

PRACTICAL MODERN WATCHMAKING

A SERIES OF
EDUCATIONAL BULLETINS
BY
THE HOROLOGICAL INSTITUTE
OF
AMERICA

For Distribution to Members of the Institute

PART II—MANIPULATION OF WATCH HAIR SPRINGS

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Traditional Time & IHC185



*Horological
Institute of
America*

c/o U. S. NATIONAL BUREAU OF STANDARDS
WASHINGTON, D. C.

MAY - 1942

A Brief History of the Educational Bulletin Service

AT the Institute's annual meeting May 24, 1937, a resolution was passed directing the Chairman of the Educational Committee to submit plans and cost-estimates for a new educational program, which was presented, and authorized by unanimous vote at the 1938 meeting. The proposal was to send to all Institute members, a loose-leaf binder containing an initial set of treatises on the design, construction, repair and adjustment of watches, from barrel to balance; and later to send additional periodical bulletins on new developments in horology as these may appear. A finance committee was appointed to collect the needed funds, a large amount, from members of the trade.

The finance committee reported to the 1939 Institute meeting, that the "business recession" prevented raising the large fund needed for the program as planned. Conditions not having improved sufficiently by 1940, the Advisory Council decided to get started with, at least, a part of the program, which was done, in May 1941, by issuing binders containing articles on the Lever Escapement by H. L. Beehler, President of the Institute—work which was quickly recognized as of outstanding value—and technical data sheets of high value from the Elgin, Hamilton and Waltham watch companies. Institute members were willing to finance this by paying the actual printing and postage costs per volume for the parts issued, until such time as it may become possible to raise funds for completion of the work, by contributions on a large scale, from the trade in general.

In line with the above, the additional treatises herewith covering Hairspring work and its relation to Timing and Adjusting are being distributed; and it is hoped that further articles can be made available from time to time, as important contributions to the literature of horology.

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Washington, D. C.—Feb. 15, 1942.

Manipulation of Watch Hairsprings

Section 1—Hairspring Truing

ILD-TIME hairspring truers make the statement that you cannot teach people to true hairsprings. They must learn it themselves. From the observations of the writer in hundreds of cases this has some semblance of truth. All that really can be done in a teaching process is to supply the watchmaker or learner with the necessary tools and material, make a statement covering the fundamental details, and then demonstrate the actual manipulative operations. The learner must possess intelligence and mechanical aptitude, a proper visual capacity, and knowledge of the work at hand, so that the mental images resulting from observation will be changed into good judgment and effective correction of errors.

After good judgment or correct decision has been made concerning the existing errors, the learner must have the mechanical aptitude required to make the proper corrections. The requirements necessary to become expert in the art of the proper manipulation of hairsprings are intelligence, mechanical aptitude, knowledge and ability. Skill is the development of mechanical aptitude and ability is the sum of intelligence, mechanical aptitude and knowledge.

Success will not come as a result of a few attempts, but will require constant practice and study; study of the results of your own manipulative actions, and comprehension by the learner of the result of these actions. Therefore, obtain a large quantity of old hairsprings, or purchase new ones, bend the outside coils toward and away from the center, grasping the spring at several points from the end. Begin by grasping the spring at a point 90 deg. from the outside end, and bend the spring toward the center, then away from the center. Continue this practice, grasping the spring 180 deg. from the end, then 270 deg. and finally 360 deg. It will be necessary to establish decisions according to the results obtained.

After becoming familiar with the results of the bending operations, your fear of hairsprings will gradually disappear, and as you proceed through the operations required in collecting and truing your degree of skill will depend upon your own efforts in relation to the amount and degree of your mechanical aptitude.

Above all else—practice continually, do not be satisfied with mediocre results, and you may be surprised how easy hairspring work really is.

MAKING THE SPRING

After the hairspring wire has been drawn to the proper width and thickness, the spiral form shown in Fig. 1 is formed by winding two or more springs into a "forming box" in such a manner as to produce a reasonably perfect spiral.

By proper heat treatment the wire is "set" in the form established in the forming box, and when the springs are removed and separated each spring can be

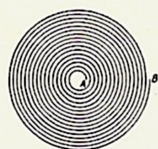


Fig. 1



Fig. 6



Fig. 8

considered a perfect spiral from the point *A* outward to *B*, as shown in Fig. 1.

COLLETING

Tools required: Two pairs of all-steel, hand-made tweezers, No. H3 or 3c (Fig. 2). One 2 in. eye loupe. Do not get in the habit of using a double loupe or straining your eyes by the use of a 3 in. or 4 in. loupe. One



Fig. 2

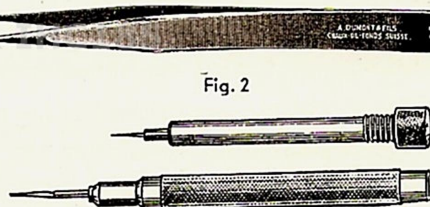


Fig. 3

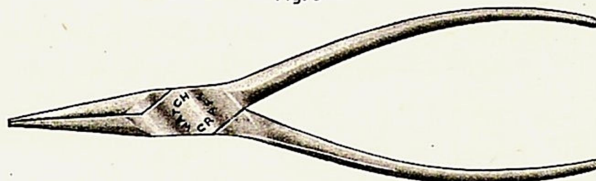


Fig. 4



Fig. 5

collecting arbor (Fig. 3). One pair of fine snipe nose pliers (Fig. 4). One fine quality cutting pliers (Fig. 5).

Material required: Hairspring collets (assorted sizes). Hairspring stud and collet pins. Assortment of hairsprings. Ten 16-size balance wheels fitted with staffs and trued.

All of the material can be purchased in assortments and at low cost. It is advisable to use new material whenever possible. It is obvious that the collets must have a hole diameter to fit the collet shoulder of the balance staffs.

The first step in the colletting operation is to break or cut out several of the inside coils to permit the hair-spring collet to fit the inside of the spring properly (Fig. 6). The amount of spring that should be broken out depends upon the diameter of the collet and the distance between two coils. (Spacing.)

If the diameter of the collet is .070 in. and the space between two coils is .006 in. the distance from point *D* to *G* should be .091 in. (Fig. 7.)

Fig. 7 is representative of a specific case in which it is desired to fit a hairspring with definite dimensions to a collet of specified diameter. From experience and gen-

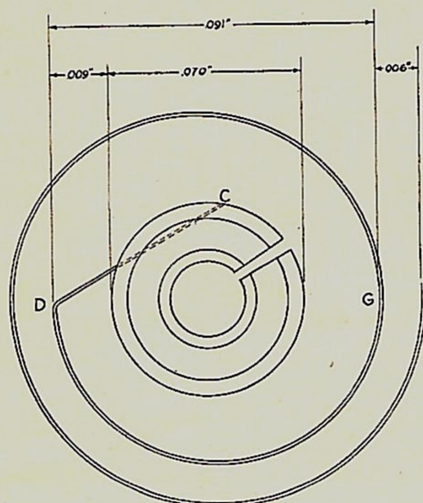


Fig. 7

eral accepted practice, the space from the edge of the collet to the first coil, point *D* is considered correct when it is one and one-half times the space between any two coils.

From the sketch it can be observed that the space between coils is .006 in. One and one-half times .006 in. equals .009 in.

It is also important to realize that by locating point *D*, .009 in. from the edge of the collet, that the point *G*, directly opposite *D*, will be .012 in. from the edge of the collet. This is true because for each full turn of the spiral form, the radial distance will have increased .006 in. Therefore, in a half of a turn it will have increased .003 in.

A careful study of all dimensions shown in Fig. 7 is important, because at first sight one might think that the collet should be located so that each edge or the center would fall mid-way between *D* and *G*. In the following studies the statement is made that a hairspring is true around the collet when the inside coils look like perfect circles, when it is being tested in a pair of hair-spring-truing calipers.

Applying the information given in Fig. 7 to any other combinations of spring and collet dimensions, we can say that the space from *D* to the edge of the collet should be one and one half times the distance between any two coils. Also that the distance from *D* to *G* should be three and one half times the distance between coils, plus the diameter of the collet.

In any event and in the final analysis, it is clear that watchmakers cannot measure these various conditions, and in most springs the exact space between the edge

of the collet and the first coil *may* be more or less than this stated amount. The exact distance will depend upon how close or how far away the spring actually falls when it is true in the round.

To accurately answer the question regarding how far the first coil should be from the edge of the collet is somewhat like the statement of Abraham Lincoln when he was asked "How long should a man's legs be?" He said, "A man's legs should be long enough to reach to the ground."

The length of spring from *D* to *C* should be as long as the collet hole plus the distance from the edge of the collet to the first coil. The spring can then be broken or cut off at point *C*. It is important to keep in mind that the spiral form is perfect up to point *C*, and that all of the coils are on the same plane when observed from the edge of the spring.

FORMING THE TONGUE

The portion of the spring that enters the collet hole is known as the tongue and is shown in Fig. 8.

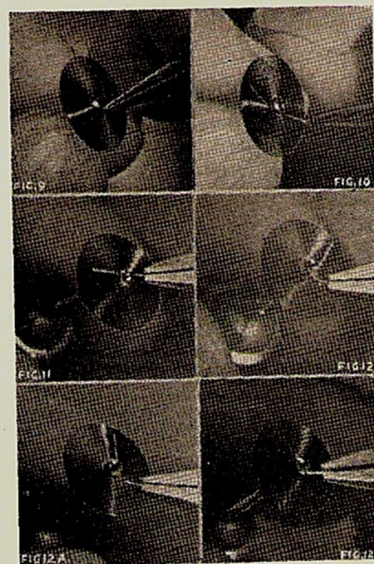
The tongue is formed by grasping the spring at *D*, holding it firmly with one pair of tweezers and with the other pair bending the point *C* toward the center. The bend at *D* can also be made with a pair of overcoiling tweezers, No. 20-0. In this operation the spring must lie flat on the bench. The curved portion is then straightened and laid at such an angle as to permit it to enter the collet hole and allow the collet to be located in the center of the spring, as shown in Fig. 7.

We must now bear in mind that the spring is true up to the point *D* and that the forming of the tongue established the first distortion to the spiral form.

The spring as shown in Fig. 8, with the tongue properly formed is now ready to be attached to the collet. This is known as "pinning in."

PINNING IN OPERATIONS

I—Place collet on colletting arbor, with top of collet upward and hairspring hole toward you.



II—Insert tongue in collet hole by grasping spring firmly at point *D*, allowing tongue to extend away from you. Great care must be taken, so as not to bend or

distort any inside coils. The hairspring can be prevented from tipping by holding the colletting arbor firmly in the left hand and bringing thumb and first finger under the spring so as to hold it flat, as shown in Fig. 9.

III—Place small end of the tapered brass pin in the collet hole, against the side of the hairspring opposite the collet center, and from the same end of the hole that the tongue entered. (Fig. 10.) The pin must enter and leave the collet hole above the main body of the spring.

IV—Pull the tapered pin very tight with snipe nose pliers, using a pulling and twisting motion. (Fig. 11.)

V—Break off both ends of the brass pin still projecting from each end of the collet hole. The projecting ends should be broken off in the following manner:

- (a) Grasp small end of the pin with pliers and maintain a firm pull on pin.
- (b) Turn collet holding tool in a clockwise direction, bending pin at a sharp 90 deg. angle close to collet. (Fig. 12.) The pin will break off clean by slightly reversing motion of collet holder. (Fig. 12-A.)
- (c) Grasp the large end of the pin with the snipe nose pliers, maintain a slight inward pressure on the pin and break off by turning the collet-holding tool in a counterclockwise direction bending pin at a sharp 90 deg. angle as previously described. (Fig. 12-B.) No portion of the pin should project from collet.

It is quite obvious that this operation of colletting requires great care, and at best some or all of the following errors are established. It is well to practice this pinning operation over and over, using several dozen springs, or until it can be done easily.

ERRORS

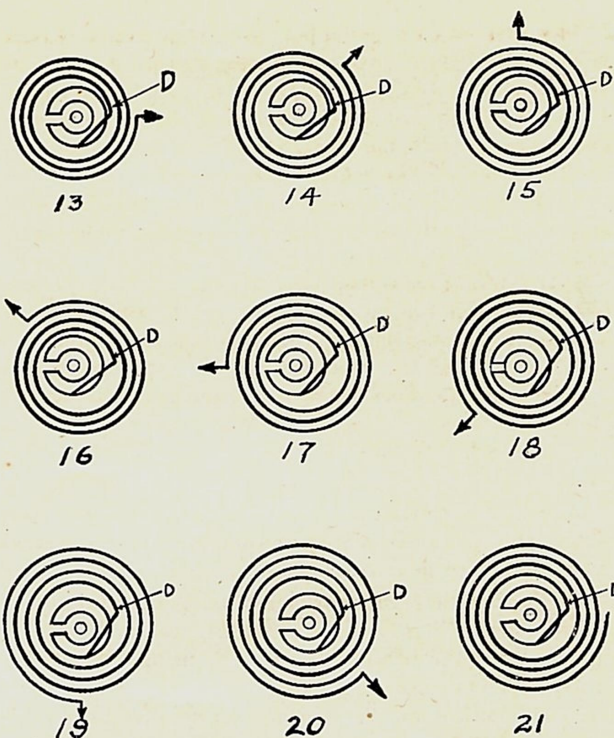
A study of the errors that will be established in the round:

1. Point D at the beginning of the tongue becomes fixed too close to the collet. (Fig. 13.)
2. Point D at the beginning of the tongue becomes fixed too far away from the collet. (Fig. 17.)
3. Point D at the beginning of the tongue becomes bent at an angle so as to fix the first coil too close or too far away from the collet. (Figs. 15 and 19.)
4. Any other combination of errors can also exist as shown by Figs. 13 to 20, an analysis of which shows that the collet is off center in eight different positions. In each, the direction in which it is off center is indicated by the arrow. Fig. 21 shows collet placed properly in center of spiral and when pinning operation is done perfectly, no truing will be necessary.

A study of the errors that will be established in the flat:

Following the original line of thought, that the spring is true in the round up to the point D, Fig. 8, it also follows that if the "tongue" is not bent upward or downward during the operation of bending in the tongue, that the collet will be flat with relation to the spiral portion of the spring and, therefore, the hairspring will be true in the flat.

There are six major errors resulting from the colletting operation that cause the spring to be out of true in the flat:



1. Point C of the tongue is bent down. (Fig. 22.)
2. Point C of the tongue is bent up. (Fig. 23.)
3. Point C of the tongue becomes fixed high in the collet hole.
4. Point C becomes fixed low in the collet hole.
5. The flat face of the tongue is not pinned in a vertical position.
6. The tongue becomes fixed as shown in Figs. 24 and 25.

From these six conditions we may have any one of the four conditions shown in Figs. 22, 23, 24, 25.

When the point C of the tongue is bent downward in relation to the spiral portion of the spring, it will cause all of the coils to be high opposite the pinning point as shown in Fig. 22.

This condition will also exist if the point D is fixed low and the point C high in the hole.



FIG. 22.



FIG. 24

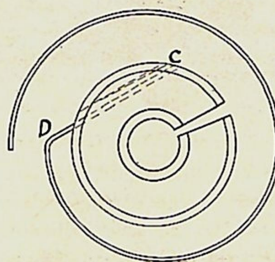


FIG. 23.

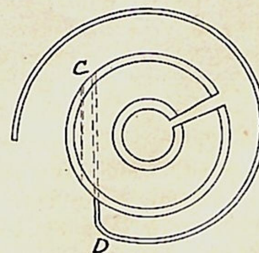


FIG. 25.

When the point *C* of the tongue is bent upward in relation to the spiral portion of the spring, it will cause all the coils to be *low* opposite the pinning point as shown in Fig. 23.

This condition will also exist if the point *D* is fixed

high and the point *C* low in the hole.

When the flat face of the tongue is not pinned in a vertical position, but becomes fixed at some angle as shown in Figs. 24, 25; the spiral portion of the spring will be high, or low, 90 deg. from the pinning point.

Section 2—Truing in the Round

THE term "hairspring truing" has reference to the attachment of the hairspring to the collet. If it were possible to attach the spring to the collet so that the collet would be flat and central with the spring, all springs would be true in the round and flat. The operation of hairspring truing is necessary to correct the errors caused by the "breaking out" and "pinning in" operations.

The actual work consists of bending the first "one eighth coil" so as to place the spring level and central with relation to the collet.

Eight conditions of improper pinning have been previously shown in Figs. 13 to 20. At first sight, it will appear as if the inside coil of each spring is bent and different from each other. Each of these springs, however, is identical and the reason for the difference in appearance is caused by placing the collet slightly off center in eight different directions; this shows the spring out of true in the round, and represents the various errors introduced by "collecting." It explains more clearly that if these eight collets had been properly pinned, perfectly in the center of the spiral, the spring would look like Fig. 21.

HOW TO DETERMINE WHEN THE SPRING IS TRUE IN THE ROUND

The examination of the hairspring for true in the round (and flat) is accomplished by placing the balance wheel, with the hairspring and collet attached, in a pair of "hairspring truing calipers." (Fig. 26.) Hairspring truing calipers of this type, with a steel support for the

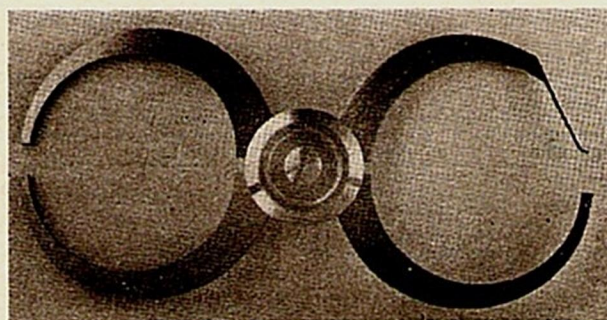


Fig. 26

top pivot, enable one to have a clear, unobstructed vision of the hairspring collet and the inside coils of the spring. They also make it easier to make the necessary bends, with the tweezers. Fig. 27 shows the balance in proper position for inspection in the round and Fig. 28 for the flat. The balance and hairspring must be rotated in the calipers at a speed slow enough to keep the spring from vibrating unnecessarily, and also fast enough to let one observe the errors.

While the balance wheel is rotating in the calipers, if the first three or four inside coils appear as "perfect circles" concentric with the balance staff, the spring can

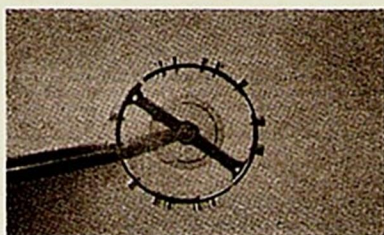


Fig. 27

be considered true in the round. If the inside coils do not appear as perfect circles, but seem to jump, or describe irregular or imperfect circles, then the spring can be considered out of true in the "round."

One of the most difficult parts of spring truing is the ability to see the spring and to determine what are im-

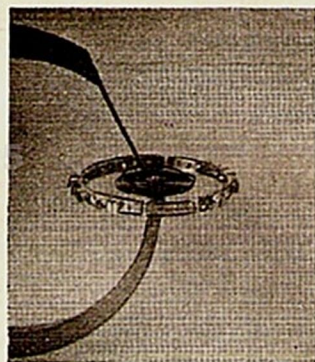


Fig. 28

perfect circles and also to decide where the imperfection is located in relation to the pinning point. For beginners in hairspring truing it is necessary to spend considerable time in actual study of these errors and to be able to decide correctly which of the eight conditions previously shown (Figs. 13 to 21) is your problem.

When examining springs for trueness in the round, do not be misled by expecting to follow the spiral form of the spring, as it rotates in the calipers. You must observe the first three or four inside coils only. When they appear to be perfect circles, the spring is true in the round.

A good learning procedure, is to collet about two dozen springs, then stake them on balance wheels that are true in the round and flat, and also have good staffs and pivots. After the springs are staked on the staffs, the entire assembly should be "dipped" in a good cleaning solution, properly rinsed, dipped in alcohol and dried in boxwood sawdust. Use a camel's hair brush to remove the sawdust from the balance wheel and spring. When

this is completed, each wheel should be placed separately in the calipers. Spin or rotate the wheel at a proper speed and look directly into the center coils, using a 2 in. eye loupe. Study each one of the 24 springs and compare the errors with those shown in Fig. 13. Here also some difficulty will develop, because generally these springs will not be absolutely like those in the drawings. They will, however, be characteristically alike. Go over these springs several times, making a mental or written decision, comparing each spring with the nine conditions shown in Figs. 14-21.

After arriving at a decision concerning the errors of each spring, and having recorded the relationship that exists between the springs and the nine sketches shown, we can then turn our attention to the actual bending operations.

DETAILS OF BENDING OPERATIONS

In the following sketches we will give detailed instructions concerning the necessary bending operations required to correct the errors in the round as represented by Figs. 14 to 20.

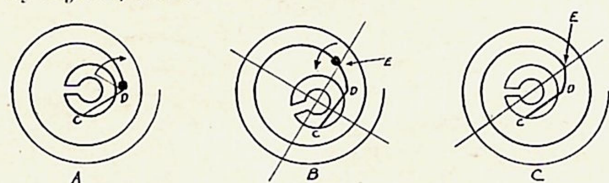


Fig. 29

Specific Instructions for Figs. 13 and 20.

1st. Grasp inside coil at *D* (Fig. 29 *A*) with tweezer points as shown in Fig. 30.

2nd. Bend inside coil away from collet as shown by the arrow.

3rd. Grasp inside coil at *E* and bend spring toward collet as shown by the arrow in 29 *B*.

Experienced spring truers make a pulling bending operation at once, by grasping the spring at *E*, bending the part from *D* to *E* away from the collet and at the same time bending the portion beyond *E* toward the collet. It is advisable to make these bending operations while using an eye glass, so as to teach yourself the exact results of each bend. It is necessary to establish a conscious mental image of how the spring responds to the bends that are made.

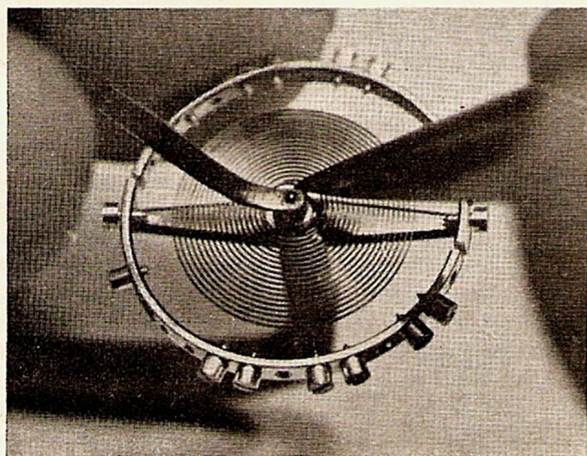


Fig. 30

4th. At 29 *C* the arrow points to the point *E* which must be located the proper distance away from the collet, which is indicated as .009 in. in Fig. 6. It must be understood that this distance depends absolutely on the opening of the spring, or the amount that was broken out preceding the pinning in operation.

It may also be observed that the drawing shows a sharp end at *E*. This bend is not exactly in keeping with the most desirable practice, but should be a general curve as shown in Fig. 8. However, great judgment must be used concerning this debatable condition.

Good judgment is one of the most valuable qualities a watchmaker can possess. One must know when a spring is in a condition to satisfy practical and theoretical requirements and then let it alone. Therefore, in connection with the ideas concerning sharp bends at point *E*, when the spring is true in the round and a sharp bend present, it is advisable to allow it to remain. Further bending to remove the sharp bend will only create other difficulties and also weaken the spring at this point. However, avoid sharp bends if possible.

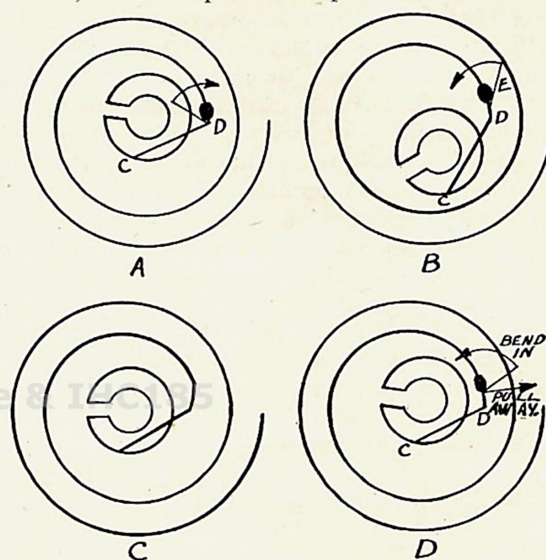


Fig. 31

Fig. 31 is a reproduction, giving specific instructions concerning Fig. 14.

The bending operations in Fig. 31 are very similar to those in Fig. 29, with the exception that here we will consider that point *D* is located almost the proper radial distance from the center, but not quite so. Our sequence of bends will be:

1st. Grasp spring at *D* with tweezer points.

2nd. Bend inside coil away from collet, in the direction of the arrow. It is obvious that the spring must be bent just the proper distance. Practice and experience will reveal this fact to the learner.

3rd. Analyze the conditions shown in Fig. 29. It will be evident that the point *E* will not necessarily be quite as far from *D* as the condition shown in Fig. 31. Also at this stage in the learning process, two or three light bends can be made which should produce the desired curve shown in *C*.

4th. The pulling, bending operation referred to previously can also be used effectively here. Grasp the spring at a point slightly beyond *D* as shown in Fig. 31, sketch *D*. Pull the spring radially away from the

collet and bend the spring inward by turning the tweezers about the point *D* in the direction of the circular arrow.

Fig. 32 is a reproduction giving specific instructions for the errors shown in Figs. 15-19.

In Fig. 32 the point *D* is shown the correct distance away from the collet, but the point *E* which is 90 deg.

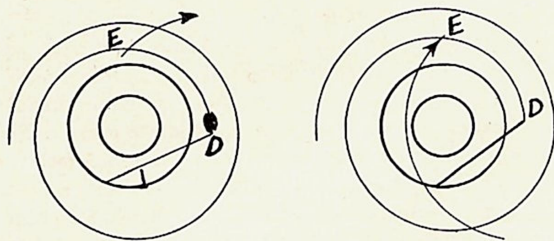


Fig. 32

around the circumference from *D* is too close to the collet.

The bending operation necessary in this condition is simply to grasp the spring at *D* and bend it with the turning motion indicated by the arrow. The difficulty in this operation will be that of bending the point *E* the exact distance away from the collet. If it is bent too far away, the spring will look like the condition shown in Fig. 19, and will require a reverse bending operation from that just described for Fig. 15.

The principle involved for each of these conditions is the same but the direction of bend is reversed.

Figs. 33-34-35 give instructions for the errors shown in Figs. 16-17-18 respectively. The bending operations described here are all of a similar nature and should be studied carefully so as to determine and decide upon the exact direction to bend the spring. In these three figures the direction of pressure is indicated by the inclination of the arrows.

In analyzing the bending operations necessary to true the spring in the round, it can be seen that all correc-

tions are directed toward locating the collet in the center

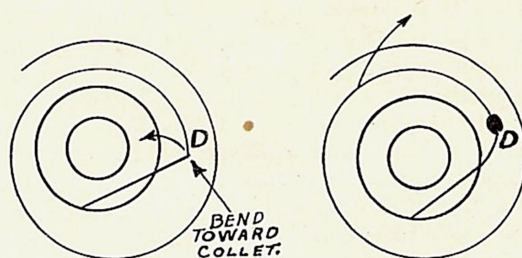


Fig. 33

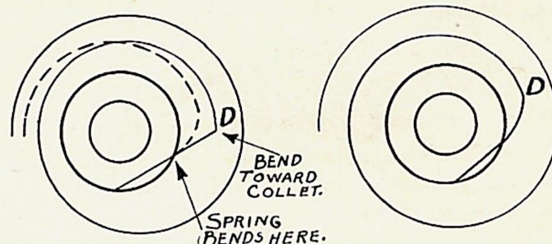


Fig. 34

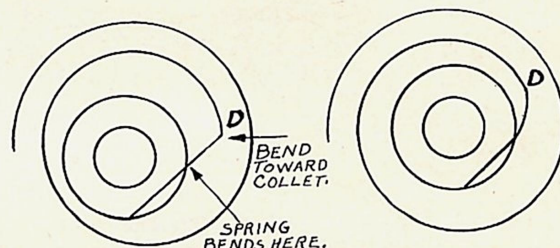


Fig. 35

of the spiral. Much practice and good judgment are required, and also a conscious mental picture of just what happens when certain bends are made. Under no circumstance should a learner make any of these suggested bending operations blindly, but he should observe the actual results with an eye loupe.

Overcoiling

Section 1.

OVERCOILS are formed on hairsprings so that closer isochronal rates may be obtained than is possible with a "flat hairspring."

An isochronal balance unit (balance wheel, hairspring, and roller complete) is one that will have the same period in the high that it has in the low arcs of motion.

In order that a balance and hairspring unit shall possess this quality of isochronism, it is necessary that the torque on the balance staff shall at all times be directly proportional to the angle through which the balance turns. This statement can be more readily understood by a study of Fig. 1.

It is assumed here that the balance wheel is properly mounted in the plates and jewels of a watch. The pallet has been removed so that the balance is permitted to come to rest with the hairspring unstressed and the center of the jewel pin directly on the line of centers of the escape, pallet, and balance jewel holes. In Fig. 1,

the balance arm is pointing to the zero position.

Let us now assume that the balance wheel is manually turned so that the balance arm is moved through an angle of 1° which winds up the hairspring, and thereby places a torque on the balance staff, let us say of .0100 gram centimeter. Now let us further assume that the balance wheel is forcibly moved through angles of 2° - 3° and successively on up to 270° .

If the torque on the balance staff increases in direct proportion to the angle through which the balance is turned, there will be a torque of .0200 gram centimeter at 2° ; .0300 gram centimeter at 3° ; and 2.700 gram centimeter at 270° .

If this condition exists, the balance unit will be isochronal, and the period of the balance will be the same for any angular swing of the balance, from 10° to 270° .

Figure 2 is intended to show that with a flat hairspring the above assumptions are not true, but that as

soon as the balance wheel is moved through angles of 10° - 20° and so on up to 270° , that the eccentric motion of the spring tends to force the balance pivots away from the stud during the winding up process and toward the stud during the unwinding process. The equal torque is, therefore, disturbed by the friction on the staff due to the radial thrust of the spring.

Abraham Louis Breguet conceived the idea to bend the outside coil up and lay it over the top of the main portion of the flat spiral, with the idea in mind of permitting the entire spring to wind and unwind more concentrically.

It was found by practical experiment that a spring equipped with an "overcoil" of this type actually permitted the spring to remain more central during the vibrations of the balance wheel and thereby decreased the isochronal error.

Figure 3 shows the result of a spring fitted with an overcoil. Here we are able to visualize that during the winding and unwinding of the spring that the torque

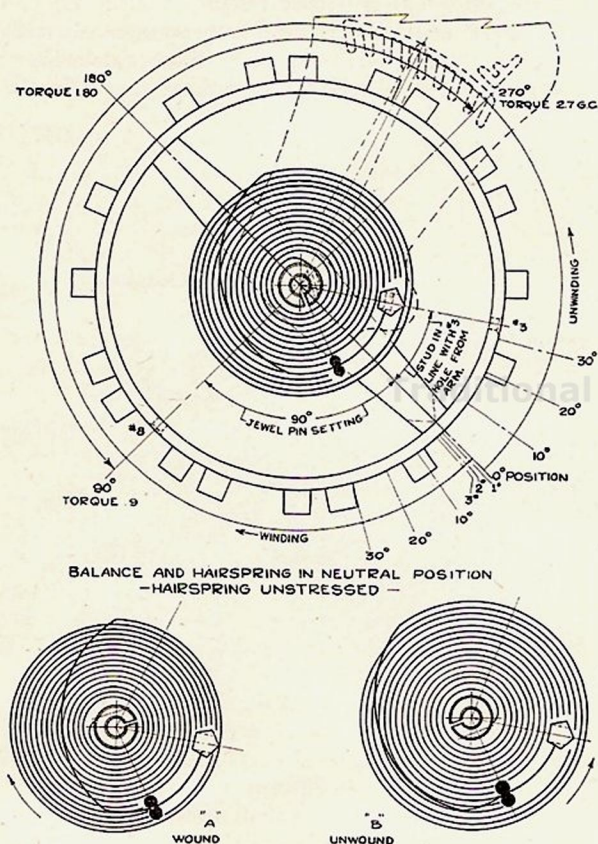


Fig. 1.

on the balance staff will conform more closely to the conditions established in Fig. 1, therefore, more perfect isochronism will result.

The main purpose of this article is to describe and lay down rules for the manipulation of the spring so that overcoils may be formed and altered that will satisfy practical requirements.

We make no claim concerning the absolute theoretical correctness of the form of overcoil presented here, nor do we wish to imply that it is possible to present a perfect isochronal overcoil. For practical watchmakers

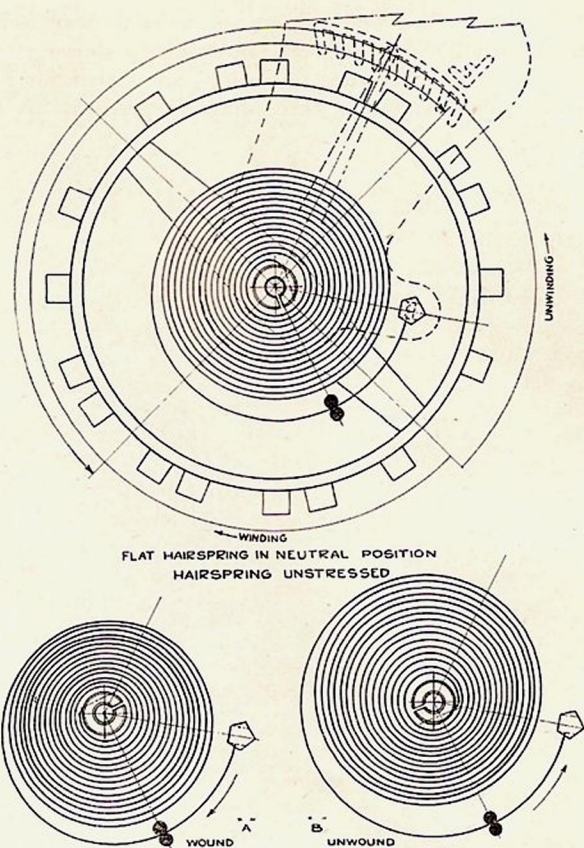


Fig. 2.

working in a field where overcoils of every description are encountered, it becomes necessary to be able to:

1. Form complete new overcoils.
2. Reshape bent and distorted overcoils so that they may function as originally intended.
3. Reshape bent and distorted overcoils so that the spring may satisfy the conditions of proper height and correct centering.
4. Reshape overcoils so that closer isochronal rates may be obtained.

It will be advisable here to consider and make a statement relative to the actual rate changes due to changes in motion when flat springs and overcoiled springs are fitted to balance wheels.

1. With a solid balance wheel fitted with a flat hairspring the isochronal error will usually be as follows: The rate will be slower in the low arcs than in the high arcs of motion. The difference may be as high as 50 seconds between $\frac{1}{2}$ turn and $1\frac{1}{2}$ turns.

2. With a solid balance wheel fitted with an overcoiled spring, in which the overcoil goes almost straight across the main portion of the spiral, similar to Fig. 4, the isochronal error will usually be as follows: The rate will be faster in the low arcs than in the high arcs of motion. From these two conditions it would seem that if an overcoil could be formed that would lie some place between the two extreme conditions shown in Figs. 2 and 4 that the rate in the high and low arcs of motion would be more nearly equal. Practical tests will show that this statement is true.

It can also be seen that bending the overcoil in towards the balance staff will cause the short arcs to take

a faster rate, and that bending the overcoil away from the staff will cause the short arcs to take a slower rate. For Fig. 5 it is intended to clarify these statements by showing the overcoil in three different positions, A, B

CHART SHOWING
HAIRSPRING
WITH AN
OVER COIL

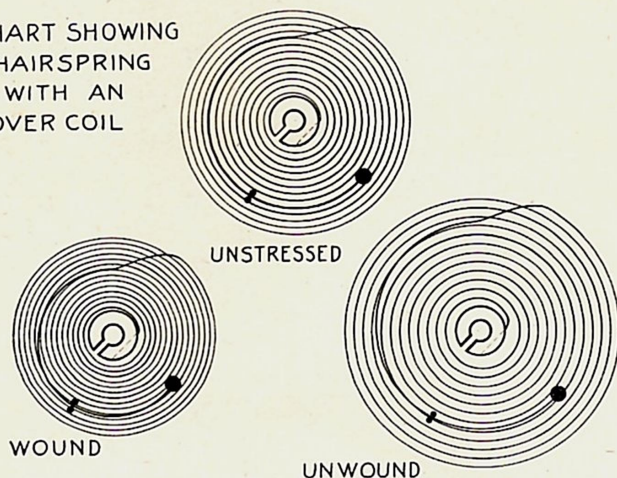


Fig. 3.

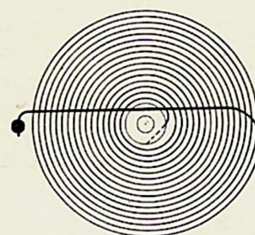


Fig. 4.

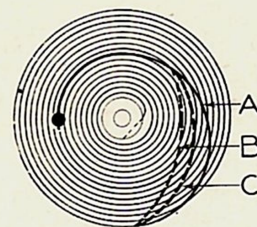


Fig. 5.

and C. Let us assume here that with the original overcoil, represented by A, that the rate is still slow in the low and fast in the high arcs of motion. The portion represented by the dotted lines is bent inwards, towards the staff so as to conform to conditions shown at B. Now the rate has changed so that it is fast in the low and slow in the high arcs of motion. The correction therefore has been overdone and it will be necessary to move the portion shown in dotted lines away from the staff, to the position represented by C.

The effects of these bends can be proven quickly with the use of a timing machine and by those watchmakers possessing the skill necessary to reshape the overcoils.

Section 2.

FORMING THE OVERCOIL

Referring to Fig. 6, we can see that the overcoil starts to rise at point A and from A to B it remains parallel with the adjacent coil 13. At B the spring starts to bend inward forming the coil BCG.

The actual operations required to establish the conditions shown in Fig. 6 are:

1. Grasp the spring at A with a pair of good quality Dumont tweezers held in left hand.
2. Grasp the spring at A with a second pair of Dumont tweezers.
3. Hold the left-hand tweezers rigid in a vertical position so that the spring will lie flat on the bench.
4. Bend the spring upward with the tweezers in the right hand. It will be observed that the spring at B must be raised to the proper heights for the finished overcoil. This will require judgment and skill in making the first bend.
5. When B has been raised to the proper height, it will be necessary to bend the part BC' and G' downward so that it will be parallel with the main body of the spring.

6. The overcoil must now be bent inward so as to form curve BC. This is accomplished by the use of a pair of overcoiling tweezers. Grasp the spring at B with a pair of Dumont overcoiling tweezers 10-1 and squeeze J at a point slightly beyond the 7th coil counting from the outside, as shown at H. No bending is permitted between the two points B and C, because this curve has the same radius as it had before it was bent inward at B.

7. It will be observed that before the overcoil is made, a horizontal line touches the outer end of the flat spring

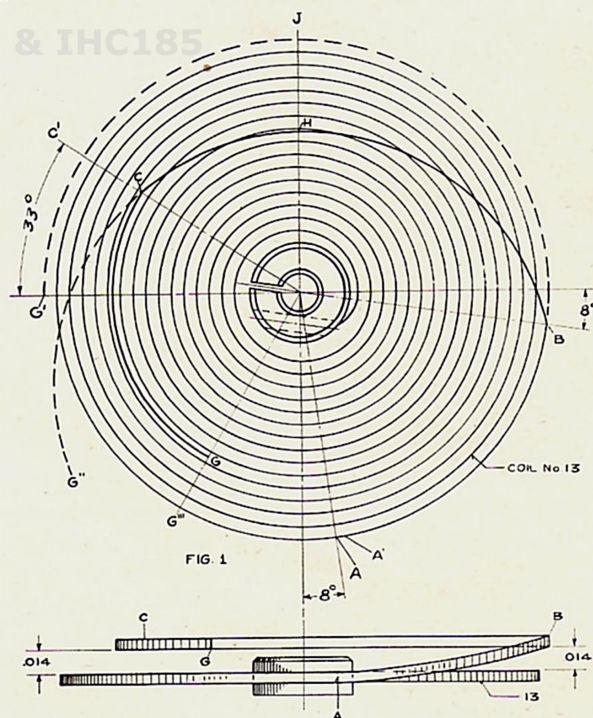


Fig. 6. Where to bend spring to form overcoil.

and goes through the center of the balance staff. Point B is 8 degrees below the horizontal and C' is 33 degrees above it. The point C will be located where a line from C' to the center crosses the overcoil. Grasp the spring at this point with the overcoiling tweezers and bend the remaining part of the overcoil inward. The radius of CG is located on the balance staff; therefore, this curve

must be concentric with the staff, and must be reformed with the overcoiling tweezers to lie between the fifth and sixth coils counting from the outside.

The overcoil must rise gradually from *A* to *B*, and from *B* to *G* it must be the same height from the main body of the spring at all points.

FINISHING

The term "finishing" deals with the leveling, centering, circling the overcoil and proper fitting or closing of the regulator pins.

Before proceeding with explanatory remarks concerning the various manipulative operations of finishing, it may be well to assume certain conditions as follows:

1. That all overcoils are laid correctly, as shown in Fig. 6 (article on overcoiling) so that the entire coil from *B* to *G* is the correct distance above the spiral and the correct distance away from the balance center.

2. That the studs are fitted at perfect right angles to the overcoil.

3. That the regulator pins are correctly located so that the distance from the balance center to center of regulator pins is identically the same as the distance from balance center to the overcoil. (Part *G-C*) Fig. 7.

4. That all stud holes in the balance cock are properly located.

5. That all stud holes in the stud are properly located.

6. That the spiral portion or body of the spring starts at *A* and is level, and at right angles to the balance wheel and balance cock.

7. That the entire spiral portion of the hairspring is centered, therefore the spaces between all coils are equal.

8. That the overcoil is designed and formed so that when properly attached to the stud and the stud fitted to the cock, that the portion *C-G* will conform to the curve made by the regulator pins in moving from *F* to *D*. This portion of the overcoil *C-G* must also be located in the middle of both regulator pins, and remain in this position for any location of the regulator pins.

9. That the overcoil *C-G* is located directly in the center of the regulator pins, and is so perfectly circled that as the regulator pins are moved from *F* to *D* that the portion *C-G* will remain perfectly stationary, not moving either towards or away from the balance staff.

10. That the motion of the balance wheel is $1\frac{1}{2}$ turns in the flat position and $1\frac{1}{4}$ turns in the edge position.

Then the operation of finishing will become merely one of putting the balance and hairspring in the watch.

Otherwise all of the details of finishing are a direct result of the following errors:

1. Studs improperly located on spring
 - (a) Not at right angles to spring.
 - (b) Hairsprings bent at point *G* causing conditions shown in Figs. 8-9.
2. Overcoils too high or low.
3. Variation in the height of overcoils.
4. Radius from balance center to points *G*, *F*, *E*, *D*, *C* more or less than the required standard.
5. Radius from balance center to center of regulator pins more or less than required standard.

RULES FOR FINISHING

A consideration of the stated hairspring errors and the method of correction.

Figure 8 shows the overcoil bent towards the balance staff. This is a direct result of a bend at point *G*. When the stud is placed in balance cock the overcoil should conform to the conditions shown in Fig. 7, but because of the bend at *G*, the overcoil will gradually curve inward towards the balance staff. The correction of this condition is known as "Circling the Overcoil."

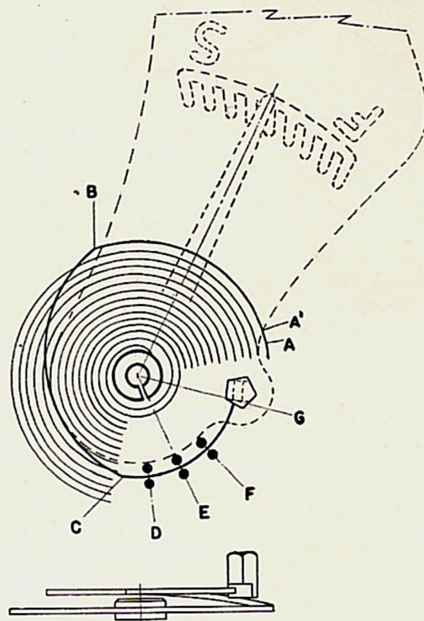


Fig. 7

E, regulator pins, with regulator on center.
F, regulator pins, with regulator to slow.
D, regulator pins, with regulator to fast.

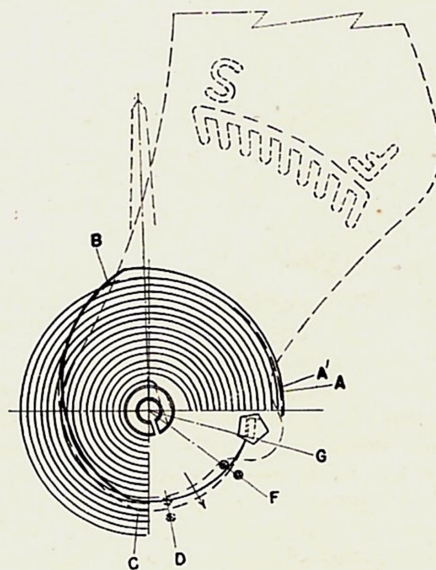


Fig. 8

Chart showing overcoil bent toward balance staff. Arrow shows direction overcoil must be bent to correct.

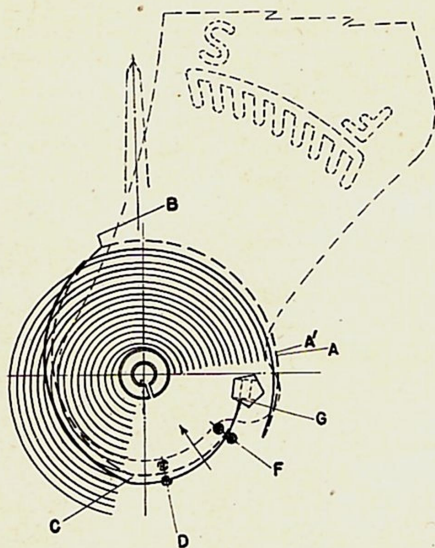


Fig. 9

Chart showing overcoil bent away from balance staff. Arrow shows direction overcoil must be bent to correct.

Inspection of the watch which reveals this condition proceeds as follows:

1. Place regulator at the "slow" side of the balance cock, which moved the regulator pins to point F.
2. Move regulator from "slow" to "fast," moving regulator pins from F to D.

As the regulator pins move from F to D, the overcoil will move away from the balance staff. This shows that the overcoil is not circled. To correct this condition, move the regulator so the regulator pins will be as close to the stud as possible, then bend the overcoil in the direction of the arrow. Repeat the operation of moving the regulator from "slow" to "fast" and again observe the overcoil to determine if it remains motionless, or if it moves either towards the staff or away from the staff.

Figure 9 shows the overcoil bent away from the balance staff. From the explanation covering the condition in Fig. 8 it is possible to make the following statements in reference to circling the overcoil.

1. When the overcoil moves away from the balance staff, as the regulator pins are moved away from the stud, it will be necessary to bend the overcoil away from the staff to correct the error. Fig. 8.
2. When the overcoil moves towards the staff, as the regulator pins are moved away from the stud, it will be necessary to bend the overcoil.

Figure 10 shows the overcoil bent 180° from the stud, bending point B towards the balance staff. The overcoil C-G under this condition will no longer lie over the top of the fifth coil as shown in Fig. 7, but depending upon the amount of bending at the point 180° from the stud, the overcoil may lie over the sixth or seventh coil. All of the coils underneath the regulation pins will be wider apart than the coils underneath the balance cock and the spring will be "out of center."

The remedy for this error is to grasp the spring with a pair of good tweezers 180° from the stud and bend the overcoil in such a manner as to carry point B away from the balance staff.

Figure 11 is just the reverse from Fig. 10 and all of the errors and the remedy stated above will be reversed.

Figure 12 shows the overcoil bent at point B carrying point A towards the staff. This will cause the spring to be "out of center." The remedy is to bend the spring at point B so as to carry point A away from the staff.

If all the figures from 1 to 14 are studied carefully, keeping in mind the conditions shown in Fig. 7, one begins to lay a mental picture of all the fundamental operations of finishing.

ANALYZING THE MAJOR ERRORS

Circling the overcoil. If the overcoil is not circled it becomes apparent at once that the spring undoubtedly was originally bent at point C. Here we have a condi-

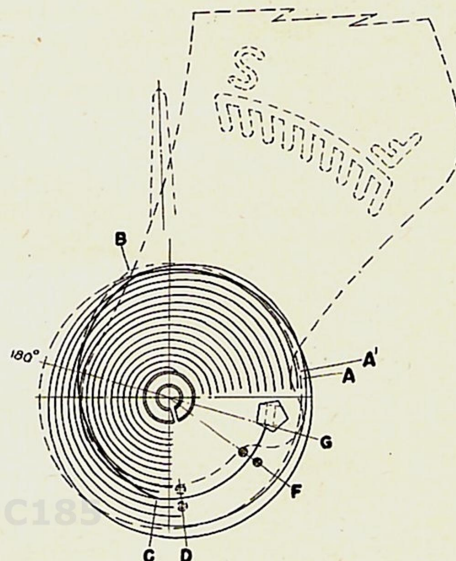


Fig. 10. Chart showing overcoil bent 180° from stud, bending point "B" toward staff.

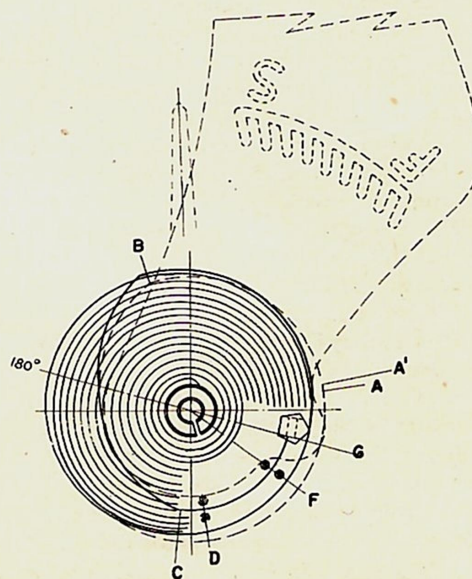


Fig. 11. Chart showing overcoil bent 180° from stud, bending point "B" away from staff.

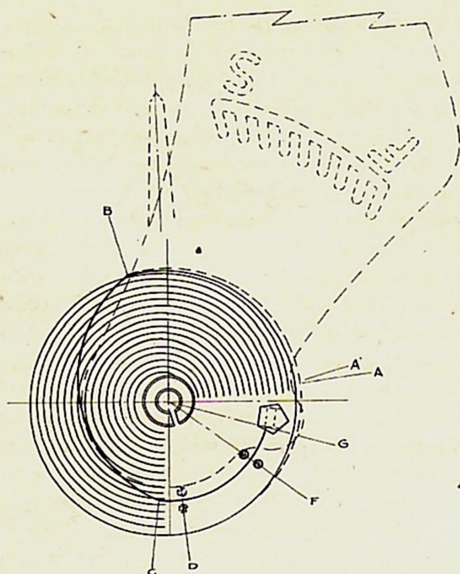


Fig. 12. Chart showing overcoil bent at point "B", taking point "A" toward staff.

tion similar to conditions shown in *Figs. 8 and 9*, the correction of which makes it possible to vibrate the spring and circle the overcoil at the same time.

Vibrating the spring and circling the overcoil. After the overcoil has been bent away from the balance staff as explained in *Fig. 8*, the regulator pins should be

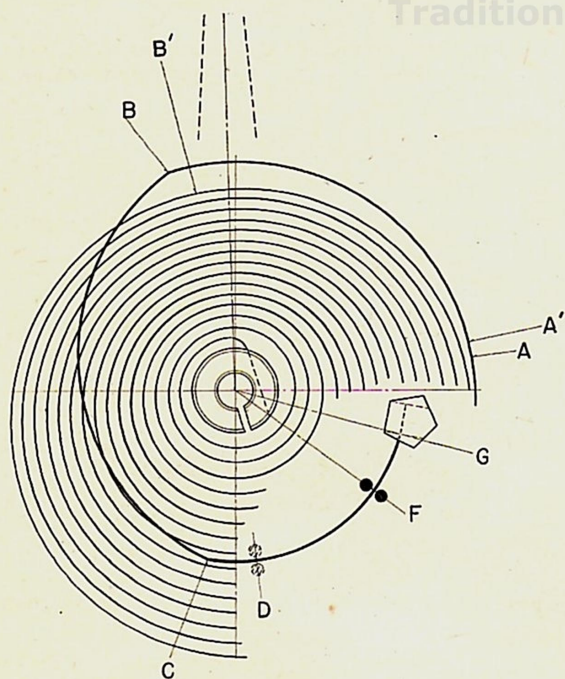


Fig. 13. Chart showing overcoil bent at point "A", taking point "B" toward staff.

moved to position *F*. Look at the position of the overcoil between the pins, and it will probably conform to one of the following conditions:

1. Equally spaced between the pins.
2. Closer to outside pin.
3. Closer to inside pin.
4. Touching inside pin.
5. Touching outside pin.

(Note—During this operation the regulator pins should be straight.)

If the overcoil touches either the inside or outside pin, the overcoil should be bent so as to bring it more central between the pins. This then will establish one of the first three conditions named above.

Let us now assume that the overcoil is directly in the

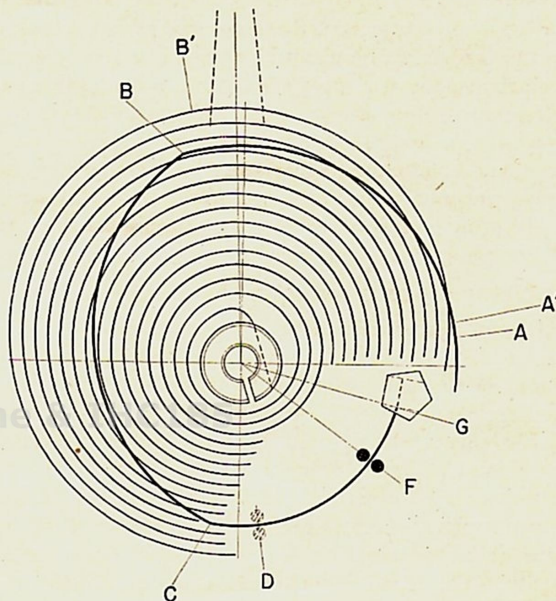


Fig. 14. Chart showing overcoil bent at point "A", taking point "B" away from staff.

center of the two pins; make sure of this condition by stopping the balance wheel with the jewel pin in the fork slot and observe the location of the overcoil with a double eyeglass. Now move the regulator so the pins will be located at *D*, look at the overcoil again and decide if it still remains in the same central position between the pins. If it does, it can be seen that when the regulator pins are closed up to the spring that it will be possible to move the regulator from "slow" to "fast," carrying the pins from *F* to *D* without disturbing the location of the overcoil.

This method of locating the overcoil in the center of the regulator pins for all points from *F* to *D* accomplishes two operations at once. That is, it:

1. Vibrates the spring between the regulator pins.
2. Circles the overcoil.

Adjusting

Section 1.

ADJUSTING should be approached with the knowledge that the balance wheel and hairspring, as a combined unit, constitute the time-keeping element of a watch. The mainspring, train and escapement are

necessary only to establish a means for maintaining the balance wheel in motion and to indicate its period.

Further consideration should be given to the fact that we as watchmakers are concerned only with ways and

means of assembling this unit so as to permit it to function within a degree of accuracy consistent with the design and quality of the watch. Without the ability to do excellent balance and hairspring work, adjusting will be impossible, and for those who have not mastered the art of a proper manipulation of hairsprings, no accurate results can be expected.

The analysis of adjusting can be broken down into three major problems:

- 1st—Temperature adjusting.
- 2nd—Isochronal adjusting.
- 3rd—Position adjusting.

Each of these problems should be considered separately and on its own merits. No attempt will be made in this article to study the disturbing effects of temperature changes upon the balance and hairspring of a watch. This subject has been covered rather completely by the various watch manufacturers in the last 25 years. We are also moving rapidly into an era where the use of self-compensating hairsprings and mono-metallic balance wheels has reduced temperature errors to a minimum, and eliminated the necessity for watchmakers to be much concerned about this condition.

We will, therefore, confine our discussion to a study of isochronal and position adjusting only.

ISOCHRONAL ADJUSTING

It has been shown in the article on overcoiling, Section 1, Fig. 1, (p. 129, June issue) that if the energy stored in the hairspring by the impulse of the escapement releases itself in the form of an equal torque on the balance staff we will have an isochronal balance wheel unit. Equal torque as used here means that all of the energy stored in the hairspring will be utilized in returning the balance wheel to its neutral position, with none of it dissipated in side thrust on the balance staff pivots. The aim of isochronal adjustments, therefore, is to establish the forces of the hairspring so that the watch rate will be the same in the high as in the low area of motion.

Because of the variation in the direction of the forces directed on the balance staff, as a result of the continual

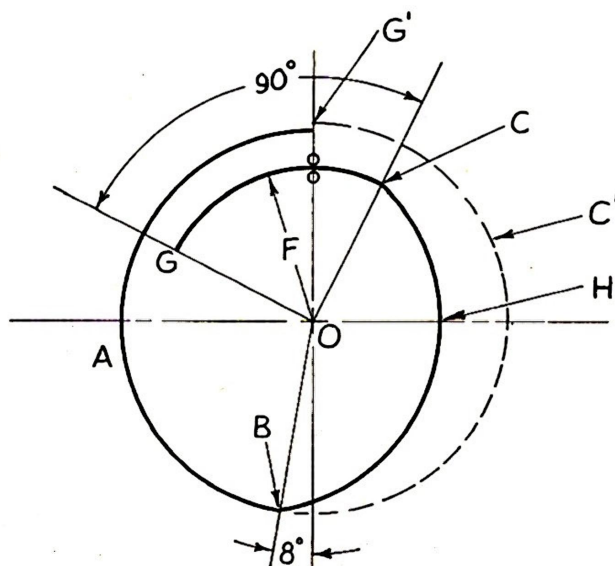


Fig. 15

motion of the inner pinning point at the collet, and its relation to the outer pinning point at the stud, it is a debatable question whether a theoretically correct form of overcoil has ever been developed. However, the design shown in Fig. 15 can be considered desirable, because of its simplicity and because it will satisfy all practical requirements for close isochronal rates.

It will be observed that no empirical measurements or ratios are ascribed to this form, such for instance that the radius F from the balance center to the center of the regulation pins should be .67 of the full radius of the spring. The reason for this lies in the fact that if the hairsprings and overcoils of various watches are examined, it will be found that on some watches the overcoil lies over the first or second coil and on other over the fifth and sixth coil. In fact, it may lie over various coils from the first to the sixth, depending upon the make or grade of watch. Now the makers of these watches either do not know about such a requirement, or they consider it unnecessary, because it is not followed. The isochronal rates of all these watches are, or at least can be, established within a tolerance of possibly not over five or six seconds per 24 hours between $1\frac{1}{2}$ turns and $11\frac{1}{2}$ turns of motion.

The watchmaker is therefore confronted with the unusual difficulty presented by the use of all types of overcoils; he is concerned with and desires to know a practical method whereby he can by slight manipulation of the overcoil, improve the isochronal errors when they are encountered in his daily work.

The actual and only bending permitted on the overcoil is that of laying the portion $C-B$ towards the balance staff or away from it as described in Fig. 5. (Overcoil-

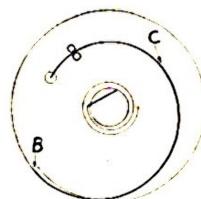


Fig. 16

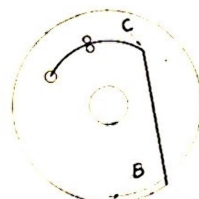


Fig. 17

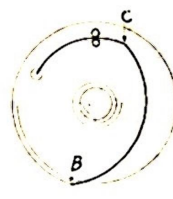


Fig. 18

ing, Section 1, p. 131, June issue.) This rule and condition will be true for all overcoils, regardless of the type. Figs. 16, 17, 18 show the three most common overcoils in use today.

Practical isochronal adjusting is very closely associated with finishing, and the successful bending of that portion of the overcoil which will be called $C-D$, either towards the balance staff or away from it, again requires great skill and much practice. It must be borne in mind that when corrections are made the entire spring and overcoil must satisfy the conditions described in Fig. 7 under *Finishing*.

In the following dimension the word "overcoil" will refer to that portion marked $C-B$, Figs. 6 to 15. (See pp. 95, 97, 99, 101, July issue.) Point C or B specifies the end referred to. Position A , B or C refers to the exact location of the "overcoil" as described in Fig. 5. *Regulator Circle* will refer to the spring included between C and G .

Let us assume that we have just re-conditioned a 16-size watch. With the use of a timing machine its rate

can be taken at 10 different motions, beginning at $\frac{1}{2}$ turn, increasing the motion in steps of $\frac{1}{8}$ turn up to and including $1\frac{5}{8}$.

Table 1 shows the actual rate of the entire isochronal test.

Table 1—Watch Rates; Seconds per 24 Hours

Motion of Balance Wheel	1st Test, Overcoil at A	2nd Test, Overcoil at B	3rd Test, Overcoil between B & C	4th Test, Overcoil at C
$\frac{1}{2}$ turn	-39 sec.	+27	+08	+02
$\frac{3}{8}$ turn	-32 sec.	+20	+05	+02
$\frac{1}{2}$ turn	-24 sec.	+14	+00	+01
$\frac{3}{8}$ turn	-18 sec.	+07	-03	+00
$\frac{1}{2}$ turn	-15 sec.	+03	-05	+00
$\frac{1}{2}$ turn	-10 sec.	+00	-07	+01
$\frac{1}{2}$ turn	-07 sec.	-01	-09	+00
$\frac{1}{2}$ turn	-05 sec.	-01	-08	+00
$\frac{1}{2}$ turn	-05 sec.	+00	-08	+01
$\frac{1}{2}$ turn	-05 sec.	+06	-05	+02

The rates obtained in Table 1 are shown in Graph 1, in which the rates of the watch in seconds for 24 hours are plotted vertically and the motion of the balance wheel is plotted horizontally.

In the first test, the isochronal curve is marked "curve established by overcoil at A." The analysis of the rates as we proceed from the first to the fourth test does not definitely establish the overcoil as being located exactly at A, B or C. The only deduction that can truthfully be made is that the portion of the overcoil from C to B (Fig. 15) is too far away from the balance staff, because the rate is slow in the low arcs and fast in the high.

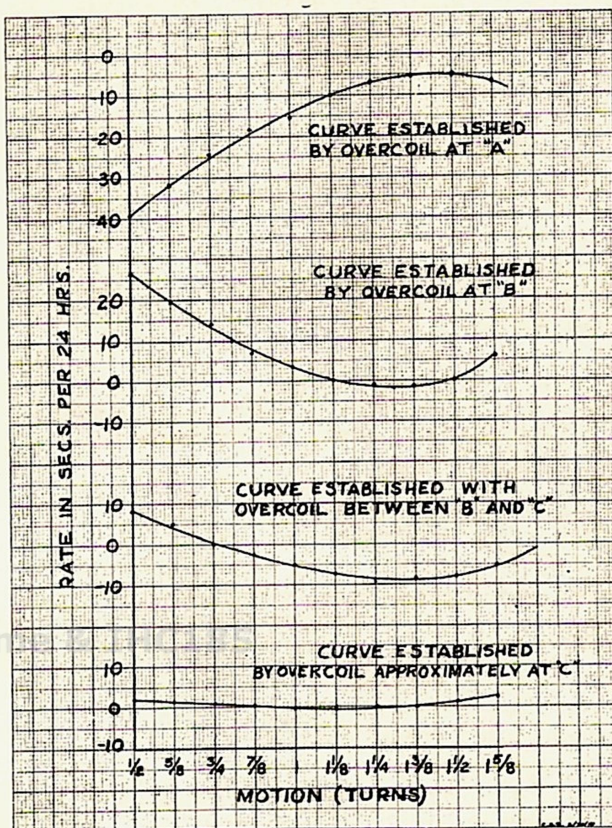
In Test No. 2 the overcoil was bent towards the staff. (See detailed analysis for relocating overcoil.) The isochronal curve for this test is marked "curve established by overcoil at B." Here again it cannot be stated definitely that the overcoil is located at B; all we know is that the overcoil is too close to the staff, because the rate has reversed itself and is fast in the low arcs of motion and slow in the high.

The third test is a slight improvement over the second and by the above reasoning we can assume that the overcoil lies between position B and C (Fig. 5).

The isochronal rate in the fourth test can be considered very good, and from this it is reasonable to as-

sume that the overcoil is correctly located at some place close to its theoretically correct position.

The isochronal rates shown in Table 1 and plotted in Graph 1 were taken with a 16-size watch in excellent condition, and the main coils of the hairspring were bent and centered and the regulator circle properly situated between regulator pins tightly closed.



Graph No. 1

Section 2.

RELATION OF REGULATOR PINS TO THE SHAPE OF OVERCOIL

The proper fitting of regulator pins is a very important consideration in connection with isochronal adjustments. Some watchmakers advocate that isochronal and position errors can be corrected by opening or closing the regulator pins.

All of the isochronal errors shown in Graph No. 1 were established by bending the overcoil towards and away from the balance staff as described in Fig. 5 with the letters A-B-C.

So that a clear picture of the effect of opening the regulator pins can be presented, the tests are continued with the same watch, in the manner shown in Fig. 19.

Five intermediate tests were made following test No. 4 in Table No. 1 and Graph No. 1 which are not recorded here, the desire being to improve the isochronal rate, which actually was accomplished and is recorded in Test No. 1, Table and Graph No. 2. In Graph No. 2 the time variation is represented in minutes per 24 hours, each vertical line therefore is .03 seconds per 24 hours.

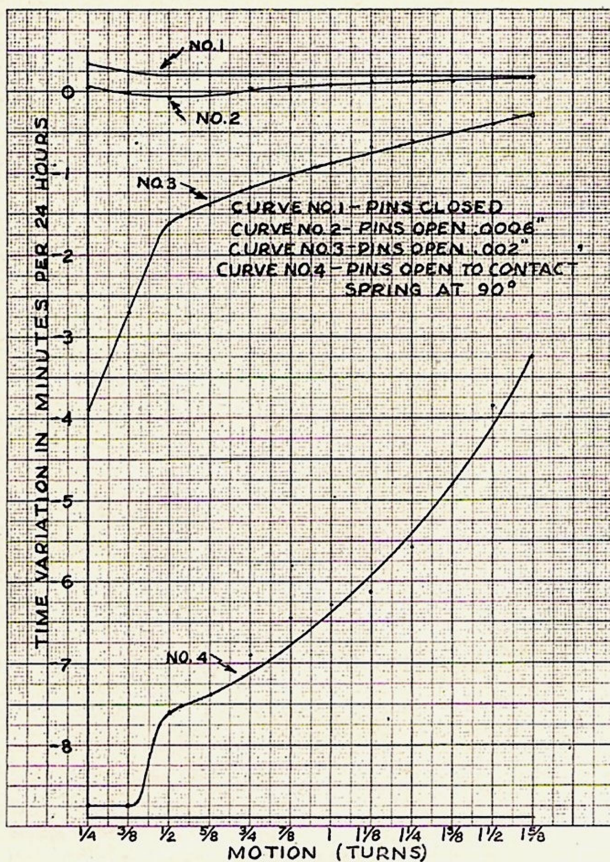
Table 2—Watch Rates—Minutes and Seconds per 24 Hours

Motion of Balance Wheel	1st Test Overcoil at C Reg. Pins Closed Tight	2nd Test Overcoil at C Reg. Pins Open	3rd Test Overcoil at C Reg. Pins Open	4th Test Overcoil at C Regulator Pins Open to Contact at 90°
$\frac{1}{4}$ Turn	+00.21	+00.03	-3.54	-8.45
$\frac{3}{8}$ "	+00.15	±00.00	-2.42	-8.45
$\frac{1}{2}$ "	+00.12	-00.03	-1.36	-7.36
$\frac{5}{8}$ "	+00.12	±00.00	-1.24	-7.24
$\frac{3}{4}$ "	+00.12	+00.03	-1.12	-6.54
$\frac{7}{8}$ "	+00.12	+00.03	-1.06	-6.27
1. "	+00.12	+00.05	-0.54	-6.18
$1\frac{1}{8}$ "	+00.12	+00.06	-0.42	-6.07
$1\frac{1}{4}$ "	+00.12	+00.06	-0.36	-5.36
$1\frac{3}{8}$ "	+00.12	+00.07	-0.30	-4.48
$1\frac{1}{2}$ "	+00.12	+00.09	-0.24	-3.51
$1\frac{5}{8}$ "	+00.12	+00.12	-0.18	-3.15

By comparing the isochronal rate curves of Test No. 2 recorded on Graph No. 1 and 2, we can make the following statements:

1—In order to obtain close isochronal rates it is necessary to have the regulator pins closed.

2—Opening the regulator pins makes the rates in the low arcs relatively slower than the rates in the low



Graph No. 2

areas of motion of the same watch taken with the regulator pins closed.

3—Opening the regulator pins has a similar effect upon the rate as that of moving the overcoil away from the balance staff.

4—Closing the regulator pins has a similar effect upon the rate as that of moving the overcoil toward the balance staff.

DETAILED ANALYSIS OF POSSIBLE METHODS OF RELOCATING THE OVERCOIL SO AS TO OBTAIN CLOSE ISOCHRONAL RATES

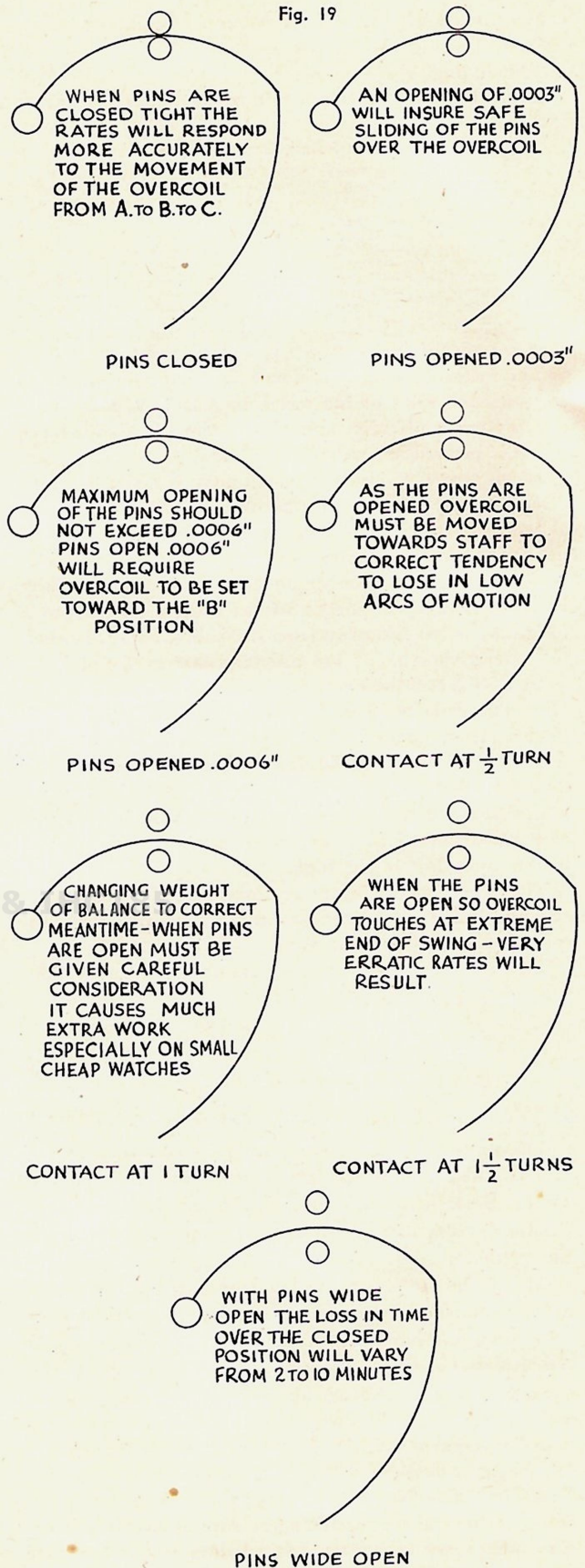
These bending details are applicable to the finishing operation and the minute care in explaining the various bends is to point out that when centering the spring all bends made at points C-B affect the isochronal rate of a watch, also to lay a foundation of basic bends to make finishing better understood and easier to do.

Figure 20—Spring bent at point C, moving regulator circle and stud toward the balance staff. This represents the condition with balance wheel and hairspring out of the watch. Arrow indicates direction of bending.

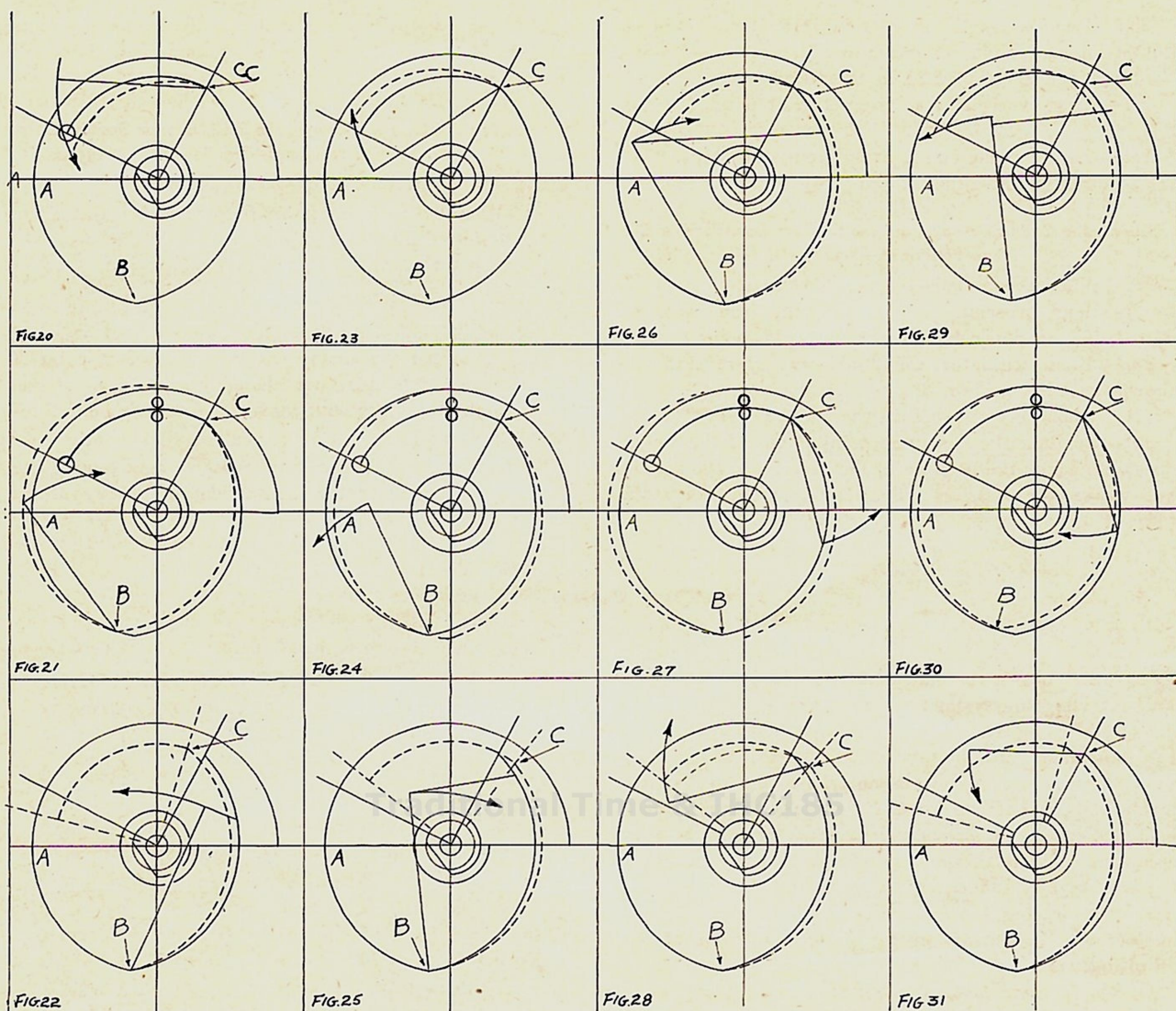
Figure 21—View of same spring after being placed in the watch. It will be noticed that the stud hole and regulator pins locate the regulator circle in its proper place, but due to the bend at point C the overcoil will be held in position B and thereby throw the body of the spring out of center, as shown by the dash line. To center, grasp the spring at point B and bend the outside coil A in the direction of the arrow, or toward the balance staff.

Figure 22—It will be noticed in Fig. 17 that the first bend, at point C, bent the stud toward the balance staff.

Fig. 19



While the hairspring is still out of the watch the overcoil could have been bent inward at point B, as shown in Fig. 22.



A little study of the three Figs. 20, 21 and 22 is worth while. In Fig. 20 it will be seen that the arrows indicate that the spring should be bent toward the staff at point B, and in Fig. 22 the arrow indicates that the overcoil should be bent toward the staff. This seems confusing and contradictory. However, it must be borne in mind, that when attempting to move the overcoil toward or away from the balance staff, the relocating operation always requires two bends. In almost all cases it requires more than two bends, so as to lay the overcoil correctly and make the spiral portion of the spring as perfectly centered as possible. Therefore, it is assumed in this analysis that each bend will be absolutely correct.

Moving the Overcoil Toward the Staff, or from Position C to Position B. Fig. 5 (p. 131, June)

(A) When accomplished out of the watch:

1st—Bend regulator circle and stud toward balance staff from solid to dotted line in direction shown by arrow in Fig. 20.

2nd—Bend overcoil, or position C to position B toward staff from solid to dotted line in direction shown by arrow in Fig. 22.

(B) When accomplished in the watch:

1st—Bend overcoil toward staff at point C (Fig. 21).

2nd—Bend outside coil A toward staff at point B from dotted to solid line as shown by arrow in Fig. 21.

From this we can see:

1st—That bending the overcoil toward the staff from point B out of the watch, requires the stud and regulator circle to be bent toward the staff, from point C.

2nd—That bending the overcoil toward the staff in the watch at point C, requires the outside coil A to be bent toward the staff from point B.

It must be understood further that merely bending the overcoil toward the staff, either in or out of the watch, does not make the correction suggested for isochronism, made in Fig. 5. As stated before, two bends are required in order to keep the spiral or main body of the spring as perfectly centered as possible.

Moving the Overcoil Away from the Staff or from Position C to Position A—Fig. 5

(A) When accomplished out of the watch:

1st—Bend regulator circle and stud away from balance staff, from solid to dotted line, as shown by arrow in Fig. 23.

2nd—Bend overcoil away from staff, from solid to dotted line, as shown by arrow in Fig. 25.

(B) When accomplished in the watch:

1st—Bend overcoil away from staff at point C (Fig. 24).

2nd—Bend outside coil A away from staff at point B, from dotted to solid line, as shown by arrow in Fig. 24.

Moving the Overcoil Away from the Staff or from Position C to Position A—Fig. 5

(A) When accomplished out of the watch:

1st—Bend overcoil away from staff, from solid to dotted line, as shown by arrow in Fig. 26, point B.

2nd—Bend regulator and stud away from staff, as shown by arrow in Fig. 28.

(B) When accomplished in the watch:

1st—Bending the spring at point B out of the watch does not change the position of the overcoil in the watch, but moves the outside coil A away from the staff. (Fig. 27).

2nd—Therefore, the overcoil must be bent away from the staff at point A, carrying the outside coil A toward the staff.

Moving the Overcoil Towards the Staff, or from Position C to Position B—Fig. 5

(A) When accomplished out of the watch:

1st—Bend overcoil at point B toward the staff, from solid to dotted line, as shown by arrow in Fig. 29.

2nd—Bend regulator and stud toward staff at point C, as shown by arrow—Fig. 31.

(B) When accomplished in the watch (Fig. 30):

1st—Bending the spring toward the staff at point B out of the watch does not change the position of the overcoil in the watch, but moves the outside coil A toward the staff.

2nd—Therefore, the overcoil must be bent toward the staff at point C, carrying the outside coil A away from the staff.

Poise

Section 1.

IN order that the balance and hairspring act as a perfect vibrating system, the balance wheel must be influenced only by the energy stored in the hairspring and be totally unaffected by any outside forces. We will assume, therefore, that there is no friction on the balance pivots and our balance wheel is free to oscillate without being influenced by any outside driving force such as an escapement. With these assumptions, it can be seen that the only outside influences that could affect the balance wheel, neglecting temperature, would be *gravity* and *magnetism*. This brings up the problem of poise of the vibrating assembly.

Of the various factors involved in the timing of a watch, poise is probably the main factor in obtaining a watch which will time accurately in various positions. If it is assumed that a hairspring is isochronous, and that a balance system is perfectly poised, a watch should keep perfect time in all positions, independent of the amount of motion of the balance wheel.

The degree of isochronism of a watch can only be determined in the cock-up and dial-up positions. In the vertical positions with the 6, 9, 12 and 3 up, poise will play a very important part in the time obtained from the watch. Since the balance wheel and hairspring make the oscillating system, any out-of-poise anywhere in this system will cause a time-keeping error in different vertical positions.

Not only must the balance wheel, rollers and balance staff be absolutely poised, but the hairspring collet and hairspring as well must be poised with similar accuracy.

This reference to the poise of the hairspring does not mean that the balance wheel should be poised with the hairspring attached, but means that the truing, leveling and centering should be done with such accuracy that the weight or forces of the spring will be evenly distributed around the balance staff.

In case the balance wheel is not poised and is oscillating with the balance staff in a horizontal position, the balance is affected not only by the hairspring, but also

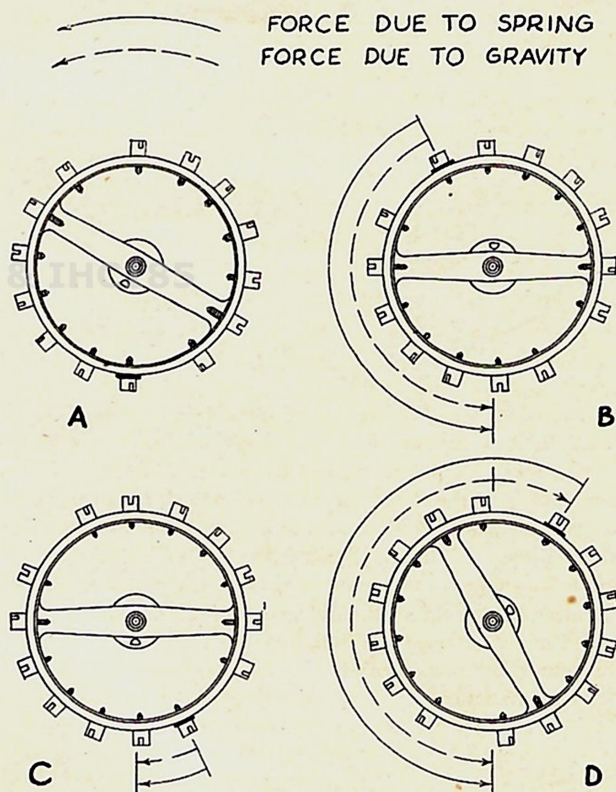


Fig. 32

by the action of gravity on the unpoised portion of the oscillating system.

EFFECT OF GRAVITY

Assume that the balance wheel is out-of-poise due to a weight so placed that when the balance staff lies in a horizontal plane the center of gravity or mass of the balance wheel is directly underneath the center of rotation when the balance wheel is at rest in its zero position. (Fig. 32-A.)

Now consider that the balance wheel is in motion, but moving through less than one turn (180 deg. each side of the neutral position). When the balance wheel comes to rest at the end of an outward swing with all the energy stored in the hairspring as potential energy, the unbalanced portion will be near the top of the balance wheel. (Fig. 32-B.)

As the potential energy in the hairspring is transformed into motion of the balance wheel, the force of gravity acting on the unpoised weight will add additional kinetic energy to the balance wheel in the same direction as that added by the hairspring with the result that the balance wheel will be acted upon by a stronger force and will move faster than when acted on by the hairspring alone. This will make the watch go faster.

Now assume that our unpoised weight has reached the bottom of its path with all the energy stored in the balance wheel, and none in the hairspring. The kinetic energy stored in the balance wheel during the next portion of its path will be given up partly to the hairspring and partly to raising the unpoised portion of the balance. (Fig. 32-C.) Thus our balance wheel will transform its kinetic energy to potential energy faster than if under the influence of the hairspring alone. The result of this is again as if a stronger hairspring were used and the balance wheel during this portion of its path will come to rest sooner. From this it can be seen that if the unpoised balance described above is making less than a one-turn motion, it will take less time to complete an oscillation than a poised balance would, and the watch will be fast.

Now suppose that it is making more than a one-turn motion (Fig. 32-D). Starting with the balance wheel in its position of rest at the extremity of any definite vibration, with all energy stored in the hairspring, during the first portion of its path until the unpoised portion reaches the top, the hairspring will be acting to move the balance wheel in the opposite direction. During this portion of its path, the balance moves as if acted upon by a weaker hairspring. After reaching the top of its path and going down to the zero position of the balance wheel, the hairspring is seemingly strengthened by the energy added to the balance wheel from the unpoised weight. Thus during one portion of the path the unpoised weight is making the balance wheel move slower, in the other portion of its path the unpoised weight is making it move faster than a poised balance wheel, and it might appear that there may be some motion at which these effects would counteract each other.

The figures in Table 3 show the results of an actual test indicating the change in rate between the 12 and 6 up positions, due to change in motion. Counterpoise remains as stated under Fig. 32-A. The difference in rate

MOTION	270°	290°	330°	350°	360°	380°	400°	420°	438°	442°	444°
RATE, 12 UP	57.0	46.0	37.0	33.0	12.6	02.8	01.4	09.8	15.5	17.8	17.4
RATE, 6 UP	74.4	71.6	64.0	59.0	44.2	34.6	27.0	23.8	18.0	18.8	17.4
DIFFERENCE	131.4	117.6	101.0	92.0	66.8	37.8	25.5	15.0	02.5	01.0	00

Table 3

will be in direct relation to the theory laid down in the preceding text and the magnitude of errors will depend upon the amount of weight added to the balance wheel.

Chart No. 3 plots time against motion, and shows

that with a motion of 270 deg. (135 deg. each side of the center line) the 12 up position runs 131.4 sec. faster than the 6 up position. By increasing the motion of the balance wheel this gain of 131.4 sec. is gradually reduced until at a motion of 444 deg. we have obtained a zero rate.

The following explanations are given for the sake of greater clarity in presenting the effects of counterpoise on position rates. All watchmakers who possess timing machines should test a watch in the 12 and 6 up positions so as to check the matter of counterpoise.

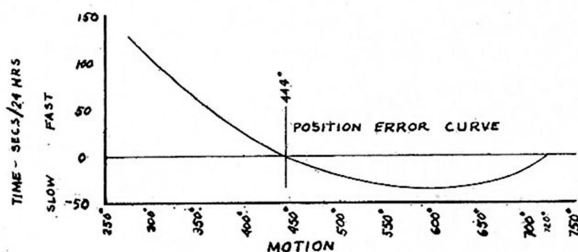


Chart 3

CONCLUSIONS ON EFFECT OF COUNTERPOISE

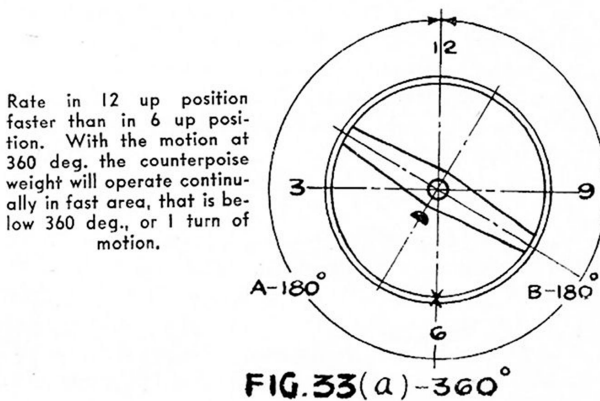
1st. Assume a watch in the 12 up position with the counterpoise weight at the *bottom* of the balance wheel:

(a) If the motion is under 444 deg. ($1\frac{1}{8}$ plus turns), the rate will be *faster* in the 12 up than in the 6 up position.

(b) If the motion is over 444 deg. ($1\frac{1}{8}$ plus turns), the rate will be *slower* in the 12 up than in the 6 up position.

2nd. Assume a watch in the 12 up position with the counterpoise weight at the *top* of the balance wheel, then

(a) If the motion is under 444 deg. ($1\frac{1}{8}$ plus turns),



the rate will be *slower* in the 12 up than in the 6 up position.

(b) If the motion is over 444 deg. ($1\frac{1}{8}$ plus turns), the rate will be *faster* in the 12 up than in the 6 up position.

Analyzing the above conclusions in relation to Fig. 33-a, b, c, it is possible to make the following statements:

1st. When the force of the spring and the action of gravity on the weight are in the same direction the rate will be fast.

For 12 deg. the counterpoise weight is acting in the slow area, or 6 deg. beyond the vertical line. The retarding effect at this motion is not enough to cancel the effect during the 360 deg. before the vertical line, therefore the rate in the 12 up position will be faster than the 6 up rate.

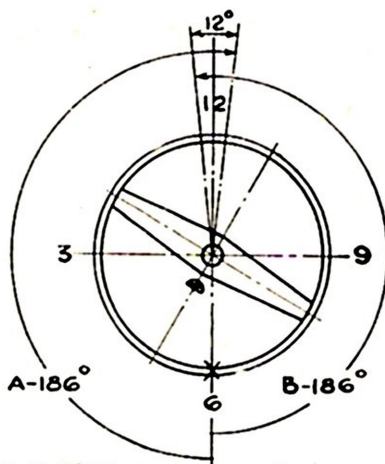


FIG.33 (b) - 372°

Rate in 12 up position will be the same as in the 6 up position. Losing effect of counterpoise weight during 84 deg. of motion cancels gaining effect during 360 deg.

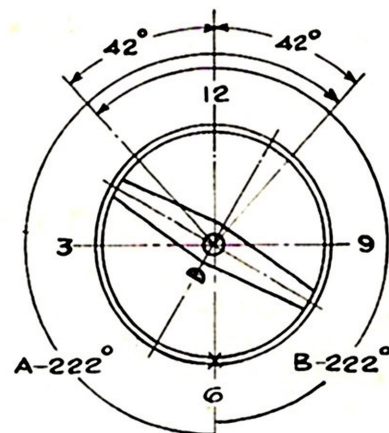


FIG.33 (c) - 444°

2nd. When the action of gravity on the weight and the force of the spring are in opposite directions the rate will be slow.

From these two rules it can be seen that when the counterpoise weight is at right angles to the 12 up position as shown in Fig. 34 that counterpoise will not affect the rate in either the 12 up or 6 up position, but the 9 and 3 up positions then become the axis of greatest vibration.

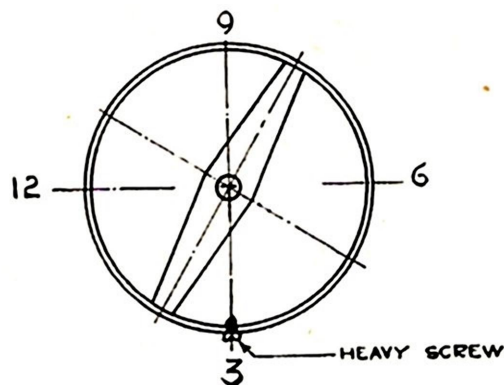


FIG.34

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Section 2

EXPLANATION OF VERTICAL POSITION RATE TABULATIONS

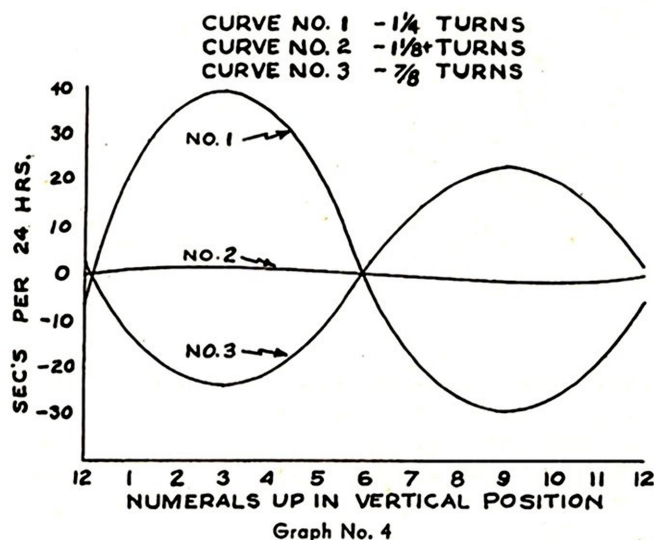
The columns of figures in tables 4 and 5 are timing machine tests indicating 24-hr. rates from which curves No. 1, 2 and 3 in graphs 4 and 5 were plotted.

The first column for each curve shows the number which was up in the vertical position when the particular observation of the 24-hr. rate was made. These are timing machine rates and the readings were taken and recorded in the order shown, 12 up, 1 up, 2 up, etc. The third column for each curve lists the variation in rates. These variations were obtained in the following manner: rates with opposite points on the dial up were compared, thus it is seen that with 12 up the watch runs at -06 or 6 sec. slow per 24 hr., while with the 6 up it runs -01 sec. per 24 hr. slow. From this it is a short step to the conclusion that the watch runs 5 sec. per 24 hr. slower in the 12 up position than in the 6 up position. This is recorded by placing a -05 opposite the 12 up position. Similarly it is evident that the watch runs 5 sec. per 24 hr. faster in the 6 up position than it does in the 12 up position and this is recorded by placing +05 in the rate vibration column opposite the 6 up position. In this manner the other rate variations were determined and recorded.

HOW THE CURVES WERE PLOTTED

An examination of graph 4 will show that the rate or time variation is shown on the vertical scale where one

small division represents a gain or loss of 1 sec. in each 24 hr. The heavy horizontal lines are marked 0, +10, -10, etc., for convenience in reading. Along the horizontal scale the position up is indicated in order from 12 to 12, with each heavy vertical line indicating a new position.



Now if the watch would take a zero rate in all 12 positions we would put a small dot where the 12 vertical lines (12 to 12) cross the zero horizontal line, and when these dots were connected a straight line would be formed. The watches, however, did not take a zero rate as shown in the tabulations, so it is necessary to plot the rates, using curve 1 as an example, as follows:

1. Place a dot on the 12 vertical line, 6 sec. or lines below the zero horizontal line showing that the watch is 6 sec. slow per 24 hr. in this position.

Table 4—Vertical Rate Tabulation for Graph No. 4

Position	Curve No. 1		Curve No. 2		Curve No. 3	
	Rate	Variation	Rate	Var.	Rate	Var.
12	-06	-05	0	0	+02	+01
1	+21	+39	01	+01.5	-13	-25
2	+35	+61	01.5	+02.5	-21	-36
3	+39	+69	01.5	+03.5	-24	-42
4	+34	+61	01	+03	-21	-36
5	+22	+41	00.5	+02.5	-13	-26
6	-01	+05	0	0	+01	-01
7	-18	-39	-00.5	-01.5	+12	+25
8	-26	-61	-01	-02.5	+15	+36
9	-30	-69	-02	-03.5	+18	+42
10	-27	-61	-02	-03	+15	+36
11	-19	-41	-02	-02.5	+13	+26
12	-6	-05	0	0	+02	+01

2. Place a dot on the 1 vertical line, 21 sec. or lines above the zero horizontal line.

3. Repeat this procedure for all positions, 2-3-4, etc., on to 12, placing all slow or minus rates below the zero line and all fast or plus rates above the zero line.

4. Connect these dots in order with a smooth curved ink line. This will form curve 1 as shown.

The different curves 1 to 3 on graphs 4 and 5 were plotted from data obtained under different conditions as is noted both in the tabulation and on the charts. Curve 1 is for a motion of the balance wheel of $1\frac{1}{4}$ turns, curve 3 is for a motion of the balance wheel of $\frac{7}{8}$ turn. Curve 2 is for a motion of the balance wheel of 444 deg. ($11\frac{1}{8}$ plus turns).

It is advisable to check the rate curves with the tabulations to make certain just exactly what it is that the curves represent. It should then be seen that the distance and direction whether up or down from a point on the curve to the zero horizontal line will show just how slow or just how fast the watch is running in that particular vertical position.

Table 5—Vertical Rate Tabulation for Graph No. 5

Position	Curve No. 1		Curve No. 2		Curve No. 3	
	Rate	Variation	Rate	Var.	Rate	Var.
12	-02	-08	+01	+02.5	+06	+10
1	0	-06	+01	+02	+04	+08
2	+02	-02	+00.5	+00.5	+03	+05
3	+04	+04	0	0	0	-01
4	+05	+06	-01	-02	-02	-06
5	+06	+08	-01.5	-02.5	-03	-09
6	+06	+08	-01.5	-02.5	-04	-10
7	+06	+06	-01	-02	-04	-08
8	+04	+02	0	-00.5	-02	-05
9	0	-04	0	0	+01	+01
10	-01	-06	+01	+02	+04	+06
11	-02	-08	+01	+02.5	+06	+09
12	-02	-08	+01	+02.5	+06	+10

particular vertical position, in seconds per 24 hr. The curves when understood give a picture of the variation in rate for each position and their relation to each other.

To convey ideas by means of words and sketches is a difficult task, and many watchmakers look upon charts and graphs as a very mysterious problem beyond their comprehension. This is not at all true, and we urge all

watchmakers to study and analyze this work. Because it will be found extremely simple, once the methods used in this paper are understood.

DISCUSSION OF THE TABULATIONS AND GRAPHS NO. 4 AND NO. 5

From the rate tabulation for graph No. 4, curve No. 1, we can see that the two positions having the greatest variation in rate are 9 up and 3 up where the 9 up is 69 sec. per 24 hr. slower than the 3 up and the 3 up is 69 sec. per 24 hr. faster than the 9 up.

Now let us consider curve No. 3 where the motion of the balance wheel has been reduced from $1\frac{1}{4}$ turns to $\frac{7}{8}$ turns. Here the effect of counterpoise is shown clearly, and as a result of a change in motion all of the fast position rates have changed toward slow and all of the slow rates have changed toward fast.

This bears out the statements made concerning "Effects of Counterpoise." A further analysis of these rates in relation to figures a, b, c will show that for curve No. 3 the 9 up position is performing according to rules given under Fig. 33-a, and the following method can be used to determine the exact point on the balance wheel where the counterpoise weight is located.

1. From rates shown in graph 4 decide which position has the fastest rate. In the low motion, in this case curve No. 3.

2. Observation shows this to be the 9 up position.

3. Let mainspring down, allowing watch to stop.

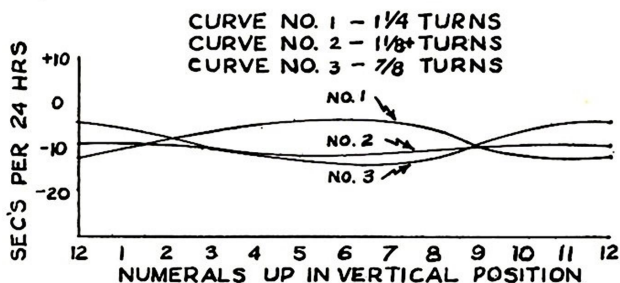
4. Place the watch movement in a vertical position on the bench with the 9 up and 3 down.

5. Have dial facing back of bench and balance wheel facing front.

6. Make a sketch of balance wheel, showing line of centers of escape, pallet and balance jewels, location of balance arms and location of jewel pin. Location of balance screw at bottom.

7. Now wind the mainspring slightly, just enough to drive the balance at a motion of $\frac{1}{2}$ turn. This will cause the heavy screw to move 90 degrees to the left and 90 degrees to the right of its former neutral or vertical position. During this condition of motion the heavy point is operating under the principles explained in Fig. 33-a, that is, one turn of motion or under which should be observed and studied carefully.

8. Wind the mainspring a little more to increase the motion to a point where the heavy screw rises to $\frac{7}{8}$ turn and finally to one turn. At one turn the heavy screw will reach the top of the vertical line and any increase



Graph No. 5

in motion beyond this point will carry the heavy screw into the region where the rate for this distance beyond

the vertical line will be slow instead of fast as shown in Fig. 33-b.

9. Wind the mainspring again, increasing the motion gradually until it reaches its maximum swing. When the heavy screw reaches a point 42 degrees beyond the vertical line it has arrived at a point where the losing effect cancels out the gaining effect as explained in Fig. 33-c.

10. Take the balance wheel out of the watch, remove the hairspring, and place the balance on a poising block or in poising calipers. The heavy screw will then turn the wheel to the position shown in Fig. 34.

The data used to obtain graph No. 4 were obtained from the watch that failed to pass the five position test. It is now obvious that this failure was due to an excessive counterpoise weight located on the 3-9 axis with the 9 up. This was found to be the case upon examination of the balance on a poising block.

The watch that passed the five position test was used to obtain the data for graph No. 5 position rates. Curve No. 1 shows for a motion of $1\frac{1}{4}$ turns. Curve No. 2 is for a motion of $1\frac{1}{8}$ turns, and curve No. 3 for a motion of $\frac{7}{8}$ turn. A comparison of these curves will show that even with a small variation in vertical position rates at any one motion that the shape of the curve tends to become nearly a straight line at a 444 degree motion and reverses its curve at a low motion from what they were

at a high motion. These rate curve characteristics show the action of the counterpoise weight even though it is obviously a very small one, both from the results of the examination and the vertical position rate variations.

The 24-hr. rates in the dial and cock up positions were minus 02 sec.

Now generally speaking if a watch has a zero rate in the flat position with the regular pins open and balance wheel poised, it will have a rate of about minus 15 in the vertical positions. This particular watch had its regulator pins slightly open and the slow rates in the vertical positions as compared to the flat seem to bear this out. Also in the general case, if a watch has a zero rate when in the flat position and regulator pins are closed, the rate will be faster in the vertical positions than it would be if the regulator pins were open.

The fundamental facts shown in this article concerning the effects of counterpoise are not given with the idea of teaching watchmakers how to counterpoise in order to produce good position rates, but just the opposite—they are given so that watchmakers may realize the disastrous results of the slightest poise error any place in the balance and hairspring unit. When these counterpoise effects are properly understood much greater care will be exercised in the hairspring work and also in the work of truing and poising the balance wheel.

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