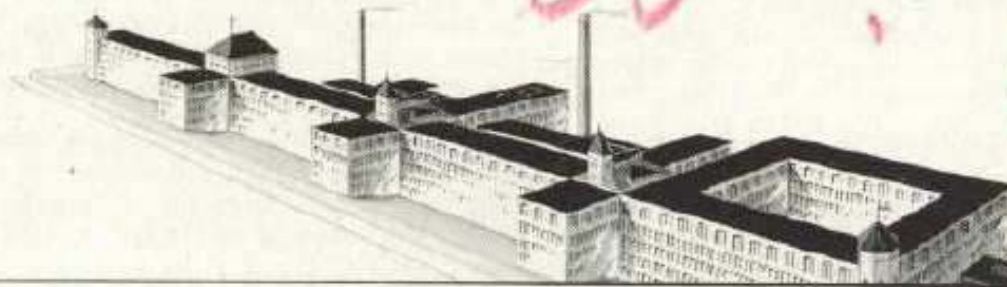# Watchmakers'
HANDBOOK

Watchmakers' Handbook

Revised Edition

WALTHAM WATCH COMPANY
WALTHAM, MASSACHUSETTS

TIME AND TIMING

See the minutes how they run!
How many make the hour complete,
How many hours bring about the day,
How many days will finish up the year.
(Henry VI)

NE revolution of the earth on its axis in relation to a fixed star has, on account of its perfect uniformity, been adopted as the standard for measuring time. We are told that three barleycorns make an inch, and that the distance from the Equator to the North Pole is very near 1,000,000,000 centimeters. But we know, positively, from the calculations of the eclipses that one revolution of the earth is made in exactly the same length of time now as 2100 years ago within ½₀₀ part of a second.

The time required by the earth in making one revolution on its axis, in relation to a fixed star, is called a sidereal day, and is about ⅓₆₅ shorter than a mean solar day. This difference is caused by the earth's travelling around the sun once a year, in what might be called the same direction as it revolves on its axis. This, from our point of view, makes the sun lose one round in every 366, as compared with the fixed stars.

True sun time is the time occupied by the earth in making one revolution on its axis in relation to the sun, — that is, from midday to midday, as the sun passes the meridian. The duration of these intervals varies during the year, because the earth's orbit around the sun is not circular, but elliptical, with the sun in one of the foci. The earth travels faster when it is in the part of this orbit which is nearest the sun, on account of the greater attraction of that body. The variation of time during a year from this cause is as great as seventeen minutes plus or minus from mean time.

Mean time is obtained by dividing a whole year in as many equal parts as the number of solar days it contains. If we take one of these mean solar days of 86,400 seconds for a comparison, the sidereal day is 86,164.09 seconds long, or exactly 3 minutes 55.91 seconds shorter than the mean solar day.

To illustrate the general principles of timing, it may be of interest to first make a comparison between the balance in a watch and the pendulum in a clock, as both of them evidently perform the function of measuring, or beating, time.

HOW THE PENDULUM WORKS

The pendulum, as we all know, requires no special spring to bring it to its center line, the perpendicular, as the force of gravity furnishes the necessary power for doing this work in a very ideal way. When a pendulum is put in motion, it makes a vibration in a certain interval of time, in proportion to its length, regardless of its weight, because the force of gravity acts on it in proportion to its mass. The length of a pendulum is reckoned from its center of suspension to its center of oscillation, which latter point is located a short distance below the middle of the bob. If a weight is added above this point, the clock will gain, because it raises the center of oscillation and has the same effect on the timekeeping as raising the whole bob, which is equivalent to a shortening of the pendulum. If a weight is added below this point, it has the opposite effect, as it really lengthens the pendulum.

Reasoning from these facts we come to the conclusion that we can make a certain change in the rate of a clock in three different ways. We may make it gain (1) by raising the bob, (2) by adding weight above the center of oscillation, and (3) by reducing the weight below that point.

An interesting fact in relation to the pendulum, which may not be generally known among watchmakers, is that its rate of vibration varies slightly with change of latitude, and also of altitude (that is, its height above the sea level), making a clock lose at the Equator and at high altitudes, and gain as we go nearer the sea level and the Poles. This is due partly to the distance from the center of the earth, which is greater at the Equator than at the Poles, and partly to the centrifugal force resulting from the rotation of the earth on its axis.

WALTHAM ★ ★ ★ *First American Watch*

Page 2

Both these factors tend to make an object weigh less (on a spring balance), at the Equator than at the Poles, and also cause a change in the rate of a clock. In a table on page 31 is given the value of gravitation (g) and the length of a pendulum beating seconds (1) for a few principal points, and also formulas by which these factors may be calculated for any place on the earth of which the latitude is known. In view of these facts we might state, as a fourth way of making a clock gain — although not a very practical one — is to move it to a locality nearer the Pole.

HOW THE BALANCE WORKS

A balance differs from a pendulum in three fundamental respects: first, it is poised; consequently the force of gravity has no effect on it, except as it influences the friction on its pivots; second, the oscillations are controlled by a spring instead of the force of gravity; third, a weight added to a balance will increase its inertia and hence will always make it vibrate slower, provided it is not thereby put out of poise. The retarding effect will be greater the farther the weight is placed away from its center since the inertia of the balance depends not only on its weight but also on its diameter.

One difficulty encountered in the first attempt to make accurate pendulum clocks was the variation in the dimensions of metals caused by difference in temperature. All metals have the property of expanding with increase of temperature, the different metals showing a somewhat different rate of change. An alloy of iron and nickel (64 parts of iron and 36 parts of nickel) called Invar expands less than any other metal; less than $\frac{1}{10}$ as much as iron — over the same temperature range.

In the timing of clocks the length of the pendulum is all-important. In a watch the rate is affected by the stiffness of the spring, as well as the dimensions of the balance and spring. As temperature affects all these factors, especially the stiffness of the spring, it is absolutely necessary to devise some means of compensation before reliable timepieces of either form can be made.

So far as this problem applies to clocks, the mercury pendulum proves to be a very satisfactory solution, at least so far as accuracy is concerned. The bob of this pendulum is composed of one or more tubes of glass or iron, and these tubes are filled with mercury to a certain height. When of proper dimensions, the expansion and contraction of this column of mercury raises or lowers its mass to exactly compensate for the change in the length of the pendulum rod due to variations in the temperature.

This method, although very satisfactory for clocks, cannot, of course, be applied to watches, for obvious reasons, but for this purpose we make use of the property of the metals alluded to above, namely, the difference in the ratio of expansion in different metals.

A number of holes are drilled radially through the bi-metallic rim, and these holes are tapped to receive the balance screws. Usually about twice as many holes are made in the rim as the number of screws used in the balance; this is done to give opportunity for moving the screws in the final adjusting to temperatures. The object in using screws in the balance rim is twofold: first, to provide the necessary weight (mass) in the rim, and second, to have this weight movable for temperature adjustments, as stated above.

EFFECT OF TEMPERATURE

Figures 1-7 inclusive show how change in temperature affects the bi-metallic rim of the balance. With a rise in temperature, the free ends of rim bend inward toward the center thus reducing the effective inertia of the balance and compensating for the decrease in strength of the hairspring. This is the greatest source of error resulting from the temperature change.

When a watch is to be adjusted to temperatures, it is run 24 hours, dial up, in a temperature of 90 F., and its rate compared with a standard. It is then run 24 hours, dial up, in a temperature of 40°F. If it shows a gain in the 40° temperature, as compared with the running in the 90°, it is said to be under-compensated. This is remedied by moving some screws nearer the free ends of the rim.

WALTHAM ★ ★ ★ *Watchword of Quality*

STEEL

BRASS

Figure 1

Figure 1 shows two bars of metal of equal lengths when at normal temperature. The dotted lines indicate the relative amount of expansion of the two metals, steel and brass.

STEEL
BRASS

Figure 2

Figure 2 shows the two metals joined by fusion.

STEEL
BRASS

Figure 3

Figure 3 shows the effect of heat on the bi-metallic bar. The greater amount of expansion of the brass portion causes the bar to curve upward.

STEEL
BRASS

Figure 4

If cold was applied instead of heat the bar would be turned in the opposite direction as shown in Figure 4.
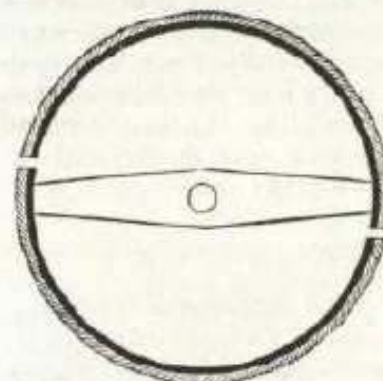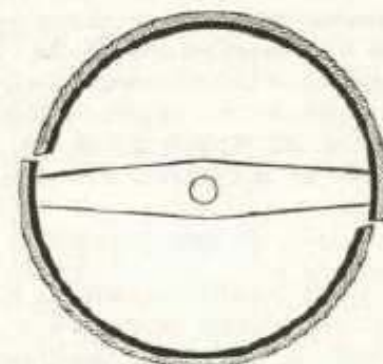
Figure 5

Figure 6

Figure 5 shows a watch balance in which the arms and inner portion of the rim are of steel. The outer portion of the rim is brass, fused to the steel rim, the rim being severed at two points near the arm, thus allowing freedom for the movement of the rim under the changes of temperature. Figure 6 shows this balance under the influence of heat.
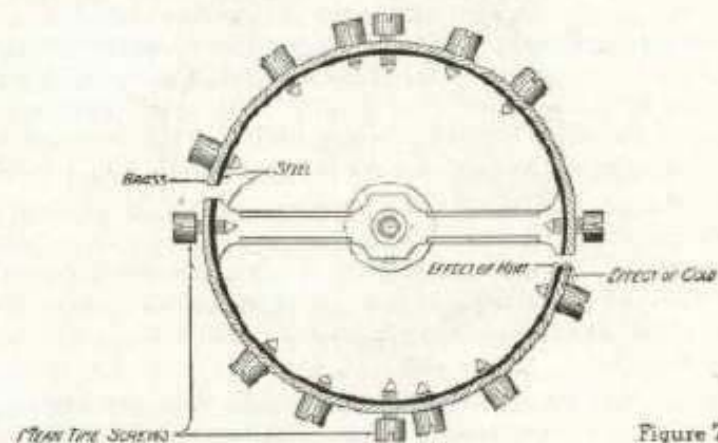
BRASS — STEEL

EFFECT OF HEAT — EFFECT OF COLD

MEAN TIME SCREWS

Figure 7

WALTHAM ★ ★ ★ Established in 1850

This will, of course, result in a greater compensating effect, because the screws which we move nearer the ends of the rim must travel a greater distance in or out in relation to the center of the balance when the balance is exposed to changes of temperature. After the screws have been moved, the movement is tried again the same length of time, and so on, until it runs the same in both temperatures. When a screw is moved in one side of the balance, it is, of course, necessary that the corresponding screw in the other side should be moved the same.

NEW, IMPROVED WALTHAM BALANCE

In all new Waltham movements a new hardened balance with an uncut rim is used, (as illustrated in Figure 8) with a new alloy hairspring furnishing temperature compensation. This combination of balance and
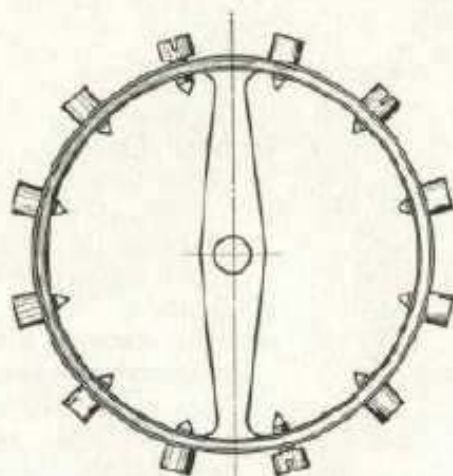

Figure 8
Modern Waltham Balance

spring is not affected by any usual magnetic field. Previous attempts to substitute a combination of this kind for the bi-metallic compensating balance have been unsatisfactory, both because the hairspring was so weak that, unless exceptional care was used in handling, it became deformed and useless, and because the balances made from alloys weaker than steel were easily deformed and made useless.

Waltham has overcome these deficiencies by using, for the balance, a non-magnetic alloy that has nearly the same hardness as steel in the compensating balance, and by developing a new compensating hairspring alloy having practically the same strength as the hardened and tempered steel spring that has always contributed to the ease of repairing Waltham Watches.

The mean time screws used in the Waltham balances furnish an excellent means for accurate timing, as two, on opposite sides, can be turned an equal amount in (making the watch run faster) or out (slower) without changing the poise of the balance.

The following is the effect of one-half turn of two mean time screws:

18 size and 16 size	2½ seconds per hour
Colonial Series and 12 size	2½ seconds per hour
0 size and 3-0 size	3 seconds per hour
Jewel Series	3½ seconds per hour
10 Ligne	3½ seconds per hour
7¼ Ligne rectangular	2½ seconds per hour
4 Ligne baguette	2½ seconds per hour
4½ Ligne semi-baguette	2½ seconds per hour
6½ Ligne oval	2½ seconds per hour
7½ Ligne barrel shape	2½ seconds per hour
8¾ Ligne round	2½ seconds per hour
6¾ Ligne round	5 seconds per hour
6¾ Ligne barrel shape	5 seconds per hour

WALTHAM ★ ★ ★ *First American Railroad Watch*

THE WALTHAM HAIRSPRING

All Waltham hairsprings are made of Conel. Conel is the name of a patented alloy invented and developed by our skilled metallurgists. In order to insure the utmost in uniformity it is produced under strict laboratory control from the time it is first melted and cast in an induction furnace to the time it is formed into hairsprings.

The name itself, Conel, comes from two words con-stant and el-asticity because the alloy maintains nearly constant elasticity (stiffness) with change in temperature. Actually the alloy is so made that hairsprings from it will increase slightly in stiffness with a rise in temperature to compensate for the expansion of the balance.

If a steel spring were used with a continuous rim monometallic balance wheel made, for example, out of beryllium copper, the watch would lose approximately 6.2 seconds for each degree Fahrenheit rise in temperature.

A rise in temperature will expand the spring, increase the width, length and thickness in the same proportion. The effect of changes in width and length cancel out but the increase in thickness will make the spring stiffer, actually causing an increase in rate amounting to about 0.78 seconds. This tendency to increase in stiffness, however, is swamped by the drop in the modulus of elasticity, that is, most metals become inherently more yielding with temperature rise and the spring therefore becomes less stiff. The error in rate from this source is relatively large and amounts to 6.3 seconds so that due to the spring alone there is a net loss in rate of 5.4 seconds approximately for each degree Fahrenheit rise in temperature.

The remaining error 0.87 seconds comes from the expansion of the balance which causes a loss in rate when the temperature rises.

The use of Conel hairsprings in watches presents a big improvement when compared with steel hairsprings in unadjusted watches. Unadjusted watches with steel hairsprings and compensating balances have twenty-four hour temperature errors which vary from losing 1.2 seconds to gaining 1.2 seconds per degree Fahrenheit change in temperature or a total of 2.4 seconds per day.

Since all watches with Conel hairsprings made from any one lot of the alloy have identical errors, and since no lot is used which has a total twenty-four hour temperature error of more than 0.4 seconds, per degree Fahrenheit, all watches with Conel hairsprings have temperature errors less than 1/6 the error in unadjusted watches with steel hairsprings.

For Waltham's highest grade movements the hairsprings are made from carefully selected lots of Conel which have a total twenty-four hour temperature error of less than 0.2 second per degree Fahrenheit change in temperature.

An especial advantage of the use of Conel hairsprings lies in their application to small watches. In very small watches fitted with steel hairsprings and compensating balances, even when the watches are adjusted for temperature, the twenty-four hour temperature error cannot be made less than 1.4 seconds per degree Fahrenheit change in temperature because of the limitations inherent in the size of the compensating balance. With Conel hairsprings, since the material does not have any error to start with, size has no effect upon the hairspring and even the smallest watches have a twenty-four hour temperature error of less than 0.4 second per degree Fahrenheit change in temperature.

Associated with the lack of a temperature error are other remarkable properties. Conel is rust-resisting, more so than blued steel. Springs made of Conel have a hardness approximating the hardness of a steel hairspring. Conel is not affected by ordinary magnetic fields.

To correct for position error all Waltham hairsprings are furnished with overcoils. An overcoil, as shown to the left, is an outer terminal curve of the hairspring made in conformity with Phillip's theory. This makes the center of gravity of the hairspring coincide with the center of the balance at every stage of its vibration and thus reduces the position error.

WALTHAM LEVER ESCAPEMENT

The proper action of the human heart is no more essential to insure a sound and healthy body, than is the proper adjustment and action of the escapement to the reliable performance of the watch. If the watch escapement is properly made and adjusted, it will not only run, — but will run with marvelous accuracy. So the time-keeping qualities of the watch are in large measure dependent on the condition of the escapement. It is, therefore, of great importance that every watchmaker should acquire an intimate knowledge of all the actions that are involved in the kinds of escapements with which he has anything to do.

The only kind of escapement used in Waltham Watches is the detached lever escapement, sometimes designated as the anchor escapement. This escapement requires no special introduction to watchmakers, for by extensive use, and by the test of time, it has been proved to be the most practical as well as the most reliable form. We show some drawings of the lever escapement that they may be convenient for reference, and an aid to a clearer understanding of the text. (Figures 9–15).

The function of the escapement is to impart to the balance, regularly, and with as small loss as possible, the power which has been transmitted through the train from the mainspring to the escape pinion. In the lever escapement this is accomplished by means of two distinct actions: — first, the action of the escape wheel and pallet; second, the action of the fork and roller pin.

Figure 9 is a plan view of the Waltham Lever Escapement, as used in the 16 size, 1899, and 18 size, 1892 model, movements, drawn to scale 10 to 1, and giving the names of the principal parts and features. In some models the escape wheel is staked solidly to the escape pinion; in others friction tight to the shaft of the escape pinion. It has fifteen teeth, called "Club Teeth" on account of their peculiar shape, resulting from the addition of impulse faces to the ends of the teeth, and to distinguish them from "ratchet teeth," the name given to a style of pointed teeth used on escape wheels in an earlier form of lever escapement.

In descriptions of this escapement the term "exposed pallets" is used. This means that the pallet stones are visible, with the active ends standing out free from the body of the pallet, as distinguished from an earlier form of pallet with "covered stones" set in slots running in the plane of the pallet.

THE PALLET ACTION

The action of the escape wheel and pallet includes the following features: impulse, drop, lock, draft and slide, and we will consider briefly what constitutes each one of these features.

The pallet is of the kind called "circular pallet," the distance from the pallet arbor to the middle of the impulse face is the same for both pallet stones. Another kind of pallet is made with "equidistant lock;" that is, the distance from the pallet arbor to the point where the lock takes place, is the same for both pallet stones. The pallet is mounted on its arbor, which is located close to the periphery of the escape wheel.

A theoretically correct distance in relation to the diameter of the escape wheel will not allow an excess of clearance between the pallet and the escape wheel teeth when opposite the pallet arbor, and for that reason the amount of stock in the pallet is made very small at that point. The pallet is slotted for the two pallet stones in such a way as to make the inside corners of the pallet stones reach over three teeth of the escape wheel, and to make the outside corners of the stones reach over two teeth and three spaces of the wheel, with a small amount of clearance in each instance, which is called the "drop."

One other important point in relation to the slotting is to direct the slots in the pallet in such a way as to make the locking faces of each of the pallet stones present to the locking corners of the escape wheel teeth a certain angle of "draw" when the stones are in the position of "lock."

To make this condition clear, refer to Figure 9. Suppose the escape wheel is forced in the direction indicated by the arrow, but is prevented from turning in that direction because the locking face of the R pallet stone is directly in the way of a tooth. The particular tooth which is rest-

ing on the pallet stone is exerting a certain pressure directly towards the pallet arbor. If the locking face of the pallet stone were along the line B, which is at a right angle to that line of pressure, there would be no tendency for the pallet to turn in either direction, but being along the line C, which forms an inclined plane in relation to the direction of the pressure, the pressure applied by the escape wheel tooth will tend to

pull the pallet stone toward the escape wheel. This action is called the "draft" or "draw."

The turning of the pallet is, however, limited by the banking pin, and the object of the "draw" is to keep the fork against the banking pin all the time that it is not in engagement with the jewel pin. This action of "draw" is similar on the L stone; the only differences are, first, that

WALTHAM LEVER ESCAPEMENT

Figure 9

WALTHAM ★ ★ ★ First American Watch
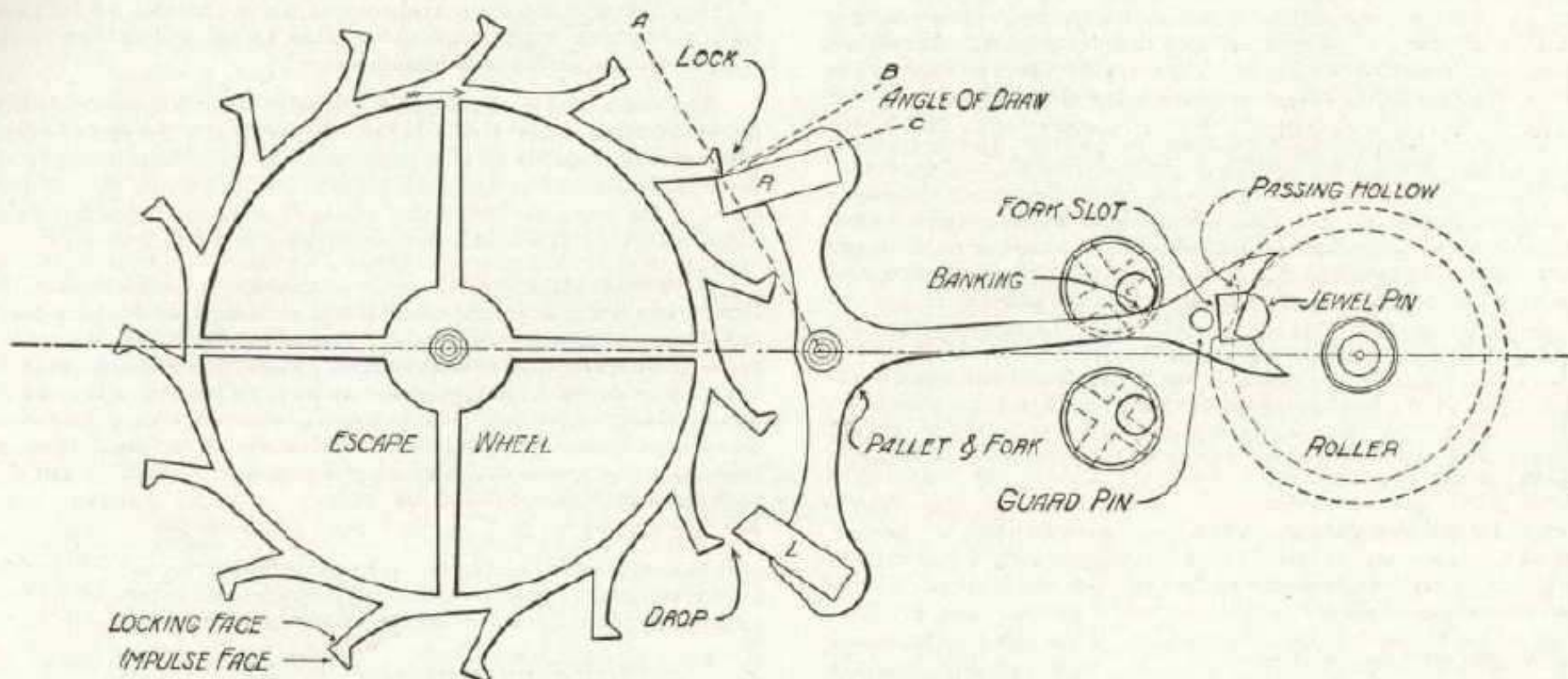
the pressure of the escape wheel tooth is exerted in the direction away from the pallet arbor, instead of towards it, and, second, that the turning of the pallet, which in this instance is in the opposite direction, is limited by the other banking pin.

A glance at Figure 9 will make it apparent that the impulse face, which is formed by the surface between the locking and the let-off corners, is at a different angle on the R from that on the L stone. The impulse angles of the stones in the escapement, represented by this drawing, are, on the R stone, 6° 30', and on the L stone 18°. The above refers in each instance to the angle of the impulse face in relation to a right angle to the locking face, or to the body of the stone. From this condition and from the direction of the pallet stones in relation to the body of the pallet, the factory names "straight" and "crooked" have been given to the R and L stones, respectively.

In books and treatises on the lever escapement, the names "receiving" and "discharging" are used, but when, as a matter of fact, both pallet stones perform the functions of receiving and discharging, one as much as the other, these names do not seem to be appropriate. For our part, we prefer to use the letters R and L to distinguish one stone from the other, and these letters may easily be remembered as right and left, this being the order in which the stones appear as we look at the top of the pallet with the fork turned toward us.

The impulse or lift is divided between the escape wheel clubs and the pallet stones; the two together cause the pallet to turn through an angle of 8° 30'; the lock amounts to 1° 30', making the total angular motion of the pallet about 10°. This is the condition when the pallet is "banked to drop," that is, when the teeth of the escape wheel will just barely pass by the let-off corners of the pallet stones as the fork comes to rest against the bankings.

A certain amount of clearance, or freedom, has to be added to this to allow for oil, etc., so that the bankings have to be turned away from the center line a small amount to allow for what is called "slide," that is, the pallet stone will slide a visible amount into the escape wheel, after the escape wheel tooth drops on to the same. The amount of slide should, however, be very small, because it causes loss of power, by increasing the resistance to unlocking, as, in order to unlock, the escape wheel actually has to be turned backwards against the power of the mainspring, and the amount of this recoil is in proportion to the lock and slide added together.

It is important, therefore, to notice the action of every tooth of the escape wheel on both pallet stones, to ascertain that each pallet stone has some slide on every tooth, and to allow only a small amount in the place where it appears to be closest.

In small watch escapements the lifting angle is increased to about 10°, the locking angle to 2° 30' and 30' allowed for "slide" making a total swing of the pallet of 13°.

MATCHING THE ESCAPEMENT

The term "matching the escapement" is used to designate the work of bringing the different parts of the escapement into correct relation to each other; in other words, to make the necessary moves in order to obtain the proper lock, draft, drop, slide, fork length, let-off, etc. The best way of learning to do this work is to have a competent instructor who is at hand ready to inspect and to give advice. The difficulties are not so great in doing this work, as in correctly determining what to do, in order to bring about certain results, and also to know when the escapement is in a proper condition. It is difficult to give in writing a comprehensive idea of how to do this work. We will, however, give a few points which we trust will be useful to the beginner.

The first thing to receive attention is the condition of the pivots on the escape pinion, pallet arbor and balance staff, to see that they are straight, and that they fit properly in their respective holes. It is absolutely necessary that each pivot should have some side shake, but it is also very important to guard against too much side shake, as such an excess causes loss of power and uncertainty in the action of the escapement. A desirable amount of side shake is .008 mm., and it should not exceed

.013 mm., and the amount of end shake should be from .02 to .04 mm. As soon as these points have been found to be correct, we are ready to try the "lock" and the "drop." In describing the pallet action, we made the statement that the lock should amount to from 1° 30' to 2° 30', depending on the size of the watch. This statement is, of course, of no practical use unless we are equipped with the necessary instruments for measuring this angle.

We may, however, use the thickness of the pallet stones for comparison and obtain practically the same results, by making the amount of lock equal to ⅛ the thickness of the stone, from the locking to the let-off corner. This corresponds very closely to the above angular measurements. If the pallet stones are to be moved, in order to change the amount of lock, it is very important to first consider what will be the effect of a certain move, besides the alteration of the lock. The drop, for example, is affected very rapidly by moving the L stone. Hence, if the drops are equal, we should make the change in the lock by moving the R stone.

If the lock is too strong, and the drop is larger on the outside, the L stone should be moved. If the lock is too strong, and the drop is larger on the inside, it is necessary to move both stones. Move the L stone out a small amount, and move the R stone in until the lock is correct.

HOW TO MOVE PALLET STONES

The moving of the pallet stones in or out in the slots will also affect the draft feature of the escapement; this is a point which we should bear in mind whenever we make a change in the position of the pallet stones. The effect from moving the R stone out is to increase the draft on both stones, whereas if the L stone is moved out and the R stone in, it will decrease the draft.

To ascertain that the escape wheel is correct, the lock and the drop should be tried with every tooth in the wheel on both pallet stones. This should be done with the bankings adjusted close, so as to just permit the teeth to drop. The best way to try this, is to move the balance slowly with the finger while the pallet action is observed through the peep holes.

After completing the adjustment of the pallet action, the jewel pin action is next to be considered. The fork should swing an equal distance to each side of the center line when the pallet is banked to drop. If we find that it moves farther on one side than on the other, it will be necessary to bend the fork close to the pallet a sufficient amount to bring it in line. This is called, "to adjust the let-off."

The test for the let-off is to see that when the pallet is banked to drop, the jewel pin is just as close to the corner of the fork, in passing out, on one side as on the other. This test is correct, provided that the fork is of equal length on both sides of the slot, as it should be. The test for the fork length is that it should allow the jewel pin to pass out on both sides when the pallet is banked to drop. This is the maximum length which is allowed for the fork.

The test for short fork is to move the balance so as to unlock the pallet, then reverse the motion and see that the pallet is carried back safely to lock by the jewel pin. This should be tried on both pallet stones. It is, however, customary to try the shake of the fork when the center of the jewel pin is opposite the corner of the fork, and not to allow the pallet to unlock from this shake.

To ensure perfect freedom in the jewel pin action, the jewel pin should be from .01 to .015 mm. smaller than the slot in the fork. The safety action is also adjusted, while the escapement is banked to drop. The guard pin should be made just barely free from the roller when the fork is against the banking, and this should be tried carefully on both sides. If this is done correctly, the roller will have the necessary clearance when the bankings are opened to allow for the slide.

The operation of moving a pallet stone requires a great deal of experience before one is able to do it satisfactorily. Special tools called "pallet warmers" have been devised for holding the pallet during this operation. In the simplest form this tool consists of a small metal plate, about as large as a 12 size barrel, with a wire handle by which it is held while it is heated. This plate should have one or more holes drilled in it as clearance for the pallet arbor. This tool is provided with a spring

WALTHAM ★ ★ ★   *Established in 1850*
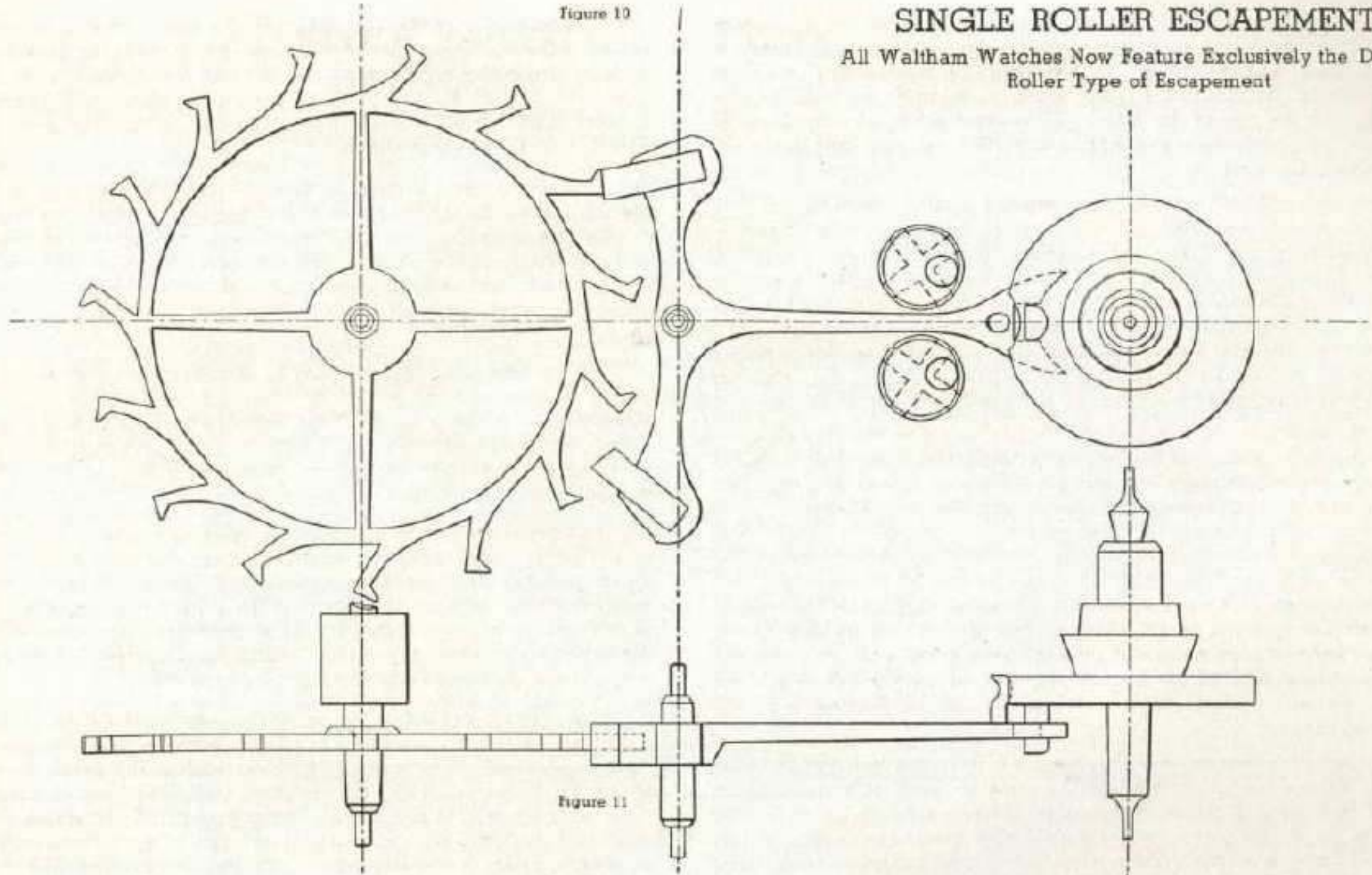
Figure 10

All Waltham Watches Now Feature Exclusively the Double
Roller Type of Escapement

Figure 11

WALTHAM ★ ★ ★ *First American Railroad Watch*

Figure 12

DOUBLE ROLLER
ESCAPEMENT
Type Used in All Modern
Waltham Watches

Figure 13
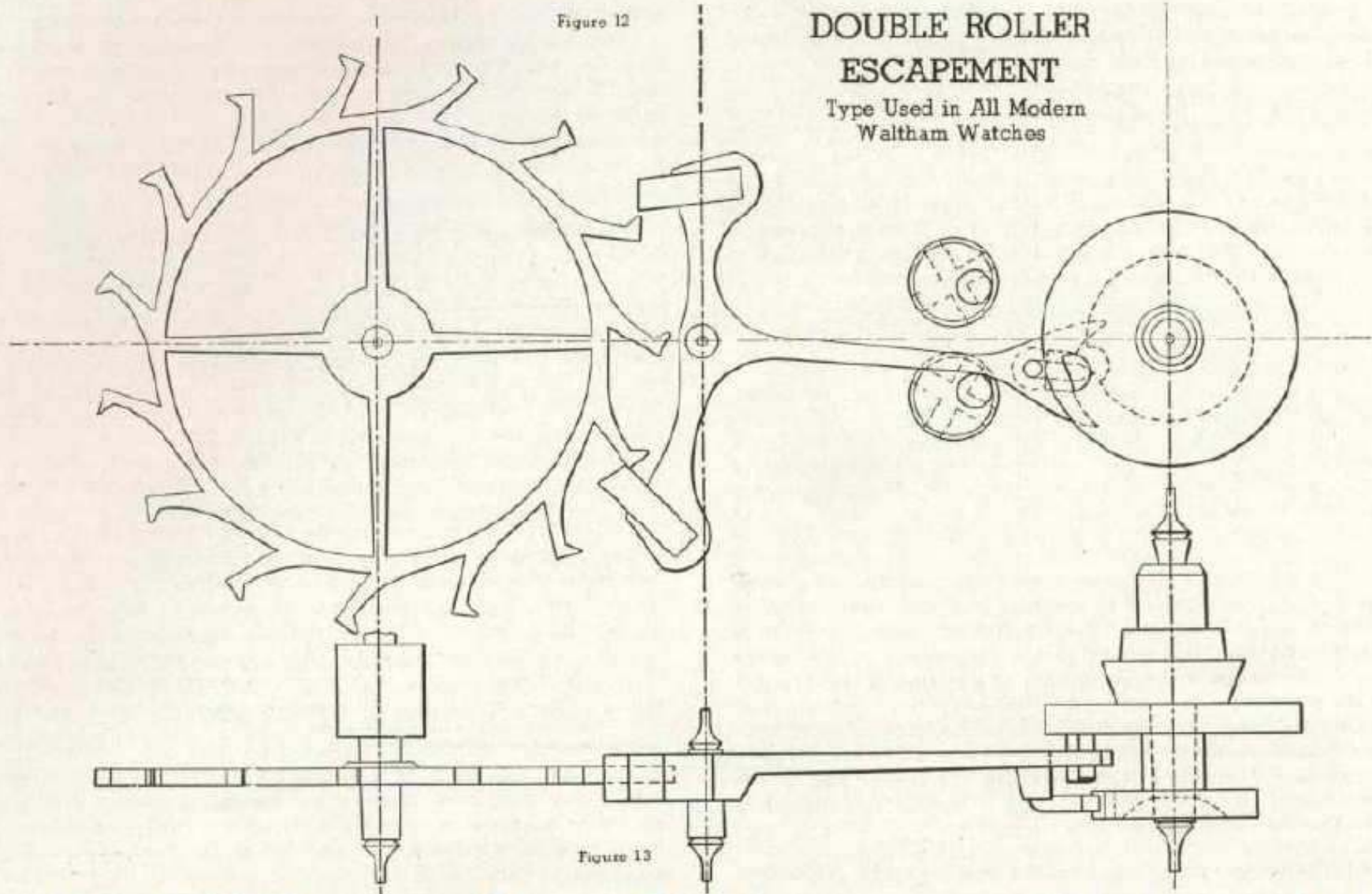
WALTHAM ★ ★ ★ *Official Watch for many world famous airlines*

clamp for holding the pallet to the plate. The pallet is placed top side down against this plate, and the whole of it is warmed over the alcohol flame until the shellac is softened so the stones can be moved.

A good way to apply shellac, for the fastening of pallet stones, is to warm some stick or button shellac over a flame and pull it out in long threads of about .5 mm. diameter. Shellac in this form is very convenient to use, as it is only necessary, when the pallet is heated to the proper temperature, to touch the end of this thread to it at the place where the shellac is wanted. With a little practice one can learn to deposit just the right amount. After the pallet is cold, all shellac on the surface should be cleaned off carefully with a scraper made of brass or nickel.

THE JEWEL PIN ACTION

The fork and jewel pin action involves two distinct functions: the impulse and the unlocking. To illustrate and make this statement clear, we will consider the different parts of the escapement in a normal position as shown in Figure 10. The hairspring, controlling the balance, has brought the fork, by means of the jewel pin, to the normal position of rest.

This leaves the pallet in a position where the impulse face of an escape wheel tooth will engage the impulse face of one or the other of the pallet stones, in this instance the R stone. Assuming the parts to be in this relation to each other, it is evident that when power is applied to the escape wheel, the escape wheel tooth, which is engaging the R stone, will cause the pallet to turn on its pivots. This impulse is transmitted to the balance by the fork acting on the jewel pin. The impulse being completed, the escape tooth drops off from the R stone, and the second tooth forward comes to lock on the L stone, with the fork resting against the banking, as shown in Figure 12. The fork slot is now in such a position that the jewel pin may pass out perfectly free.

This condition is necessary because the impulse which was given

to the balance imparted to that member a certain momentum, causing it to continue to turn in that direction until this momentum is overcome by the tension of the hairspring. During this part of the motion, which takes place after the impulse, the jewel pin leaves the fork entirely. However, the instant that the momentum in the balance is overcome by the tension in the spring, the balance will start to turn in the opposite direction, the tendency of the spring being to bring the jewel pin to the center line.

Before reaching this point, however, the jewel pin has to perform the very important function of unlocking. At the completion of the impulse we left the fork resting on the banking, with the fork slot in such position that the jewel pin passed out perfectly free. Figuring on the assistance of the draft and the safety action, which will be explained later, we are justified in expecting that the jewel pin shall pass in to the fork slot perfectly free. The instant the jewel pin has entered the slot, and comes in contact with the fork, the work of unlocking begins.

It is to be noted, that for every tick of the watch, the pallet and fork is started from the condition of rest, by a sudden blow of the jewel pin. Not only the pallet is started, but the whole train has to be started in the reverse direction, against the power of the mainspring, to unlock the escape wheel, in order to receive another impulse. The impulse on the L stone being completed, the pallet assumes the position shown in Figure 9. The jewel pin passing out on an excursion, the same as on the other side, returns to unlock, receives a new impulse, and so on, at the rate of 18,000 times per hour. It is therefore evident that lightness, as far as it is consistent with strength and wearing quality, is an essential feature in the construction of the several parts.

It was once considered necessary to attach a counterweight to the pallet in order to get it in poise. With the modern light construction of pallet and fork, it has been proved beyond a doubt that the ordinary form of counterpoise was worse than useless, inasmuch as it involved an added mass of metal whose inertia must be overcome at each vibration of the balance.

HOW THE SAFETY ACTION WORKS

The function of the safety action is to guard the escapement against unlocking from sudden shocks, or outside influences, while the jewel pin is out of engagement with the fork. In older watch movements this guard duty is assigned to the edge of the table roller and the guard pin. The passing hollow, a small cut in the edge of the roller, directly outside the jewel pin, allows the guard pin to pass the center line during the jewel pin action. This form of safety action is called "single roller" and is shown in plan and elevation in Figures 10 and 11.

As will be seen from this drawing, the edge of the roller is made straight, or cylindrical, and the guard pin is bent in such a way as to present a curved portion to the edge of the roller. The advantage gained from this construction is that the guard pin can be adjusted forward or back by simply bending it at the base, without its action being in any way affected by a reasonable amount of endwise movement of either the balance staff or the pallet arbor.

The double roller escapement, Figures 12 and 13, presents a more desirable form of safety action, for two reasons: first, the intersection of the guard pin with the roller is much greater, making it perfectly safe against catching, or wedging; second, any shock, or jar, causing the guard pin to touch the roller, will have less effect on the running of the watch, because the impinging takes place on a smaller diameter. The diagrams, Figures 14 and 15, illustrate the above statements. The wedge action of the guard pin when it is brought to the roller, is represented by the lines C and D, which are at right angles to the lines A and B, thus forming tangents to the points of contact. It will be seen that with the single roller this wedge is 17°, whereas in the double roller it is 30°, a very considerable difference in favor of the double roller. Today all Waltham Watches are made with the Double Roller Escapement.

PUTTING THE ESCAPEMENT IN BEAT

An escapement is said to be in beat when it requires the same amount of power to start the balance in one direction as in the other.

This should be tried with the mainspring only partly wound up, by arresting the motion of the balance with a pointed object held between the heads of two balance screws, and allowing the balance to move slowly, first in one direction and then in the other.

If it appears to require more power, in order to let off on one side than the other, it is said to be "out of beat," and it should be corrected by turning the hairspring collet a certain amount, on the balance staff, until it takes the same amount of power to let off on one pallet stone as on the other. This is usually done without removing the balance, by reaching in over the top side of the hairspring with a special tool made of small steel wire and flattened at the end so as to enter the slot in the collet. Great care should, however, be exercised in doing this work so as to avoid bending the hairspring out of true.

MAINSPRINGS

In customary design a spring is expected to return, after removal of the deforming load, to the same position it had prior to the application of the load. The mainspring of a watch is unique because during use it becomes permanently deformed. The watchmaker calls this change, "setting" meaning that, when removed from the barrel and allowed to develop without restraint, the spring has more turns than it had initially. The space available in a watch for the spring is so small that in order to get sufficient length of spring to keep a watch running for not less than 36 hours, the inner turns of the spring wound tight against the arbor are stressed beyond the elastic limit of the material and are, consequently, deformed or "set." Each succeeding winding of the spring produces additional "set." Naturally the "set" produced by the first winding causes the greatest change from its original form and the amount of "set" diminishes with succeeding winds. Attempting to prevent "setting" by raising the elastic limit of the spring lowers the ductility so much that the spring breaks when wound around the arbor.

SAFETY ACTIONS

Figure 14

SINGLE ROLLER

Discontinued in
Waltham Watches

Figure 15

DOUBLE ROLLER

Featured in All Modern
Waltham Watches

The temperature range between which springs may be produced that will not break nor set excessively when wound up is small. This requires the use of furnaces for hardening and tempering the steel to maintain uniform and constant temperatures. Waltham mainsprings are heat treated in furnaces built especially for this purpose. The furnaces are supplied with the most accurate and sensitive automatic temperature controlling instruments available.

WHY MAINSPRINGS BREAK

Breakage is one of the frequent mainspring complaints. As a watch mainspring is highly stressed, it cannot be expected to last forever. Failure is generally brought about by the concentration of stresses at a microscopic weak spot on the surface or edge of the spring.

Everyone knows that it requires less force to break a bar of metal when there is a nick on its surface. In the same manner surface cracks can cause spring breakage. Such cracks are aggravated by the continued winding and unwinding of the mainspring and also by corrosion effects due to rusting.

The Waltham Watch Company assures itself that the steel used is the best obtainable for the purpose; that it is free from discernible internal defects; that the surfaces of its springs are free from defects that can function as nicks and cause premature breakage. Further, we call your attention particularly to the second cause of breakage so that you, who handle these springs during the servicing of a watch, will use every precaution to prevent injury to any surface of the spring.

Another type of breakage again described as nick (or notch) failure results from careless winding of a mainspring into the mainspring barrel. A kink affects the coils beyond it and causes a spring, otherwise without discernible defect, to break prematurely. The Waltham Watch Company urges you never to wind a mainspring into a barrel by hand but always to use a winding tool, available from any supply house. Unless a winding-in tool is available, leave the mainspring in its barrel and clean it by immersion in a suitable volatile cleaner followed by re-oiling. Winding in by hand, without making slight kinks in the spring, is extremely difficult.

We must emphasize again that great care be used during the handling of a mainspring to protect the surface from injury by scratching. Use extreme care to have the spring and its barrel free from dust particles. Small abrasive particles between the coils of the spring can produce scratches during the winding and unwinding of the spring in normal use which will cause premature breakage.

The scientific methods of manufacture and tests used by the Waltham Watch Company assure the user that Waltham mainsprings are free from internal and external defects. The Waltham Watch Company has recently installed new equipment and methods that make possible mainsprings of uniform and dependable manufacture.

A mainspring should have sufficient power at the end of a 24-hour run to make the watch motion properly, and yet it must not be so strong as to overbank the watch when fully wound up. To meet these two conditions, a mainspring must have a comparatively high temper.

HOW TO WIND MAINSPRINGS

Highly tempered springs require careful handling. A good spring (meaning one of the proper temper) should never be wound on an arbor smaller than its hub or barrel arbor. To bend it into a smaller curve is dangerous, because, since it is a good spring, it may not stand the treatment. A soft spring, even when abused, will not break, neither will it give a good motion to the watch at the end of its run.

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A good spring should not be wound on an arbor which has a pin or hook long enough to project beyond the thickness of the spring at the eye. There is no hole in the next coil, so when this second coil is wound tightly over the protruding pin the spring may break, if it is a good one.

When winding a mainspring into the shell or barrel, it should be coiled on the winder only enough to allow the spring to slip easily into the barrel or shell. Do not coil it unnecessarily tight on the winder.

To prove this, take an old spring and coil it on the winder, holding it back firmly all the way; then let it out and draw it slowly between thumb and finger and you will feel the kinks, especially at the inside end. Any one of these short bends or kinks would break a good or properly tempered spring.

HOW TO MEASURE MAINSPRINGS

In the manufacture of mainsprings, it is of the utmost importance that the springs be made absolutely accurate to stated widths and thicknesses. The Waltham Watch Company has spared no expense to make possible the manufacture of this product to exact standards.

For the final measuring of the finished spring, a special gauge with metric graduations is used, which will quickly show, by the use of a large index, a variation of .005 mm. As there are 25.4 mm. in one inch, the absolute degree of accuracy insisted upon in the Waltham factory is apparent.

For gauging springs, many watchmakers use a split gauge into which the spring is placed, and the thickness or width is supposed to be indicated by a number on the margin. As no two people would exert the same amount of pressure in placing the spring in the gauge, and as constant use would wear away the metal, it is apparent that such a gauge is unreliable when used as a standard for accurate measuring.

Lists have been furnished, giving the sizes of Waltham springs corresponding to the numbers marked on these split gauges. However, such lists are not always entirely reliable as mentioned before. We strongly advocate that watchmakers use some reliable gauge, marked with metric graduations, giving in metric terms the exact width and thickness of the mainspring. Metric micrometers, made by standard tool manufacturers, are good for this purpose if they are provided with the ratchet stop which limits the amount of force which can be applied.

MAINSPRING DON'TS

Don't fail to provide yourself with the best mainspring winder that can be obtained. See that the hooks on all arbors of the winders are no longer than the thickness of the thinnest spring, and thus avoid kinking, and, therefore, unnecessary breaking of mainsprings.

Don't use a mainspring that is too long because it fills the barrel. This prevents the barrel and the main wheel from making the required number of revolutions, with the result that the watch will not run as long as it should after each winding.

Don't use a mainspring that is too strong, because it will set. This increases the chances of breakage with resultant injury to the watch.

Don't use a mainspring that is too wide. Be sure that the tip and brace do not extend beyond the limits of the cover and barrel.

Don't forget that a mainspring should not occupy more than one-third the diameter of the barrel. This leaves two-thirds to be divided between the arbor and winding space enabling the watch to run about thirty-six hours.

Don't expect a mainspring to be flat if you put it in the barrel with the fingers. This method usually injures the spring, gives it a conical form, and thereby increases the friction in the barrel.

TABLE SHOWING THICKNESS OR STRENGTH OF MAINSPRINGS

Dennison No.	Waltham Thickness in Centimeters	Dennison No.	Waltham Thickness in Centimeters	Dennison No.	Waltham Thickness in Centimeters
0000	.029	3½	.020	9½	.012
000	.027	4	.019	10	.011
00	.026	5	.018	11	.010
0	.025	6	.017	12	.009
0½	.024	6½	.016	12½	.008
1	.023	7	.015	13	.007
2	.022	8	.014		
3	.021	9	.013		

TABLE SHOWING WIDTH OF MAINSPRINGS

Dennison No.	Waltham Widths in Centimeters	Dennison No.	Waltham Widths in Centimeters	Dennison No.	Waltham Widths in Centimeters
1	.100	16	.250	31	.400
2	.110	17	.260	32	.410
3	.120	18	.270	33	.420
4	.130	19	.280	34	.430
5	.140	20	.290	35	.440
6	.150	21	.300	36	.450
7	.160	22	.310	37	.460
8	.170	23	.320	38	.470
9	.180	24	.330	39	.480
10	.190	25	.340	40	.490
11	.200	26	.350	41	.500
12	.210	27	.360	42	.510
13	.220	28	.370	43	.520
14	.230	29	.380		
15	.240	30	.390		

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Don't bend the inner or outer end of the mainspring with flat-nosed pliers. Provide yourself with specially made round-nosed pliers which will give a circular form to these parts. This will prevent short bends and will contract the inner coil, thus securing a closer fit to the barrel arbor without injuring the spring.

Don't expect a poorly fitted mainspring to work. Use a properly fitted flat mainspring with rounded edges. This will produce the least friction in the barrel, allow the greatest amount of power to the train, and give the best results as to time, service, etc.

Don't expect a mainspring to always endure (1) extreme changes in temperature, (2) straightening at full length, or (3) neglect from lack of cleaning and oiling.

Don't expect a watch that needs cleaning or other repairs to run satisfactorily by merely putting in a new mainspring.

Don't expect a mainspring to plow through too much dirt.

CONVENTIONAL WATCH CLEANING METHOD

After the movement is taken apart, remove the balance jewels, and also the escape and pallet arbor jewels (if these parts are cap jeweled). Before taking these out, however, we should see if the settings of the hole jewels are marked for position. If they are not marked, make a small dot near the edge of each setting so they can be replaced correctly after the cleaning.

The following is the order in which these settings are marked in Waltham movements. In the lower plate they are marked, as shown in Figure 16. The balance and the escape jewels are on the sides away from the pallet, and the pallet arbor jewel is on the side towards the center of the movement. In the top plate all the jewels are marked on the side towards the center of the movement. After this has been attended to, put all the parts (except the balance) in benzine, to remove oil and greasy matter. After the oil is cleaned off, string a few pieces at a time on a wire loop (see Figure 17), and wash in hot water with a medium soft brush and castile soap. While the parts are on the loop, dip in a solution

of cyanide of potassium for three to five seconds. Rinse thoroughly in clean water, immerse in alcohol for about ten seconds, followed by a second rinse in alcohol. Dry in warm boxwood sawdust.

When the mainspring is taken out of the barrel, it should be handled carefully, and no attempt made to straighten it. If the oil on it appears gummy, it should be cleaned off thoroughly with benzine. If the oil is in good condition, it is necessary only to wipe the spring with a piece of cloth by folding it around the spring and sliding it along without straightening the spring. After the spring is put back in the barrel (which should be done with a good mainspring winder), it should be oiled with good quality watch oil in sufficient quantity to insure thorough lubrication without risk of spreading on the outside of the barrel.

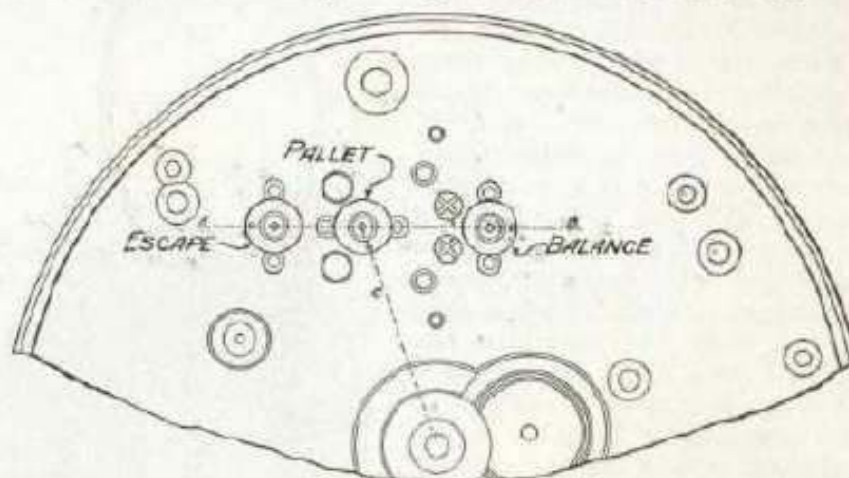
Figure 16

The escapement jewels, after going through the benzine, should be taken, one at a time, with a pair of specially prepared tweezers, to avoid their snapping off, and held against a flat board, or a large piece of cork, and brushed thoroughly, one side at a time, with a fine toothbrush dipped in alcohol. After the brushing, dip the jewel in clean alcohol, and dry between linen cloths.

After going through this process, we are reasonably sure that the jewels are clean, but to make absolutely sure, we recommend a careful rubbing with a piece of pegwood, which has been pointed so as to go through the holes, and also one which is specially shaped for rubbing the cups in the jewels.

The cleaning of the balance with the hairspring requires special care, as it cannot be brushed safely. The usual method is to put it on a hook and dip it for a few seconds, first in water, then in cyanide; rinse in water, dip in alcohol and dry carefully in sawdust. The balance may be buffed afterwards with a string of chamois skin held in a wire bow, to brighten the rim, as well as the screws. After the balance has been cleaned, it should be examined carefully for any minute fibre that might have caught in the balance screws, or particles of sawdust in the slots of the screw heads. When cleaning a balance, if the jewel pin is set with shellac, and also when cleaning pallets, care must be taken not to leave them in the alcohol too long, as it would dissolve the shellac and loosen the jewels.

The best kind of alcohol for cleaning watch parts is commercial

Figure 17

grain alcohol. We do not recommend using either denatured or wood alcohol for this purpose.

The cyanide solution referred to should be made in the proportion of seven ounces, avoirdupois, to one gallon of water, and this solution should be renewed as soon as it shows a tendency to turn dark. Cyanide of potassium is a virulent poison, and great care must be taken in handling it. It is considered deadly if reaching an open scratch in the skin. The fumes should also be avoided. A good way of keeping both the cyanide and alcohol for cleaning watches is in one gallon specimen or candy jars, with ground glass covers, and marked with conspicuous warning labels.

MODERN WATCH CLEANING METHOD

GENERAL. — Cleaning machines, available to the watch trade, make it possible to clean watch and instrument parts thoroughly in wire mesh baskets, subdivided so as to accommodate large and small parts separately. To clean a mainspring, without distorting its shape, wipe it with tissue paper, saturated with benzol or carbon tetrachloride. Dipping it into any degreasing solution is harmful, resulting frequently in rupture. The balance and hairspring unit deserves special attention. It should be suspended on a wire loop and dipped in the cleaning solutions.

PROCEDURE — Watch parts should first be strung on a wire or placed into basket of cleaning machine and then immersed in solutions in the following sequence:

1. Degreasing — Preferably non-inflammable carbon tetrachloride. Solvent for grease, fat and oil, mixes with denatured alcohol.
2. Rinse — Denatured alcohol.
3. Cleaning — Soap solution, commercially known as "Jewelry Cleaners," composed of soap, spirits of ammonia, alcohol and distilled water.
4. First Rinse — Tap water, to remove soap cleaner.

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5. Second Rinse — Distilled water.
6. First Drying Rinse — Denatured alcohol.
7. Second Drying Rinse — Commercial grain alcohol.
8. Drying — Dry air or electric fan.

EXPLANATION — Cleaning solutions containing volatile solvents should not be allowed to stand exposed to air when not in use; evaporation of these volatile solvents will decrease their cleaning efficiency.

Denatured alcohol is used as an in-between rinse, because it mixes well with both carbon tetrachloride and water.

While the basket of the cleaning machine is immersed in each of the solutions, it should be rotated and stopped a few times to allow air trapped in the basket to escape. After the basket is removed from a solution, it should be kept in motion for a few seconds to expel any excess solution before resuming the cleaning procedure.

Following the last rinse in grain alcohol, the basket should be rotated in dry air or an electric fan may be used to expedite the drying operation.

Once the watch parts are removed from the basket, they must be handled with the utmost care by means of tweezers. Touching any parts with bare fingers or using pegwood in jewel holes will destroy the value of this cleaning procedure.

HOW TO OIL A WATCH

Before final assembly of the movement, balance endstones should be mounted on balance cock and pillar plate and respective capped jewels oiled.

For the purpose of retaining a sufficient amount of oil in the pivot holes, we take advantage of a natural phenomenon, which is called capillary action. This action, roughly stated, is the tendency of liquids to run in between surfaces which are nearly in contact, and also to run upwards, quite rapidly, in very small tubes, against the force of gravity.

Capillary action is strikingly illustrated in the wick of a lamp in which the close proximity of the fibres, acting like capillary tubes, causes the oil to run upwards through the wick as fast as it burns at the top. In view of these facts, we shall endeavor to explain why a pivot sometimes will run dry in a short time because of too much oil in the pivot hole. Looking at Figure 18, we find that the hole jewel is convex on the side towards the endstone. Also, there is a certain distance between the two jewels. This space is usually made about .02 to .03 mm., and is for the purpose of providing a reservoir for the oil.
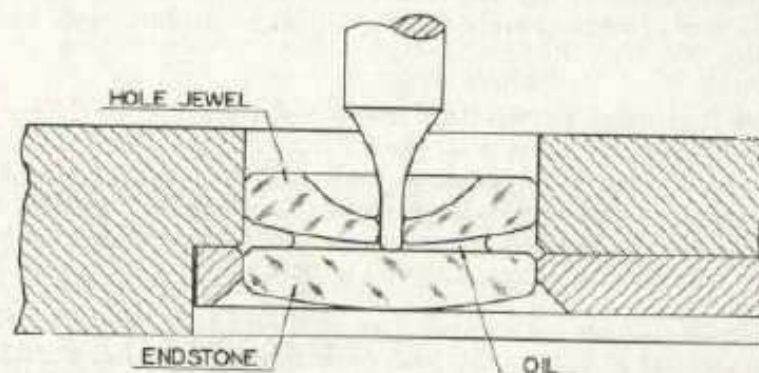

Figure 18

Friction Type Balance Jewel and Endstone

The convex shape of the hole jewel tends to keep the oil around the pivot, being attracted by the close space nearest the hole through the capillary action referred to above.

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To lubricate a capped jewel place a small drop of oil in the oil cup and feed it into the space between the jewel and the endstone with a pointed wire. The amount of oil is determined by the size of the bubble that should cover approximately $\frac{2}{3}$ of the jewel diameter. If the size of the bubble is too small, the supply will lubricate for a short time, because it is subject to drying and oxidation. If the bubble covers too large an area, the oil will be drawn away between the metal surfaces, leaving pivot and jewel bearings dry and subject to wear.

After winding the mainspring into the barrel, a sufficient supply of oil should be applied to the surface of the coils and the bottom of the barrel. Before replacing the barrel arbor, the bearings should be lubricated with a thin film of oil.

Winding arbor square and clutch teeth should be lubricated with a very thin film of white petrolatum. Setting and minute wheels need no lubrication.

After final assembly, all train jewels and bushings should be carefully oiled. The point of the oiler should contact the bottom of the jewel or bushing oil cup and the pivot simultaneously. This prevents any lubricant from spreading onto the surface of the jewel or bushing. When oiling center lower bearing, a small drop of oil should be placed on the cannon pinion friction groove assuring smooth setting friction.

After assembling the escape, a small drop of oil should be placed onto the impulse surface of the pallet exit stone. The pallet should then be moved back and forth until the escape wheel has made one revolution, thus lubricating each escape wheel tooth with a thin film of oil.

Do not oil the jewel pin nor the safety action.

It is difficult to prescribe an accurate quantity or oil drop size to lubricate a watch bearing. Experienced watchmakers will determine the amount they will use in providing a correct film on any bearing or surface that needs lubrication.

CLEANING AND OILING EQUIPMENT

CONTAINERS FOR SOLUTIONS — Wide-mouthed, one gallon glass containers with tight fitting glass stoppers should be used for all solutions. They should be filled about halfway in order to avoid any possible spilling when the basket of the cleaning machine is set in motion.

LUBRICANT — Supplies of watch oil should be stored hermetically sealed in a dry, cool place and protected from direct light. It should comply with the following essential qualifications: —

1. It shall lubricate.

2. It shall not spread.

3. It shall not easily evaporate or become gummy with age.

4. It shall not oxidize or corrode any metal it contacts.

OIL CUP — A drop of oil should be placed in a conventional transparent glass oil cup, provided with a cover. The oil should be renewed daily to eliminate contamination by dust, or other foreign matter.

OILER — It is advisable to use a plain oiler made from steel wire, flattened out on the end and notched lightly in order to hold a small drop of oil at the tip. Such wire oilers are sold by watch supply houses. The pointer, used to feed oil between hole and cap jewels, can be made from a fine needle or pivot broach. It should be shaped to a fine, polished flat point and all burrs removed. At all times, the oiler and pointer should be cleaned by pushing the tip into a piece of leatherwood or elder pith.

HOW TO REMOVE A BROKEN SCREW FROM A WATCH PLATE

After all other screws and steel parts are removed, suspend the plate on a copper wire in a 6% solution of sulphuric acid. After approximately 24 hours, rinse in water and follow cleaning procedure.

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CASING

Before casing a movement, always oil the winding bar in the pendant, where it runs in the sleeve, to prevent rust and squeaking. See that the movement lines up properly with the winding bar in the case, so it will wind and back ratchet freely. It is sometimes necessary to remove the winding bar and sleeve from the case pendant and enlarge the hole in it to one side or the other (with a round file) in order to get a perfectly free action. The length and position of the square on the negative type winding bar should also be inspected to see that both the winding and setting action is right. If the square is too long, it may be shortened by filing without removing it from the case. If it is too short, it is necessary to remove the crown and turn in the sleeve nut until the action is right.

The foregoing does not apply to positive set mechanism since this type of winding arbor is previously inserted in position in the movement itself.

See that the crystal does not touch the center, and that the hands clear the dial and the crystal, as well as each other. After the case is closed, hold the watch to your ear and listen if the balance pivots will "bump" clear on both endstones, as they should do, when the watch is tipped from side to side. This will indicate if the case in any way interferes with the freedom of the balance.

In casing small watches special attention should be paid to the following points: — The winding crown on the end of the Winding Arbor should have a cylindrical end reaching in the case. The hole in the case for this bearing should be only slightly larger than the straight part on the Crown end in the correct position. In this way the Winding Crown will be supported in the case and dust prevented from getting into the watch. The movement should be supported only on the case shoulder provided for this purpose, and no part of the movement should ever touch the bottom of the case. The periphery of the movement should fit in the case so the watch will not fall out if held downwards without bezel, but should be free enough so it can be lifted out without tools.

SOME HINTS ON MEASURING AS APPLIED TO WATCHMAKING

The success of every undertaking depends largely on the ability to figure out and make practical plans, as well as to work correctly from plans already made. The ordinary method, used in the past, is not well adapted to our line of work in this scientific age; we should accustom ourselves to speak in exact terms as well as to work correctly to given measurements.

It is doubtless true that watchmaking is in greater need of exact and systematic measurements than any other trade, and it is also true, generally, that the average apprentice gets very little, if any, instruction in the art of measuring. It is a common idea that expensive gauges and elaborate instruments are required to produce first-class work; but often we may have the essential things right before us without thinking how to apply them. It is the object of this article to point out to the watchmaker, who wants to make things, how an ordinary micrometer (Figure 19) may be used for practically all kinds of measuring.

Due to the small dimensions of our work, it is convenient to use a small unit for our linear measurements. The Metric system is very practical in this respect, using the millimeter, which is about $\frac{1}{25}$ of an inch (exactly .03937″), as a unit, and subdividing the same into $\frac{1}{10}$ and $\frac{1}{100}$ mm. The fractions we usually write in decimal form, for example: 4.30 mm. instead of $4\frac{3}{10}$ mm., and 5.76 mm. instead of $5\frac{76}{100}$ mm., etc.

The screw in modern micrometers (see Figure 19) has a pitch of $\frac{1}{2}$ mm., so one turn is divided into 50 parts, in order to measure $\frac{1}{100}$ mm., and, consequently, we must turn the screw two complete turns for one millimeter, and the second turn should be read 55, 60, 65, etc., instead of 5, 10, 15. To avoid mistakes in the beginning, in reading the micrometer, it is advisable to use a straight scale, as shown in illustration, to verify the result.

The micrometer here shown indicates 3.51 millimeter. The square

scale verifies the 3.5 millimeter; the micrometer shows the extra .01 millimeter.

The only other thing for the beginner to learn, in order to use the micrometer successfully for linear measurements, is to use as light a touch as possible in applying it to the objects which are to be measured. The unit for angular measurements is the degree, which equals $\frac{1}{360}$ part of a circle. The degree is subdivided into sixty minutes, and the minute into sixty seconds. Instead of writing the words "degrees," "minutes"

and "seconds," the symbols °, ', ", have been adopted; so, in order to denote one and one-half degrees, we write 1° 30'.

It may be well to point out an error very common among watchmakers to speak about linear measurements, such as the diameter of the pivots and thickness of mainsprings, etc., as so many "degrees." This is entirely wrong, as such measurements should always be stated in fractions of a millimeter or inch.
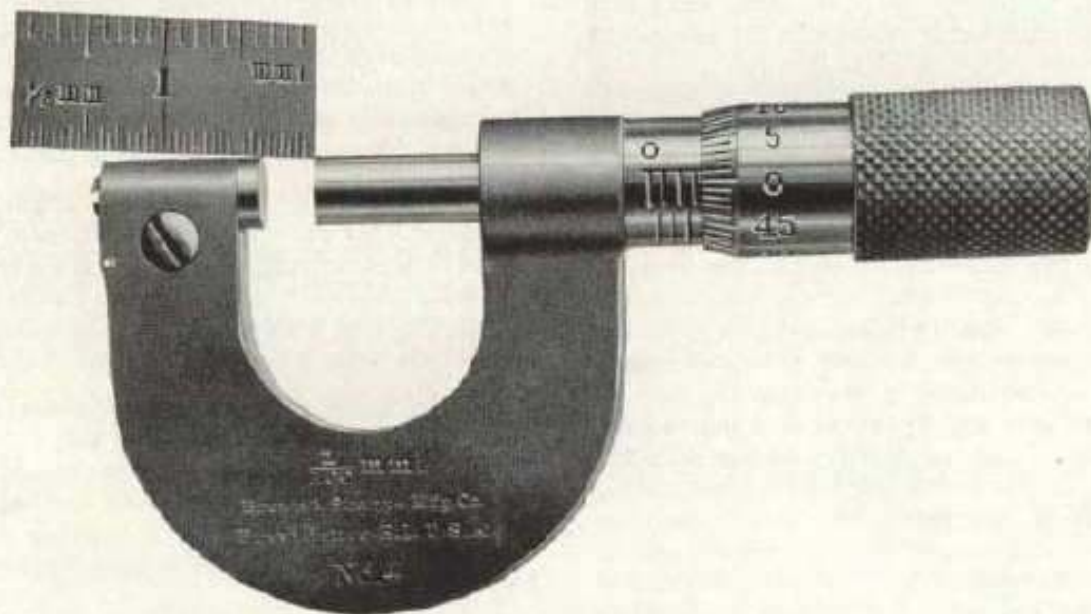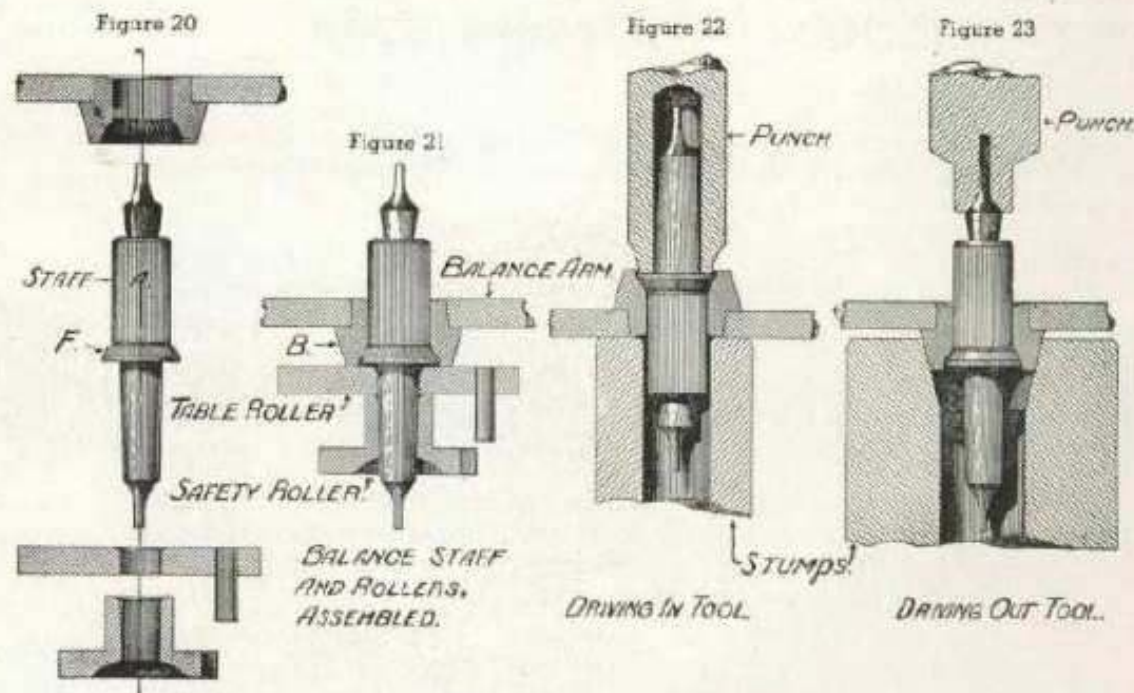

Figure 19

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THE TAPER SHOULDER DETACHABLE BALANCE STAFF

ON 16 SIZE AND VANGUARD MODELS

DRIVE OUT THE STAFF ONLY — ALLOW HUB TO REMAIN FIRMLY STAKED TO BALANCE ARM

This is an improved form of a detachable Balance Staff that is certain to appeal to the watchmaker. It permits changing a staff easily and quickly without bending the balance arm or throwing the balance out of shape. The bevel seating in the hub B fits precisely the taper shoulder F on the staff, thus insuring a level balance.

To drive out an old staff, we recommend using a tool as shown in Figure 23; to put in a new staff, a punch, as shown in Figure 22, bringing the tapered shoulder on the staff to its bearing in the hub. Tools designed for these staffs can be obtained from watch tool manufacturers in sizes to fit regular staking tool sets. The blue steel hub should always be left in the balance arm when changing a staff.

Figure 20

Figure 21

Figure 22

Figure 23

STAFF — A

F →

TABLE ROLLER

SAFETY ROLLER

B →

BALANCE ARM

BALANCE STAFF AND ROLLERS, ASSEMBLED.

PUNCH

STUMPS

DRIVING IN TOOL

PUNCH

DRIVING OUT TOOL.

WALTHAM TAPER SHOULDER DETACHABLE BALANCE STAFF

WALTHAM ★ ★ ★ *First American Standardized Watch*

THE EASY-TO-HANDLE
WALTHAM HAIRSPRING STUD

In removing a watch balance, it is usually necessary to lift it by the hairspring, the stud of which is left attached to the balance cock. This method involves the danger of possible injury to the hairspring.

With the Waltham Triangular stud (Figure 24) such danger is avoided. It is simply necessary to turn back the stud-holding screw enough to allow the stud to swing freely from its place, thus detaching the hairspring from the balance cock.

After replacing the balance, screw the balance cock into place, hold the movement on edge and allow the stud to swing into position. Then fasten into place by its screw. This eliminates any danger of twisting the hairspring.

Other types of hairspring studs cannot be replaced without first assembling the hairspring and balance unit to the balance cock. This offers a chance for oil to spread and dust to collect. The Waltham hairspring stud avoids all these dangers and is simpler and easier to remove and replace.

Figure 24

WALTHAM ★ ★ ★ *First American Watch*

THE JEWELED MAIN WHEEL

The main wheel is fitted with two jewel bearings which turn on the barrel arbor (Fig. 26). The barrel arbor (Fig. 25) is composed of two parts. Part 1, the outer member, is squared on its upper end to receive the winding wheel; an axial hole is drilled and tapped through its entire length. Part 2, inner member, is provided with a flange and square which unites steel barrel solidly between the two members.

When disassembling, hold steel barrel between thumb and index finger, fasten winding wheel or pin-vise onto barrel arbor square and turn counterclockwise. A later type barrel arbor (Fig. 28), consists of a longer inside member, end of which is drilled and tapped for winding wheel screw.

Figure 27 shows barrel arbor and main wheel construction of today. The jewels are friction fitted into the main wheel and the bearing hole size is held to within .005 millimeters.
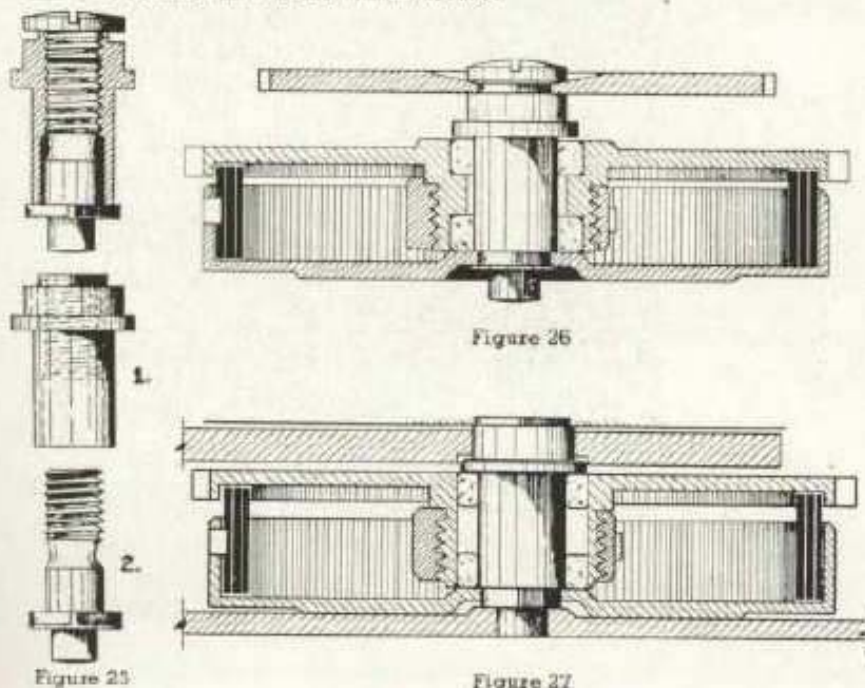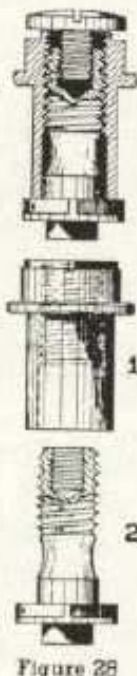
THE CONVENTIONAL RUNNING BARREL UNIT

Modern Waltham Watches are being equipped with running type barrel (Fig. 29), consisting of a barrel, cover and arbor.

Figure 30 shows jeweled running barrel used in modern 23 jewel Vanguard watches. The barrel is staked to a pivoted shaft which runs between two jewel bearings, friction fitted into pillar plate (lower) and outer arbor (upper); latter is connected with mainspring hub by means of a square.

Before taking apart, mainspring should be completely disarmed to avoid jewel breakage. When disassembling, barrel bridge should be lifted off pillar plate without removing winding wheel, which is fastened to outside arbor with a right hand thread. When removing barrel bridge, outside arbor slides out of hub square, permitting removal of winding wheel by holding square with a pin-vise and turning counterclockwise.

Figure 26

Figure 29

1.

Figure 25

Figure 27

2.
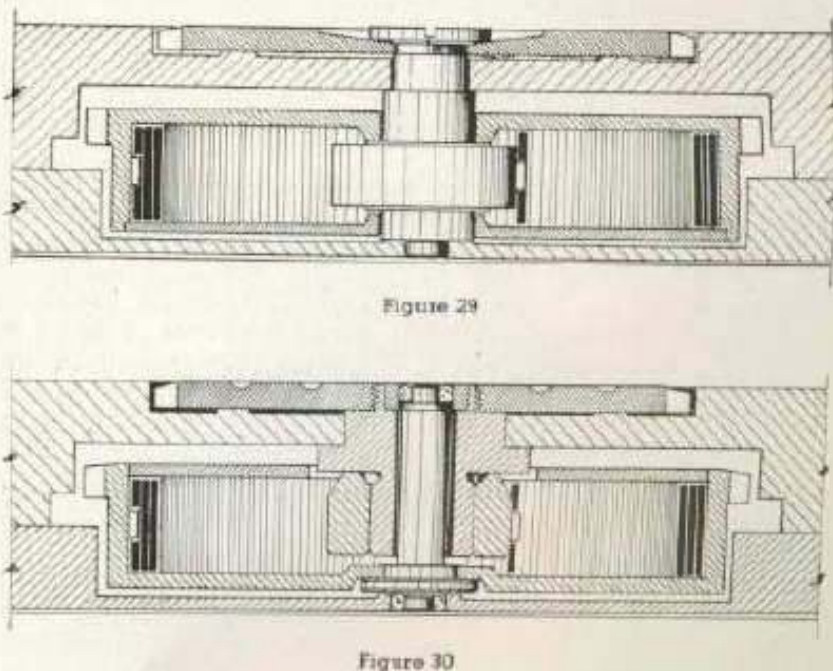
Figure 28

Figure 30

WALTHAM ★ ★ ★ *Watchword of Quality*

THE PENDANT SETTING MECHANISM

The Waltham Pendant Setting Mechanism, negative type (see Figure 31), consists of the Shipper A, Shipper Lever B and Shipper Spring C. Figure 31 shows the normal position of these parts with the setting teeth of the clutch in engagement with the hand setting wheels. If the watch is to be run out of the case, the Shipper Bar D should be pulled outward. This acting on the Shipper at E shifts the clutch from the setting to the winding position and leaves the setting wheels free.

The positive setting used at present in most Waltham Watches is similar to Figure 32. In this construction the Winding Arbor is made in one piece with a threaded end reaching through the case to receive the crown. This Arbor can be removed or fastened to the movement by unscrewing or tightening the setting lever screw.
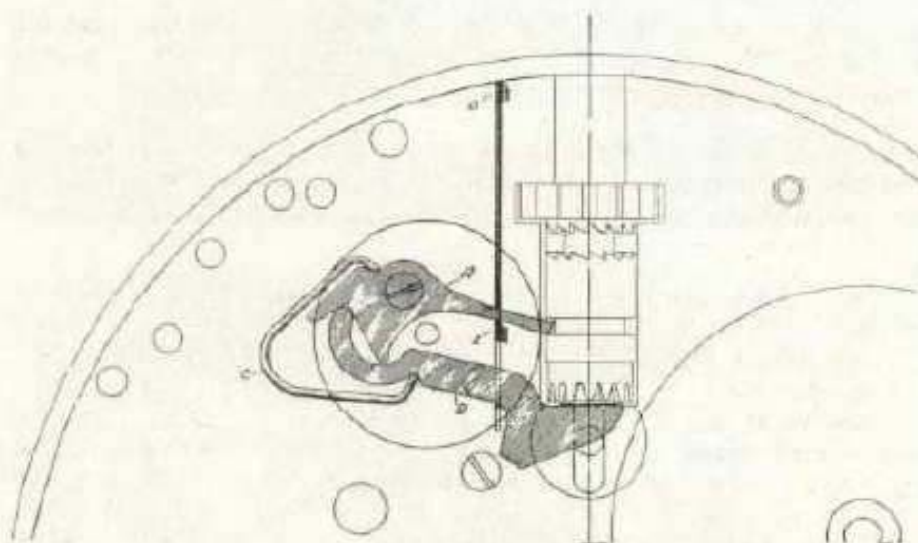
Negative Type

Figure 31
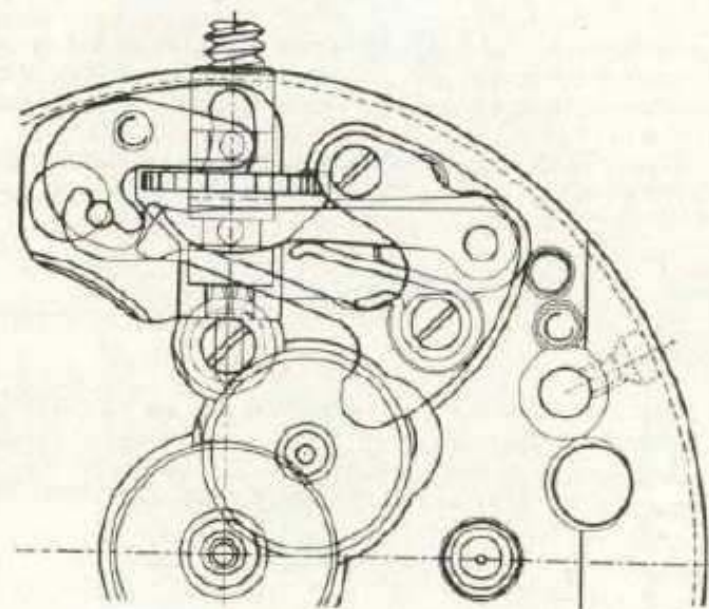
670 SETTING

Positive Type

Figure 32

WALTHAM ★ ★ ★ Established in 1850

HINTS AND SUGGESTIONS

Make it a rule to test every watch for magnetism. A small pocket compass, placed close to the balance when the watch is running, will indicate by a vibrating motion if the balance is polarized. If it is, the watch should be treated, case and all, in a demagnetizer.

When repairing a watch inspect the balance pivots carefully to see that they are straight and in good condition. Examine the endstones, and if they show any wear polish off by using a small lap, made of tortoise-shell about 30 mm. in diameter, mounted in the lathe, with a small amount of fine diamond powder mixed with oil put on the face of it. By holding the pitted endstone against this with a slight pressure, while the lap is running at a fairly high speed, it can be made as good as new in a very short time.

After this operation, it is important to clean the endstone and setting thoroughly.

Examine the balance to see that it is true and in poise. (As containing directions for truing and poising a balance, we wish to recommend a very excellent article on this subject in a book issued by Kendrick & Davis, Lebanon, N. H., entitled "Book of Tools, No. 6").

Do not open the bankings carelessly. Remember that the result of excessive slide is a dead loss of power. This loss increases rapidly with any deterioration of the oil on the pallet stones.

Do not neglect to try the jewel pin to see if it is set firmly. Even a slightly loose jewel pin is a source of trouble.

Do not open the curb pins on the regulator. The hairspring should fit between the pins, without pinching, and without play, to get the best result in timing.

See that the hairspring is centered and flat, and has a sufficient amount of clearance under all conditions. Bear in mind that its regular vibrations will be increased whenever the watch is subjected to sudden motions or shocks.

Do not neglect to remove any finger mark or greasy matter on the plates caused by handling of the movement. For this purpose, we find a buff stick very useful, — a flat stick of wood, about 14 mm. wide, covered on one side with buckskin, such as is used for buffing. The end is dipped in benzine, wiped off rapidly with a clean cloth, and used immediately for cleaning the top surface of the plates.

Do not expect a position adjusted watch to rate the same as it did originally, after any change or alteration has been made in the balance pivots, or balance jewels. Even when the work is done with the greatest care, these repairs may call for readjusting the movement.

Do not consider it a bad investment to put as much money as you can afford into up-to-date tools. Do not consider time wasted in keeping your tools in good condition.

Do not neglect to keep abreast of the times by reading good books and papers pertaining to the trade. At the same time, be mindful of the fact that you cannot learn watchmaking from books or by correspondence only.

We wish to emphasize to the young watchmaker the importance of practice or training in the various branches of his work. We would recommend, as a profitable way of spending some leisure time, to take a discarded balance and bend it out of shape, and then true and poise it repeatedly for the purpose of gaining experience. We might state that although a beginner may work on a balance all day, and still not succeed in getting it in very good order, an expert can do 20 to 25 in an hour, and get them all good. This applies equally well to the work on the hairspring, the escapement, the pivots, jeweling, and so on. In conclusion, nothing but hard work, conscientious application and study will ever bring forth a skillful and efficient craftsman.

WALTHAM ★ ★ ★ *First American Railroad Watch*

GENUINE WALTHAM MATERIAL

All Waltham parts are made to uniform sizes. For example all pivot diameters are made within a tolerance limit of .005 mm. The Jewels, Settings and Bushings are made to the same tolerance. Jewel Holes are made to .0025 mm., etc. This uniformity of material allows any watchmaker to replace broken parts without fitting troubles.

A convenient, well-designed cabinet containing four drawers together with genuine material of every day use, in sealed-at-the-factory refill envelopes, is available at a great saving on the cost of the material alone.

Not only is it a great value but it saves the watchmaker's time due to the ease with which any piece of material can be selected. A postcard will bring complete information.

MODERN TIMING MACHINES

All movements are timed on timing machines before they are cased. The use of machines eliminates any chance of human error because all the operator has to do is to put the movement into the machine and to remove it after it is timed.

The machine draws a record of the rate of the movement upon a paper chart during the thirty seconds that the movement is in it. Movements that are not entirely perfect, even though they will run, will not time on the machine. Therefore, since the machine will time only movements whose parts function properly, the successful use of timing machines by the Waltham Watch Company indicates that Waltham watches are perfect when they leave the factory.

MAGNIFYING PROJECTORS

Projectors are used at the Waltham Watch Company to insure that the form and shape of parts with irregular contours (such as watch plates, pallets and wheels) are held to correct dimensions. The part to be checked is placed upon the stage of the projector which throws an image of the part, enlarged 100 times, onto a screen upon which rests a master plate made of glass which has the exact outline of the part engraved upon it. The two images must conform exactly in order to be accepted by the Inspection Department.

THE SIZE OF A WATCH MOVEMENT

As a matter of interesting information relating to the description of American watch movements, as being of certain designated "sizes," let us say that this system of measurement is identical with that established and used by English watchmakers, and relates to the extreme diameter of the pillar plate. Being English, its unit of measurement is the English inch, and the zero, or starting point, is one inch plus five-thirtieths of an inch ($1\frac{5}{30}$), which is the diameter of an 0 size movement. Each $\frac{1}{30}$ of an inch added to this measurement represents the size of a movement. Therefore, $1\frac{5}{30}$ plus $\frac{1}{30}$ will be the diameter of a one size movement: a six size should measure $1\frac{11}{30}$, a twelve size $1\frac{17}{30}$, an eighteen size $1\frac{23}{30}$, etc.

NOTE: In order to express this in millimeters we must multiply by 25.4, which is the metric equivalent of an inch, so the general formula will be $(\frac{35}{30} + \text{SIZE}/30) \times 25.4$: and the formula for 12 size, $(\frac{35}{30} + \frac{12}{30}) \times 25.4 = 39.8$ millimeters.

The Ligne was originally accepted abroad as the unit of outside measurement on watch movements.

Divided into 12/12 (douziemes) this sub-division figures as unit for thickness of plates. 1 ligne = 12/12 = 2.256 millimeters.

Most manufacturers have abandoned this obsolete method of measurement, replacing it advantageously with the metric system.

USEFUL NUMBERS

	ϕ Latitudes	g	l
The Equator................	0°	978.10	99.102
	30°	979.35	99.229
Washington, D. C.............	38° 53'	980.04	99.299
New York.....................	40° 43'	980.21	99.316
	45°	980.60	99.355
Greenwich...................	51° 31'	981.17	99.413
Stockholm	59° 21'	981.83	99.481
The Poles...................	90°	983.10	99.609

ϕ = latitude.

g = value of gravitation in cms.

l = length in cms. of a pendulum beating seconds.

T = time in seconds.

$$g = 977.989 \left(1 + 0.0052 \sin^2\phi\right)$$

$$g = \left(\frac{l}{T}\right)^2 \; ; \quad l = g\left(\frac{T}{\pi}\right)^2 ; \quad T = \pi\sqrt{\frac{l}{g}}$$

$$\pi = 3.14159265$$

$$\left(\frac{1}{\pi}\right)^2 = 0.101321$$

Number of seconds in 24 hours = 86,400.

The effect on a pendulum from change of latitude of one degree amounts to from a fraction of a second, near the Equator, to 4 sec. + in 24 hours. The following figures are in round numbers, at the sea level.

Between Washington, D. C., and New York (1° 50') 8 sec. in 24 hours.

Between Washington, D. C., and Montreal (6° 7') 24 sec. in 24 hours.

Between New Orleans and Montreal (15°) 55 sec. in 24 hours.

Between Equator and Poles (90°) 3 min. 44 sec. in 24 hours.

MEASUREMENTS RELATING TO WATCH MOVEMENTS

Size	Lignes	MM.	Inches	Size	Lignes	MM.	Inches
28/0	3.01	6.78	.267	7	15.76	35.56	1.400
27/0	3.38	7.62	.300	8	16.14	36.40	1.433
26/0	3.75	8.46	.333	9	16.52	37.26	1.467
25/0	4.13	9.32	.367	10	16.89	38.10	1.500
24/0	4.50	10.16	.400	11	17.26	38.94	1.533
23/0	4.88	11.00	.433	12	17.64	39.80	1.567
22/0	5.26	11.86	.467	13	18.02	40.64	1.600
21/0	5.63	12.70	.500	14	18.39	41.48	1.633
20/0	6.00	13.54	.533	15	18.77	42.34	1.667
19/0	6.38	14.40	.567	16	19.14	43.18	1.700
18/0	6.76	15.24	.600	17	19.51	44.02	1.733
17/0	7.13	16.08	.633	18	19.90	44.88	1.767
16/0	7.51	16.94	.667	19	20.27	45.72	1.800
15/0	7.88	17.78	.700	20	20.64	46.56	1.833
14/0	8.25	18.62	.733	21	21.02	47.42	1.867
13/0	8.64	19.48	.767	22	21.39	48.26	1.900
12/0	9.01	20.32	.800	23	21.77	49.10	1.933
11/0	9.38	21.16	.833	24	22.15	49.96	1.967
10/0	9.76	22.02	.867	25	22.52	50.80	2.000
9/0	10.13	22.86	.900	26	22.89	51.64	2.033
8/0	10.51	23.70	.933	27	23.27	52.50	2.067
7/0	10.89	24.56	.967	28	23.65	53.34	2.100
6/0	11.26	25.40	1.000	29	24.02	54.18	2.133
5/0	11.63	26.24	1.033	30	24.40	55.04	2.167
4/0	12.01	27.10	1.067	31	24.77	55.88	2.200
3/0	12.39	27.94	1.100	32	25.18	56.72	2.233
2/0	12.76	28.78	1.133	33	25.53	57.58	2.267
0	13.14	29.64	1.167	34	25.90	58.42	2.300
1	13.51	30.48	1.200	35	26.27	59.26	2.333
2	13.88	31.32	1.233	36	26.65	60.12	2.367
3	14.27	32.18	1.267	37	27.01	60.96	2.400
4	14.64	33.02	1.300	38	27.40	61.80	2.433
5	15.02	33.88	1.333	39	27.78	62.66	2.467
6	15.39	34.72	1.367	40	28.16	63.50	2.500

Lignes	Size	Millimeters	Inches	Lignes	Size	Millimeters	Inches	Lignes	Size	Millimeters	Inches
2¾		6.20	.2440	¼	6/0	25.38	.9992	¾		44.55	1.7539
3	28/0	6.77	.2665	½		25.94	1.0213	20		45.12	1.7763
¼		7.33	.2886	¾		26.51	1.0437	¼	19	45.68	1.7984
½		7.90	.3110	12	4/0	27.07	1.0657	½		46.25	1.8208
¾	26/0	8.46	.3331	¼		27.63	1.0877	¾		46.81	1.8429
4		9.02	.3551	½		28.20	1.1102	21	21	47.37	1.8649
¼		9.59	.3776	¾	2/0	28.76	1.1322	¼		47.94	1.8874
½	24/0	10.15	.3996	13		29.33	1.1547	½		48.50	1.9094
¾		10.72	.4220	¼		29.89	1.1767	¾	23	49.07	1.9318
5		11.28	.4441	½	1	30.45	1.1988	22		49.63	1.9539
¼	22/0	11.84	.4661	¾		31.02	1.2216	¼		50.19	1.9759
½		12.41	.4886	14		31.58	1.2433	½	25	50.76	1.9984
¾		12.97	.5106	¼	3	32.15	1.2657	¾		51.32	2.0204
6	20/0	13.53	.5323	½		32.71	1.2877	23		51.88	2.0425
¼		14.10	.5551	¾		33.27	1.3098	¼	27	52.45	2.0649
½		14.66	.5772	15	5	33.84	1.3322	½		53.01	2.0870
¾	18/0	15.23	.5996	¼		34.40	1.3543	¾		53.58	2.1094
7		15.79	.6217	½		34.97	1.3767	24	29	54.14	2.1314
¼		16.35	.6437	¾	7	35.53	1.3988	¼		54.71	2.1539
½	16/0	16.92	.6661	16		36.09	1.4207	½		55.27	2.1759
¾		17.48	.6881	¼		36.66	1.4433	¾	31	55.83	2.1980
8		18.05	.7106	½	9	37.22	1.4653	25		56.40	2.2204
¼	14/0	18.61	.7326	¾		37.79	1.4878	¼		56.96	2.2425
½		19.17	.7547	17		38.35	1.5098	½	33	57.53	2.2649
¾		19.74	.7772	¼	11	38.91	1.5318	¾		58.09	2.2870
9	12/0	20.30	.7992	½		39.48	1.5543	26		58.65	2.3090
¼		20.87	.8216	¾		40.04	1.5763	¼	35	59.22	2.3314
½		21.43	.8437	18	13	40.61	1.5988	½		59.78	2.3535
¾	10/0	21.99	.8657	¼		41.17	1.6207	¾		60.34	2.3755
10		22.56	.8882	½		41.73	1.6429	27	37	60.91	2.3980
¼		23.12	.9102	¾	15	42.30	1.6653	¼		61.47	2.4200
½	8/0	23.69	.9326	19		42.86	1.6874	½		62.04	2.4425
¾		24.25	.9547	¼		43.43	1.7098	¾	39	62.60	2.4645
11		24.81	.9768	½	17	43.99	1.7318	28		63.16	2.4866

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