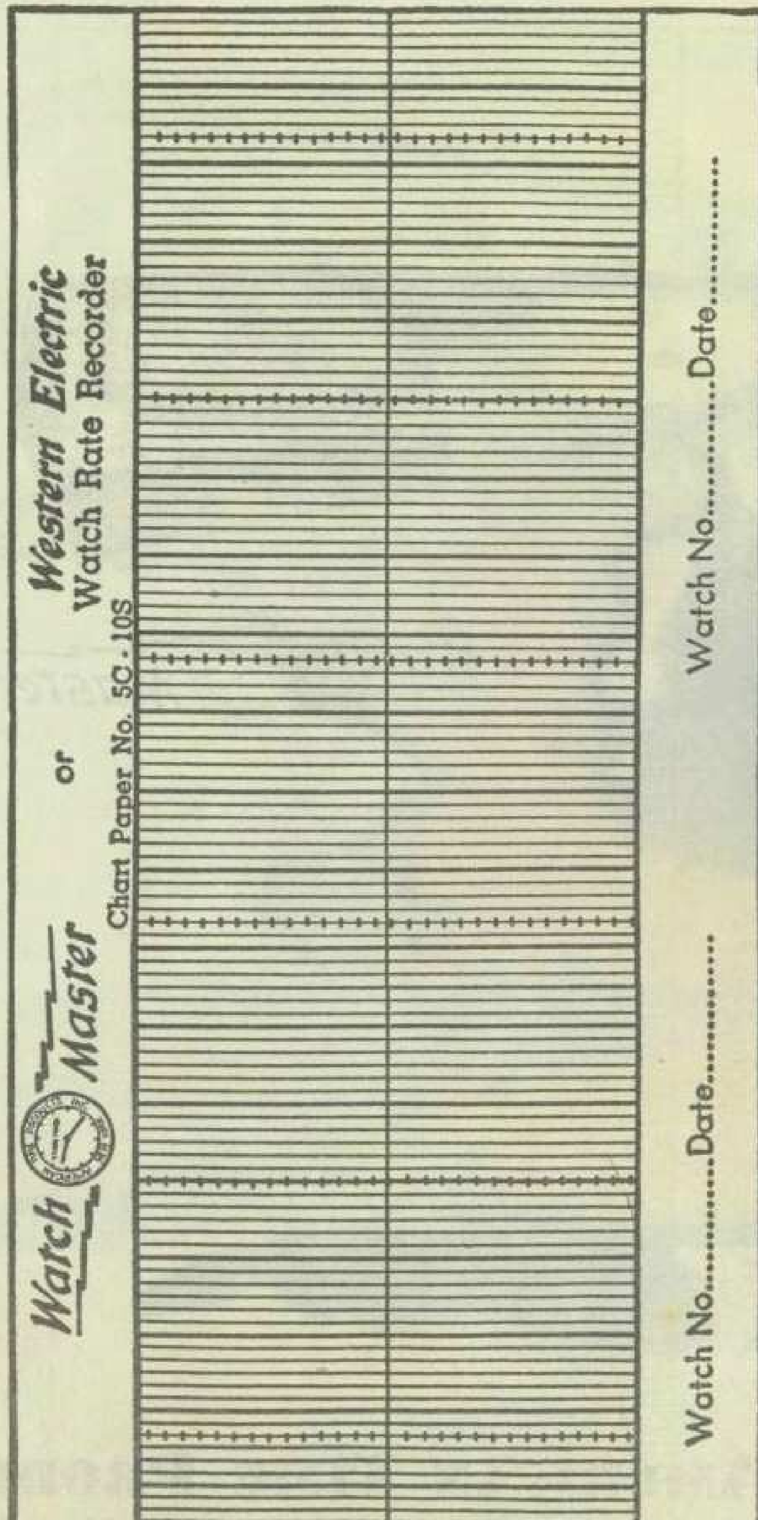
7 lines—horizontal—indicates a correct rate.

If lines slope upward the rate is fast—if the slope is downward the rate is slow. (The same as for 18,000 beat per hour movements.)

Manufacturer	*Model or Size*
Touchon	*4 ligne Rect.*
Patek Philippe	*Baguette*
Audemars Piquet	*8 ligne Rect.*
Omega	*Baguette*
Cartier	*Some Models*

FIG. 25

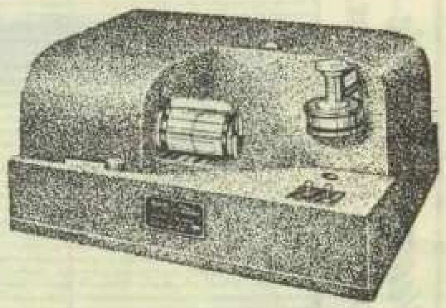
Perfect Record
21,600
Beats Per Hour



6 lines—horizontal—indicates a correct rate.

If lines slope upward the rate is fast—if the slope is downward the rate is slow. (The same as for 18,000 beat per hour movements.)

Manufacturer	*Model or Size*
Agassiz	*8 ligne (8AC)*
Waltham	*Baguett (400)*
Cartier	*Some Models*



Watch Master

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