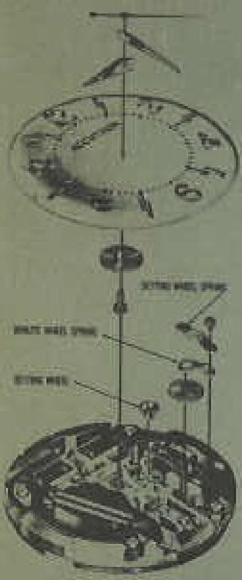
Henry B. Fried

A certified Master Watchmaker, and Head of the Department of Horology at George Westinghouse Vocational and Technical High School in New York City, HENRY B. FRIED is the author of seven books and numerous articles on watch repair.

His books include *The Watch Repairer's Manual, (D. Van Nostrand), Bench Practices for Watch Repairers (Robert Publishing Co.); The Watch Escapement; The Principles of Waterproofing Watches (B. Jadow and Sons, Inc.); The Universal Watch Material Catalogue (W.M.D.A.A.); The Packard Collection Of Unusual and Complicated Watches* (American Watchmakers' Institute) and the escapement section of the *Horolovar 400 Day Clock Repair Guide.*

In addition he has contributed articles to many magazines: *Readers' Digest, National Jeweler, American Horologist & Jeweler, Jewelers Circular-Keystone* (contributing editor and as horological consultant), *British Horological Journal; Gnomon (Tokyo), Swiss Watchmakers Journal, Ultrasonics, Jewelry, The American Watchmaker,* and many foreign language publications.

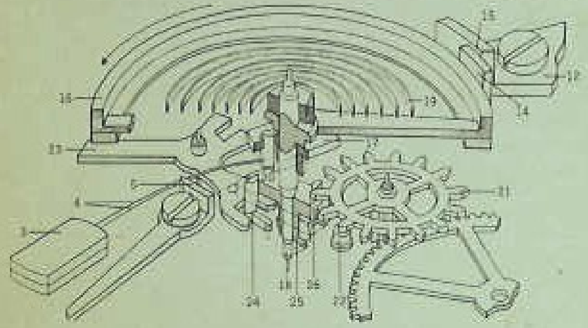
A graduate of the State of New York Industrial Teachers Training College, Mr. Fried received the Outstanding Achievement Award from the United Horological Association of America and numerous citations from many state and national organizations. His professional achievements also include the past presidency of the Horological Society of New York and the New York State Watchmakers Association; Regional Vice President of the Horological Institute of America, Technical Director of the Horological Institute of America. He is presently Technical Director of the American Watchmakers Institute, Technical Advisor, Watch Material Dealers Association of America, Horological Editor, Jewelers Circular-Keystone and has served as consultant to numerous watch companies and governmental agencies. Mr. Fried is also a collector of all forms of *Horologia* and is a charter member and Fellow of the National Association of Watch and Clock Collectors.

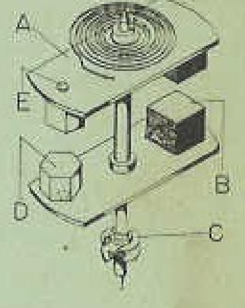


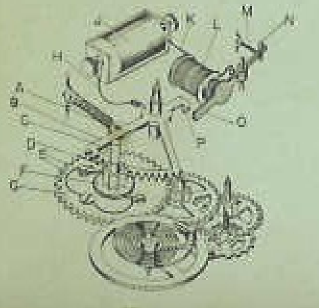
THE ELECTRIC WATCH REPAIR MANUAL

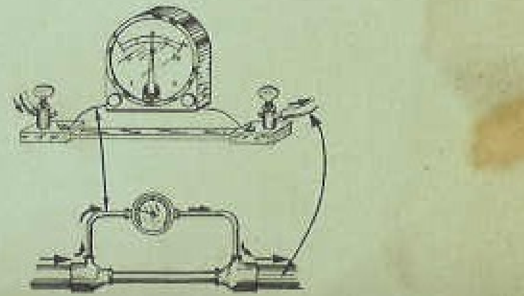
By Henry B. Fried

A complete Manual on the Repair of Electric Watches and Battery Driven Clocks









THE ELECTRIC WATCH REPAIR MANUAL

by HENRY B. FRIED

This is the first book on the repair of electric watches and it is fitting that America's leading horological educator-writer should be its author. In preparing this book on electrical watches, the author calls upon his long experience as an educator in introducing a subject normally strange to the watchmaker. Logically, he has divided this book into two parts. The first section is an orientation to the basics of electricity and basic electronics as applied to horology. The second delves directly into the repair of every currently made electric-electronic watch.

In the first section, using his well-known skill as a draftsman, he illustrates the basics of electricity in simple terms, always associating these with watchmakers' concepts and images so that the subject never seems strange or elusive. In this manner, he uses the most simple electric clocks as his models of instruction so that, aside from learning about electrical values and ideas, the reader is also given instruction in the most popular electric battery-powered clocks as well.

The use of electrical meters — the volt, ohm, ampere — is easily grasped through simple analogies and excellent isometric drawings. The use and principle of the diode, transistor, capacitor-condenser, resistor in watches and clocks are readily understood by the reader. Spark suppression, its principles and methods are similarly grasped. For example: to explain the use of the capacitor and its principle as used in many battery clocks and electronic watches, the author explains its more simple use in the "instant" demagnetizer, re-

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THE ELECTRIC WATCH REPAIR MANUAL

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INTRODUCTION

Electric watches are now an accepted segment of the watch industry. Therefore, the watchmaker is being exposed to them in ever-increasing numbers. This writer was quick to sense the need of supplying instruction in the servicing and repair of these timepieces. He also realized that the watchmaker was unfamiliar with the elements of electricity and electronics. This would cause the watchmaker to shy away from these new timepieces. Therefore, the author undertook to create a basic course of instruction in the elements of electricity and electronics, orienting this with watchmakers' everyday concepts for easier understanding and acceptance.

Thus, the instruction in basic electricity also includes the repair of popular electric clocks and those using transistorized pendulums and balances. In this manner, the watchmaker is led gradually from the most simple electrical ideas to practical electrical-electronic horological applications. The reader will profit most first reading the sections, "A Watchmaker's Guide to Electricity". Then he may begin the expositions on the electric watches in the second section.

The author wishes to thank the many manufacturers of these timepieces for their technical assistance with models and instructions. The author also wishes to thank Mr. Murray Stone of the Electronics Department of the George Westinghouse Voc. and Tech. H.S. for his suggestions and checking the manuscript on electricity and electronics, and to thank Mr. Joseph Tallal of the Horological Department of this school for his many suggestions.

Flushing, N.Y.

Henry B. Fried

Part I

A WATCHMAKER'S GUIDE TO ELECTRICITY

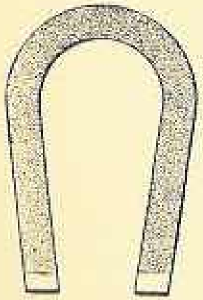


Figure 1. Permanent magnet.

Synchronous electric clocks have been with us for quite some time, and now "cordless," D.C. motor-wound clocks are greatly in evidence. Almost daily, one hears of another energy-cell powered electric watch on the market.

Sooner or later, the watchmaker will be called upon to service these timepieces, all of which operate without mainsprings, the customary winding mechanism, or an escapement. Instead, they use permanent magnets, temporary magnets, electromagnets, wire coils of many types and functions, contacts or switches, relays, diodes, capacitors or condensers, accumulators, resistors, transistors.

The average watchmaker is unfamiliar with these terms; much less does he understand their function. He views these strange timepieces with justifiable apprehension. Actually, these new types of timepieces need not be so fearsome if a study is made of the simple laws of electricity, magnetism and the elements of electronics, terms which seem more foreboding than they really are.

This series is intended as a simple course of study and review of basic electricity as it pertains to timepieces. It should help the watchmaker to better understand and service the new electric or electronic timepieces.

Every electric or electronic timepiece is based on magnetic attraction or repulsion. Therefore, we must learn something about magnets. There are three general types of magnetic functions in electric timepieces; permanent, temporary and electromagnet.

A permanent magnet keeps its magnet power almost indefinitely. Figure 1 shows the most familiar form of permanent magnet. However, permanent magnets make take any shape or form, as will be demonstrated later.

TEMPORARY MAGNETS

Figure 2. Temporary magnets.

A temporary magnet can be magnetized or attracted by another magnet, and has the properties of a magnet during the influence of any other type of magnet. When this influence is removed, the temporary magnet loses its magnetism. Soft iron and other special alloys have this characteristic. Figure 2 shows a permanent magnet influencing a temporary one in such a way that the temporary magnet has magnetic properties. The permanent magnet attracts pieces of soft iron (in this case cheap iron nails). The nails, now also magnets, attract other nails and they in turn attract others and so on. When we disconnect the permanent horseshoe magnet from the nails, the nails will no longer act as magnets and no longer attract or support others in magnetic suspension.

ELECTROMAGNETS

Electromagnets exert a magnetic force only when an electric current energizes them. Electromagnets are most often coils of insulated wire or a combination of such wire coils and temporary magnetic material. Almost every watchmaker has basic materials for carrying out simple experiments to help him in this instruction. These are an old-fashioned A.C. demagnetizer, an old file, an old staking punch (or a piece of high-carbon steel rod), a soft piece of iron (or some pieces of soft iron binding wire), a bench compass used to detect magnetism in watches and a piece of clock mainspring.

The demagnetizing coil is used to remove magnetism from watches which have become "permanently" magnetized. This is done by holding the watch or part in the coil and, while current is passing through the coil, drawing out the object in as wide an arc as possible. However, the same coil can be used to make "permanent" magnets of carbon steel objects by placing the steel in the coil, pressing the button to allow current to flow through it and then abruptly shutting off the current (while the object is still within the coil). In almost every instance, the steel piece will become permanently magnetized.

For our experiment, an old file will do nicely, since this is made of high carbon steel and makes a suitable magnet. In fact, some watchmakers purposely magnetize a large file to help them find a small steel part that has fallen off the bench, after which they demagnetize both file and part.

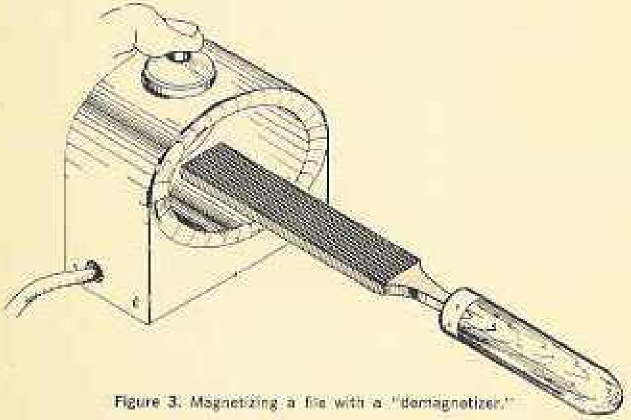


Figure 3. Magnetizing a file with a "demagnetizer."

Magnetize the file by placing its tip in the coil of the "demagnetizer" (as shown in Fig. 3). Press the button for a couple of seconds and then release the current. The result will be a highly magnetized file. If you place this near a high-carbon steel staking punch, it will not only draw the punch to itself but the punch will also become a permanent magnet (although not as strongly magnetized as the file, retaining its magnetism after the file is withdrawn. This proves that steel objects, when brought close to a magnetic field, become permanently magnetized.

CONTROLLED MAGNETISM

In watchmaking, this is not desired, even in the existing electric or electronic timepieces. Since electric timepieces operate on a magnetic push or pull, it is necessary that the magnetic influence end whenever desired. Therefore, a material must be used that can be magnetized temporarily. The most common material that fits these requirements is soft iron. To prove this, we can subject a piece of soft iron to the influence of a permanent magnet and then to an electromagnet. Laminated strips of metal from the stator of an old synchronous electric clock are made of soft iron and can be used for this experiment. If they are not available use cheap iron nails or pieces of soft iron binding wire. Place a number of these small pieces on the bench and touch one of them with the magnetized file. The iron clings to the file. As you lift the file, the iron piece will hang from it. If you bring the suspended iron piece close to others on the bench, they will be drawn to the suspended piece, in a chain effect: the pieces attracted to the magnet become magnetized themselves, and attract other magnetic materials.

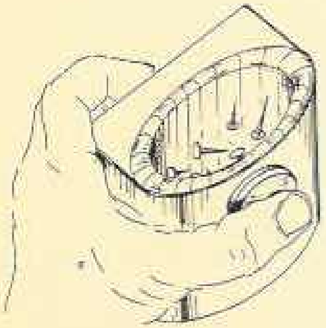


Figure 4. Nails held by current.

Disengage the iron pieces directly attached to the magnetized file. Immediately, all the other pieces part. Try to pick up some of the pieces with the one that was attached to the file. Unlike the steel punch magnetized earlier, it cannot do this. Should there be some residual magnetism remaining in any of the iron pieces, it is because there may be a small amount of carbon in the iron. However, this experiment proves that some materials can be magnetized only temporarily. In electric clocks or electric watches, permanent magnets are not used with temporary magnets—if we were to attract a magnetic balance or a pendulum, it would be necessary to stop this pull as soon as the pendulum or balance neared the magnet, in order that the moving body could return or continue on its own momentum without clinging to the magnet. For this reason, electromagnets are used. These are coils of insulated wire, wrapped around a hollow cylinder of some magnetic substance such as soft iron or an alloy with the same properties.

Your demagnetizer is an electromagnet, and this can be used to demonstrate a useful fact. Put some pieces of iron on the table. Then, place the demagnetizing coils so that the hollow

section is directly over the iron pieces. Next, press the button connecting the current. The iron will be drawn into the coil. Lifting the coil while the current is on will cause the iron pieces to cling to the inside of the coil, as shown in Fig. 4. If we suddenly release the contact button, shutting off the current, the nails or iron pieces will drop out of the coil. If we lower the coil, holding it close to the iron pieces, and again press the button, the pieces will be drawn back into the coil and fall back again when the current is shut off.

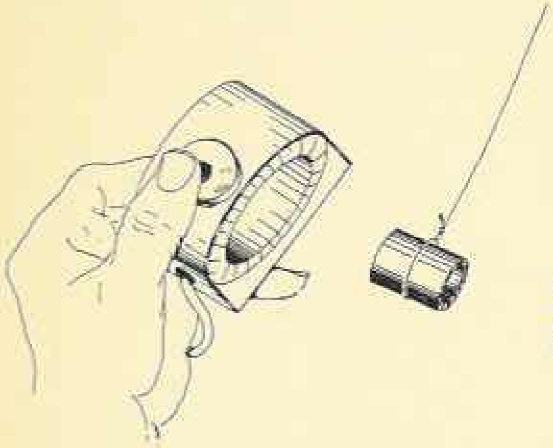


Figure 5. Weight on string is attracted by coil, becomes a simplified pendulum device.

Suppose we put an iron weight on a string, and hold our coil at a spot near the end of this "pendulum's" swing as shown in Figure 5. As the swinging weight nears our coil, we press the button. This will draw the weight nearer the coil. Just as it is about to enter the coil, we shut off the current. The pendulum will swing a bit further on its own momentum and then swing back to the opposite side. When it swings towards the coil again we press the button, and the pendulum will be drawn towards the coil once more; shutting off the current will cause a repetition of all this motion. Thus we have a means of continuing a pendulum in motion. All we need to have an electric pendulum clock is a switch to turn on the current (and shut it off automatically at the right moment) and a counting device to count the swings of the pendulum.

If we placed temporary magnetic tabs on opposite parts of a balance rim, had an electro-magnetic coil to draw these, and an automatic on-off switch, we would have a simple electric watch balance. Such a possibility is shown in Figure 6.

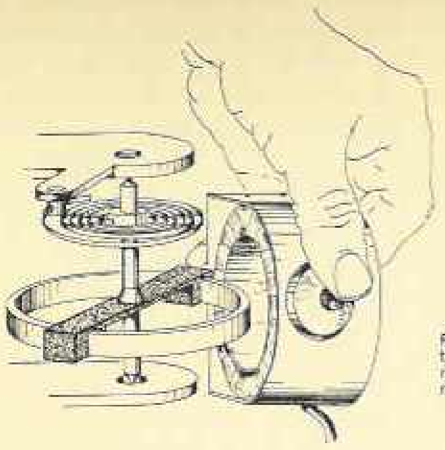


Figure 6. Simple electric watch balance is made by temporary magnets placed on rim.

COMPASSES AND CELLS

Since your demagnetizing coil runs on house current, we cannot operate a timepiece that has to be moved or carried —such as a watch. We will need some soure of electrical current that is compact and can be carried with or attached to the timepiece. Of course, we immediately think of the familiar battery. Technically, it should not be called a *battery* but rather, an *energy cell*. When two or more energy cells are linked together, the combination is called a battery. Therefore, we will hereafter call our compact electrical energy source just what it is—an energy cell. (Figure 7A); unless of course, the cells are formed as a battery as in Figure 7B. We will not now go into the construction of these energy cells or describe the type of current they deliver. However, we should have some additional information on the electromagnetic coil, that wonderful magnetic source that can be turned on and off better and simpler than water from a faucet.

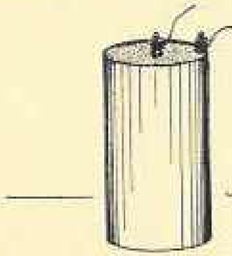


Figure 7A. Energy cell.

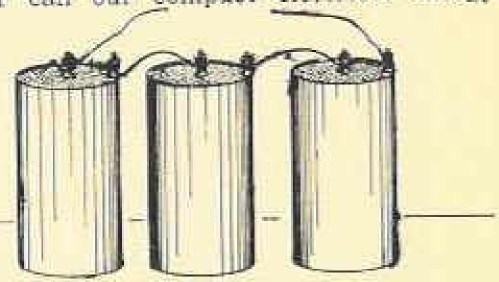


Figure 7B. Battery of cells.

To learn more about this, get a large dry cell and some insulated copper wire such as that used in bell wiring. Next take a piece of old clock mainspring about 6 inches long and shape it to a tapered point at each end, starting outward from its center. With a prick punch, indent (do not pierce) its center so that it can rest, pivot-wise, on a tack or pin sticking through the top of a piece of pithwood (see Figure 8). Then, magnetize this piece of steel in the demagnetizing coil just as you did the file. When you place the poised, magnetized, pointed steel spring on the pivot, you will notice that it will turn back and forth until it finally comes to rest with one end pointing directly north. It now acts as a magnetic compass, and will be very sensitive. This will be a teaching aid in the following lessons and many other interesting and useful things about electricity.

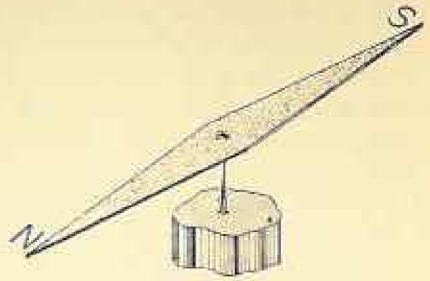


Figure 8. Elementary compass.

Since one end of this compass points to the north magnetic pole we can mark this end N and its opposite point S. This can be done with a scratch awl or colored lacquer. Generally, the darker point indicates north and the lighter colors, south.

Let us go back to our energy cell. With it we can demonstrate some things about a simple coil of insulated wire, its magnetic power, how this power can be increased, and something about the polarity of an electromagnetic coil.

If a magnet (even our own magnetized file) is suspended as shown in Figure 9, it will act just like our pivoted mainspring strip, and become a directional compass. This is because one end will be attracted to the earth's north magnetic pole and the opposite end to the south magnetic pole. Thus *all* magnets have polarity. This includes permanent, temporary and electromagnets.

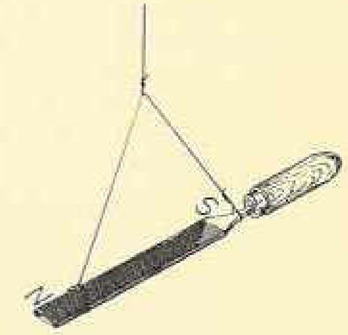


Figure 9. Swinging file compass.

POLARITY IS COMMON TO ALL MAGNETS, BUT IT MUST BE CONTROLLED WHEN PUT TO WORK TO OPERATE WATCHES

We have already shown that both temporary and permanent magnets have polarity. To prove that electromagnets have polarity, we will make our own electro-magnet. By doing so, we can learn some things about one of the most important units of all electric clocks and watches.

Take a piece of insulated bellwire about a foot long. Scrape the ends bare for about a half inch and connect one end to a terminal of a dry cell so that the rest of the wire forms a loop. Next, place the pivoted magnetic compass you have made close to this loop. Grasp the free end of the wire and touch it to the other terminal of the dry cell, making a complete circuit. The compass will swerve (Figure 10), showing that a magnetic force exists close to the wire flowing through it. (Do not allow the wire ends to remain connected to the dry cell; this might drain it.)

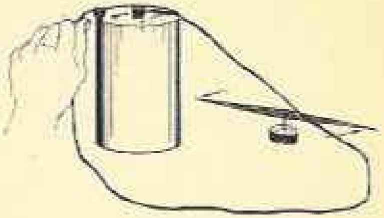


Figure 10

CONCENTRATING MAGNETISM

Let us say that a length of wire a foot long has one "unit" of magnetism per inch. But this is too weak for our purpose; we must strengthen the magnetic field. We can compress the foot of wire and its 12 "units of magnetism" into one inch of space by winding it so that it occupies only one inch. This increases the magnetic force about 12 times. While this is not exactly what occurs, it illustrates our point. We can prove this by winding the wire around a pencil or a piece of pegwood stick so that the coils are very close and compact (the wire must be insulated so that the current does not become short-circuited). Then connect the ends of this wire to the dry cell and move the compass along the coil. In Figure 11, notice how much more pronounced is the magnetic force (near the end of the coil). This proves that a coil of insulated wire concentrates the magnetic field, producing a more powerful magnet.

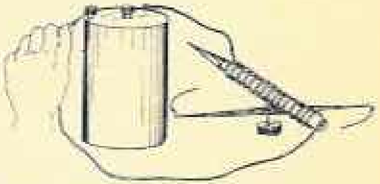


Figure 11

If we take a long section insulated wire and wind it neatly into many turns and layers, it further concentrates the magnetic qualities of the coil. There is, however, a limit to the number of turns of our coil before we lose the efficiency of the magnetic power, using only one cell.

So far, we have learned that a coil of wire can be made to create a magnetic force. We also found that the more turns

to the wire (up to a limit), the greater the concentration of magnetic force. However, much of this magnetic force extends outward, and is wasted in an area where we would rather it did not go; it may even be detrimental. If we could take this straying magnetic force and keep it close to the coil, we would have a more efficient magnet with more influence at the spot we want. We can do this by winding the wire around a soft iron core. We learned earlier that iron "absorbs" magnetism very well. In fact, some of the older watchmakers will remember that pocket watches were sometimes protected from magnetism by placing them in a sheet iron "overcase," called an "insulator." These were black lacquered and lined with velvet. The watch was protected by the casing because the iron absorbed much of the magnetism and provided a circuitous path for the magnetic lines of force around the movement. This kept these lines of force from flowing through the case into the steel parts, as might happen with a case made of brass, gold, or other metals. This property of iron is called *permeability*. Permeability is the ability of a metal to gather in the magnetic lines of force.

We can see this better if we take a magnet and place a piece of clock glass over it in a flat position. Next, place a small needle on top of the glass. As you move the magnet from spot to spot, the needle will follow along on the glass as in Figure 12. This shows that the magnetic lines of force go directly through the glass, just as light would. If you repeat this experiment with a piece of copper or brass instead of glass, the needle will behave in the same way, showing that these metals, and most others, will allow magnetic lines to pass through them readily. This is why brass makes a good casing for directional compasses; the magnetic lines of force easily pass through it to influence the magnetic needle within.

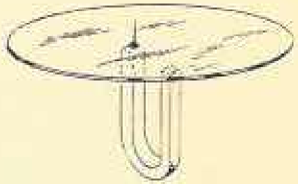


Figure 12

To understand permeability better, take an unmagnetized needle and place it on the surface of a sheet of iron. The sheet iron that makes up the base of a cheap clock dial will do. Moving the magnet under the iron plate with the needle on it has little influence on the needle. This is because the iron gathers in most of the lines of force. Some of the lines of force from the magnet will pass outward beyond the iron and attract magnetic particles, although in a limited area. Any metal or alloy which has this quality is called "permeable." Iron that is 99.95 per cent pure has a very high permeability, almost 20 times higher than iron that is only 99.91 per cent pure. An alloy often used in electric watches as a core for the electromagnetic is *mumetal*, an alloy of 18 parts iron, 75 parts nickel, 2 parts chromium and 5 parts copper.

To prove that an elctromagnetic coil wound around an iron core has a stronger magnetic force than a hollow coil, rewind the same bell wire around an iron rod or a large nail (Figure 13). Again connect the ends of the wire to the dry cell terminals. Place the pivoted compass near the end of this coil and observe the influence of the coil on the compass, comparing this influence with that exerted previously when the coil was hollow or empty. You will see that the pull is much stronger.

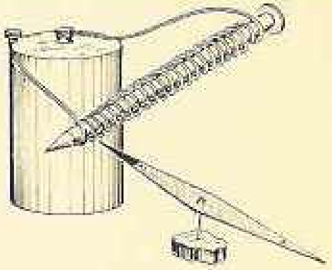


Figure 13

For this reason, electrical timepieces have their coils wound around a highly permeable metal. This strengthens the magnetic force, concentrating it at the desired spots. Also, it may sometimes be necessary (but awkward) to wind a coil in an odd shape to exert this force at one spot. (For example, close to the balance rim, or at a spot between the balance rim and the main plate as shown in Figure 14.) To obtain the same result, the electromagnetic coil may be wound around this metal or alloy, leaving some of the metal extending beyond the ends of the coil. This may then be shaped in any manner by stamping. Again, remember that permeable metals and alloys do not retain their magnetism once the magnetic influence is removed. This makes them ideal partners for the electromagnetic coil, which exerts its force only when a current is flowing through it and thus, with a switch, can be turned on and off.

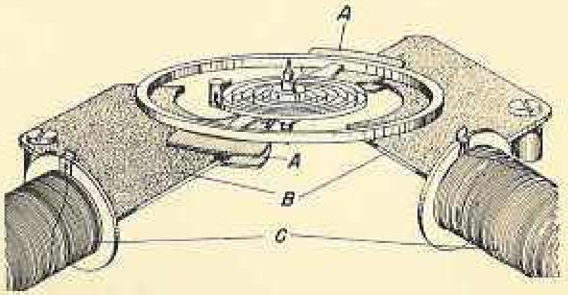


Figure 14. Electromagnet system used in Swiss clocks, similar to the plan in current Swiss electric watches. "A" points to wings made of permeable metal mounted one over the other on the balance, separated sufficiently to allow them to pass over and under the tabs, "B," of the electromagnet coils "C." When balance closes a contact, current surges through the coils.

POLARITY

If an electromagnet is connected to the terminals of a dry cell, one end of the coil will attract only the north pole of our pivoted compass while the other end of the coil will attract only the south pole opposite. In other words, the electromagnet has a definite polarity, depending on the direction the current flows through the turns of wire. When we connect one lead of the coil to the plus (+) terminal of the cell, and the opposite lead to the minus (—) terminal, the end of the coil which is connected to the plus terminal will point to the north magnetic pole (if the coils are wound in a clockwise direction). The end of the coil which terminates at the minus post (terminal) of the cell will point to the south magnetic pole (see Figure 15). Notice that on dry cells, also called energy cells, the plus terminal is usually in the center, the minus terminal at the side. In the flashlight type dry cell, the plus terminal is situated at the top, and generally has a slight button or head, while the bottom contact is the minus terminal. The plus terminal is also called *positive;* the minus terminal is also called the *negative.* Some of these types of dry cells (energy cells) are illustrated in Figure 16. Notice that some of them have the plus terminal on the base.

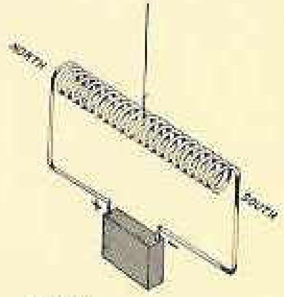


Figure 15

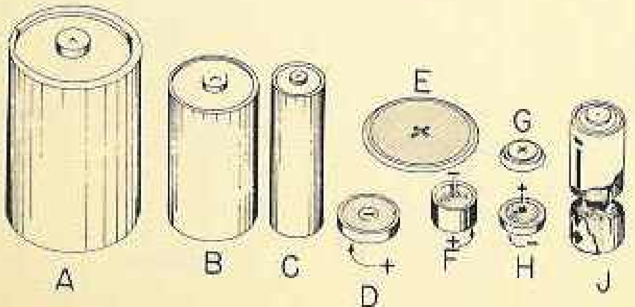


Figure 16. Energy cells. "A," "B" and "C" are the familiar flashlight types. "D" is used in the Swiss electric watch. "E" is the Leclanche cell used in some Swiss models. "F" is the energy cell used by Timex. "G" is used by Bulova, "H" by Hamilton. "J" is actually a battery of three energy cells, unsuitable for watches but widely used in compact hearing aids.

A knowledge of polarity is important in the study of electric watches because in certain watches (such as the Hamilton, Timex, Epperlin, etc.) the electromagnet is wound, and contacts are plotted in such a way that they have a definite and purposeful polarity. If it were possible to reverse the energy cell leads and connections, these watches would not operate correctly. But to study the reasons why this is important, we must learn some additional facts about magnetism.

As we understand now, magnets of all types have polarity. One end is a south magnetic pole and the other is a north magnetic pole. If we place two magnets together, they either become strongly attracted to one another or else repel one another. If we place the south pole of our magnetized file near the north pole of our pivoted compass, the compass point will quickly and strongly swing towards the file tip. If we place the same file end close to the south pole end of our compass, the compass will swing away from our file. In fact, you can discover which end of your magnetized file is the north pole by placing it adjacent to the pivoted compass and observing which end of the compass is either attracted to the file or repelled by it. From this fact we can establish that like poles attract and unlike poles repel each other. These attracting and repelling properties exist in an electromagnet with current or a permeable magnet under the influence of a magnet of any other type.

LINES OF FORCE

The "magnetic lines of force" emanating from an electromagnet or a permanent magnet arrange themselves in a definite pattern. We call them "lines of force" because we can "see" them. From numerous experiments, scientists have observed that when small iron filings are sprinkled near magnets, they arrange themselves in a definite pattern. We can easily observe this, and learn a great deal about the magnetic attraction the magnetic attraction and repulsion of magnets when they pull or push a balance, pendulum or tuning fork in certain timepieces.

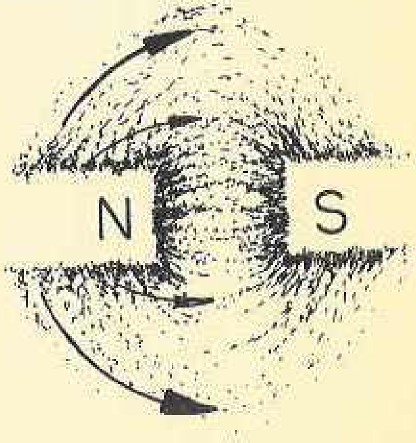


Figure 17

Magnetize another file, and from the pivoted compass, discover the polarity at each end and mark it accordingly with the north and south poles. Next, place both files end to end so the poles are of opposite polarity, separated by about three-quarters of an inch. Place a sheet of white paper over the files. Then sprinkle some iron filings from a piece of soft iron over the paper near the junction of both files. The filings will arrange themselves in a pattern (see Figure 17), and thus we can surmise that magnetism exists in lines of force. The area which these lines covers as shown by the filings is called the "magnetic field."

Lift the paper from the magnets an pour the filings into a bottle so they can be used again. Reverse one file so that its end, say the south pole, is opposite the south pole of the other magnet—but again separated by about ¾ of an inch. Cover the files with paper and sprinkle iron filings over the junction. The filings will arrange themselves over the magnetic lines of force, but they will appear as in Figure 18, because the lines of force from the similar ends repel one another. Notice also that the strongest concentration of the magnetic field is at the ends of the magnets. As indicated in Figure 17, we see that the magnetic lines of force travel from north to south.

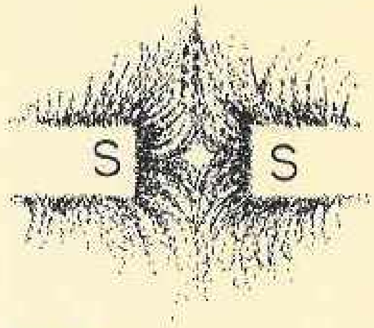


Figure 18

SHAPES OF MAGNETS

If we break a bar magnet in two, the broken ends will assume polarities opposite from their original ends. For example, suppose we have a bar magnet with a north pole at the right. We then break this in two. The original ends will remain unchanged, but the broken end of the magnet at the left will become a south pole and the broken end at the right will assume a north polarity. If we continue to break or divide these sections, we will obtain the same results (Figure 19). Eventually, the bar or rod magnet would become little more than strips or discs. However, in such a process, it is possible for the top to have the opposite polarity from the surface below.

Of course, these can be polarized in much simpler manner, but this should explain

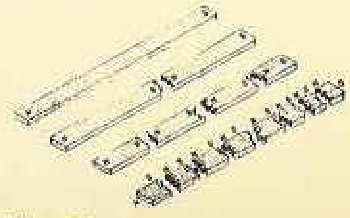
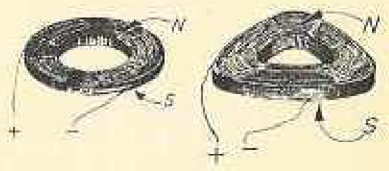


Figure 19

that magnets can be made to any shape and polarity. Thin magnets with polarities opposite one another are used in the Hamilton-type electric watch. In some electric pendulum clocks, the pendulum is made of an electromagnetic coil moving within a curved bar magnet with the same polarity at extreme ends while the center has a polarity opposite to its ends.

Electromagnets also have polarity. When a length of wire is wound in a cylindrical coil, one end will be a south pole and the other end a north pole. Furthermore, this polarity can be planned so that the ends have the polarity desired. The wire lead attached to the plus end of the cell and wound in a *clockwise* direction will have at this end a north magnetic pole, and the opposite end will become a south magnetic pole (see Figure 15). Should we compress this coil so that it forms a coil like that in Figure 20, or even one like Figure 21, its polarity would be north on top and south below, as shown in the drawing. Therefore, it is possible to have flat, permanent magnets with top and bottom opposition and equally flat electromagnets with north and south situated as the heads and tails of a coin.



Figures 20 (left) and 21. No matter what its shape, a disc formed from a compressed coil will have the same polarity as the original coil.

If we can make such a flat magnet (coil), it can be mounted on a balance (as in the Timex, Hamilton, etc.), and either a permeable material or a permanent magnet can be situated in the narrow space below and/or above the balance at such a spot that brings about the greatest magnetic efficiency on the balance motion when a "switch" turns the energy cell current on and off.

A CURRENT of electricity can be likened to water flowing through a pipe. But electricity flows through solid wires. It has pressure, rate of flow and, just as there is friction in waterpipes, there is resistance to the flow of electricity. At times, this resistance is deliberately planned.

Electrical current can be made to flow from an electric cell (another term for dry cell, energy cell or battery). The electric cell was the invention of Allesandro Volta (1745-1825), a contemporary of Breguet. Volta made a cell by immersing a strip of copper and a strip of zinc in acid. He then attached a wire to each of these metal strips, and by touching one wire to the other, created an electrical spark. Volta also introduced the idea of connecting cells together to form a battery. Actually, if we take two strips of unlike metals and immerse them in a dish of water, we create a potential source of electrical energy.

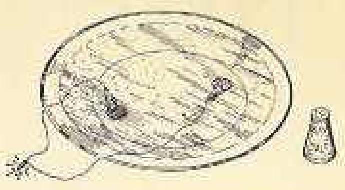


Figure 22. Simple electric cell.

To illustrate this, connect an electrical wire clip to a copper penny and another such clip to a white penny. Immerse them in water and add a bit of table salt. Touching the ends of these leads to the proper parts of a tiny light blub will cause it to glow faintly, as shown in Figure 22.

"DRY CELLS"

However, since it would be awkward to use an electrical cell requiring a liquid caustic agent or acid as an "electrolyte," a more convenient form of "dry" cell is employed. But even this is not really dry. It contains a moist paste of ammonium chloride (sal ammoniac) and manganese dioxide. The container is made of zinc, and forms one electrode, while a carbon rod in the center serves as the other electrode. There are many other compositions which can be used to create a source of electrical energy. Wrist watches and other small devices requiring a compact source of energy use different materials to make up an energy cell or battery of cells, among which are the mercury type of energy cells. The compact, button "dry" cells are designed to supply a flow of electrical pressure (volts) in small quantities over a long period of time. This type of cell can be likened to a water pistol that squirts a stream, although a very thin one. In this case, while the stream has some power, the actual volume of water is negligible.

Some types of electric cells can be renewed by recharging —e.g., the storage battery in an automobile. These operate by a combination of two rods of lead immersed in a solution of dilute sulphuric acid. If the rods are connected to a source of direct current for some minutes, bubbles form around each rod (electrode). A brown coating forms on one of the rods (the positive pole). Oxygen forms at the positive plate, changing the lead to lead dioxide. Hydrogen is freed from the negative plate, which is reduced to a spongy form of lead. When this occurs, the cell is *charged*. This is shown in Figure 23.

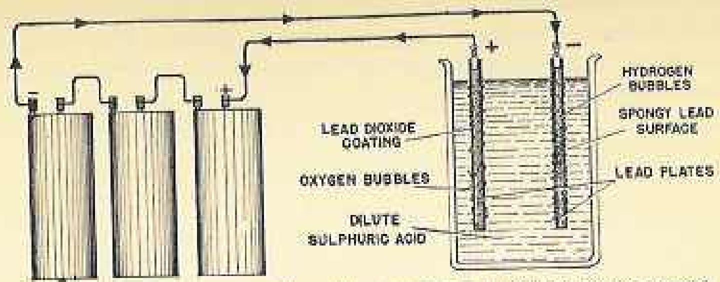


Figure 23. When a storage battery (like one used in an automobile) is charged, lead oxide and oxygen form on the positive electrode. Hydrogen, when freed from the negative electrode, changes the surface to a spongy form of lead.

In Figure 24, wires are connected to the rods and also to the terminals of a bell or a small light bulb. The bell will ring or the bulb will become incandescent for awhile; then the bell stops ringing or the light goes out. The cell has now become discharged. The rod electrodes will look just as they did before being charged. The cell can be recharged by repeating the original charging process.

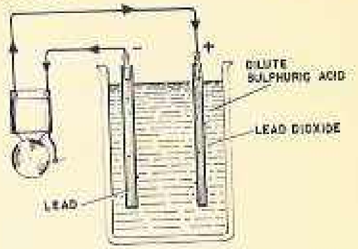


Figure 24. When connected for a time to a bell or small light bulb, a cell will "run down," or become discharged. The electrodes will then appear as they did before the charging process.

In a watch, such a cell can be shaped to fit in the back of the case. It can be recharged by connecting the terminals to another form of dry cell which will recharge it. Such a cell, shown in Figure 16-E, is in the watch being recharged by another, larger cell shown in Figure 25.

MORE ABOUT VOLTS

Generally, most cells supply 1½ volts of current. But what is a volt?

The volt is to electricity as pounds (pressure) per square inch is to a water supply. Each electric cell, regardless of size, is analogous to a shallow tank of water with a spigot at its base A larger cell is like a larger tank with the same water level as the small one. It will hold more water, and thus last longer, but the stream of water that will emerge from the spigot will be the same. (See Figure 26.)

Figure 25. Charging a watch cell.

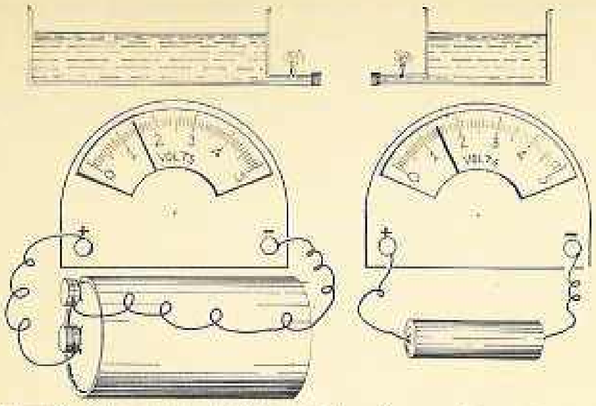


Figure 26. A large electric cell (left) will last longer than a smaller one because it has more "stored up energy." But it won't put out any more volts.

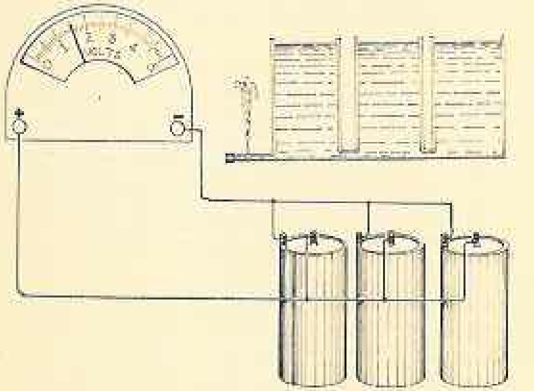


Figure 27. A battery of cells wired "in parallel" will last longer than a single cell, but the voltage will not increase.

If we connect two or more cells to form a battery, but with the leads in parallel (Figure 27), the battery will last longer than the cells would have separately, but the electrical pressure or voltage will remain the same as that produced by a single cell. Here, all of the negative (—) leads are connected to one another while the positive (+) leads are joined to one another. Such a hook-up is called "in parallel." This can be compared to a number of water tanks connected on the same level or parallel to each other, as shown in this same figure. The effect is the same in the larger water tank but with the same level of water.

Should we arrange the same tanks so that each tank's pressure is added to the other, the water pressure coming out of one one spigot will be equal to the *sum* of the pressure of each individual tank (the weight of each column of water is added to the one below it). This is shown in Figure 28.

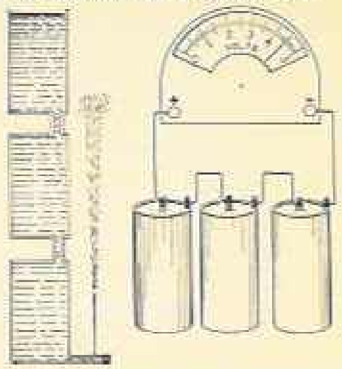


Figure 28. If connected "in series," electric cells form a battery that will produce the combined voltage of all the cells.

We can do the same thing with electric cells. If we connect the positive lead from one cell to the negative lead of an adjacent cell, and so on, we get the voltage (pressure) of all the cells thus connected (1½+1½+1½), or 4½ volts. This procedure is called "connected in series." When we continue this process, we will obtain the combined pressure of all the cells. Thus, it is possible to get a desired voltage by hooking up electric cells in series, as shown in Figure 28. The cells pictured in Figure 27 are connected in parallel. (Note: most cells, regardless of size are rated at 1½ volts.)

The Lip electric watch uses two 1½-volt cells (Figure 29), in parallel instead of in series. This does not increase voltage, but permits the watch to run longer between power cell changes.

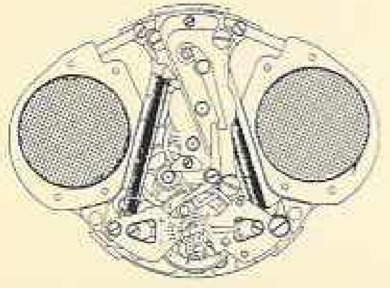


Figure 29. Two parallel cells are used to power the Lip electric watch.

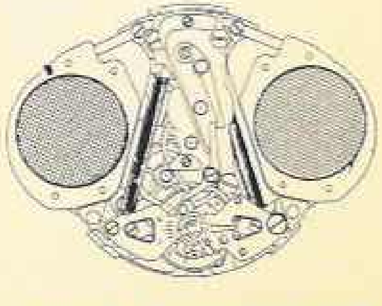


Figure 29. The Lip electric watch operates on two connected coils of wire totaling 10,000 turns.

Our comparison of an electric circuit to a water supply system does not end with pressure or voltage. In a water supply system a pipe with a large inside diameter will permit more water to flow from the reservoir in a given time than if the pipe were smaller. In electricity, the same holds true. If we use a thicker wire, more electricity will flow from the source and, like the water tank, the supply will be exhausted sooner. If we increase the pressure on the water, more gallons will flow in one minute. Likewise, if we increase the thickness of our wires, we get more electricity; if we have a battery of cells, more electrical pressure (voltage) will deliver more electricity "per second." This electrical current flow is called "amperage."

A flow of water is measured in gallons per second. This unit defines quantity as a standard interval. In electricity we also measure the quantity of electricity that passes in one second. A unit of electricity is called *coulomb* (6.28 billion billion electrons). If this passes through the wires in one second, the current is one *ampere*. This is measured with an *ammeter*.

Resistance to a current of water can be caused by friction in the pipes, the length of the pipes from the supply to the outlet, the smoothness of the bore and other factors. Thin piping offers greater resistance to the passage of water than thicker tubing, as shown in *A* of Figure 30. Here, the thicker opening of the short tubing at the right allows more volume to pass than the longer, thinner tubing at the left. Likewise, as shown in *B* and *C* of the same figure, in an electrical circuit, a very long, thin wire offers greater resistance to the passage of electricity than a shorter, thicker one. Thinner wire resists electrical flow more than does thicker wire. This is shown by the ammeter readings of the long thin wire, *B*, as compared to the short, thicker wire, *C*, in Figure 30.

Not only do the thickness and the length of the wire affect the flow of current, but so does the composition of the metal. Some metals conduct electricity better than others. Silver is the best conductor of electricity; that is why some contacts have silver tips. Next in order of superiority of electrical conduction are copper, gold, aluminum, zinc, tungsten, brass,

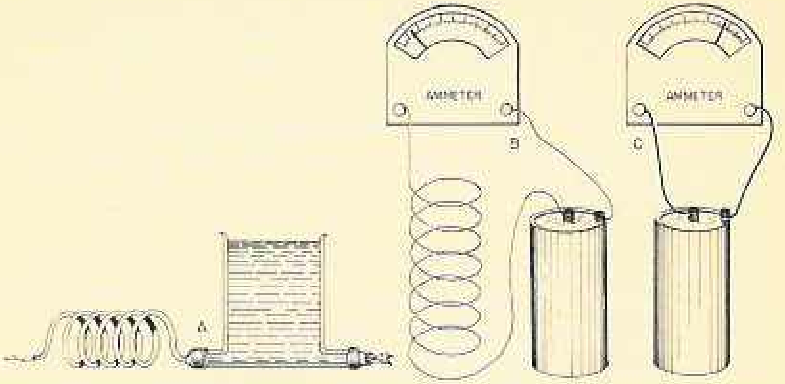


Figure 30. Just as the long, thin tube on the tank, "A," allows less water to pass than the short, thick tube, the long, thin wire, "B," allows less electrical voltage to pass from the cell than does the short, thick wire in "C."

tin, iron, nickel, platinum, soft steel, mercury and cast iron. Because silver is expensive, copper, being next best, is used most often. Carbon is also a conductor of electricity.

Conversely, some materials resist the flow of electricity. These materials are called *non-conductors*. Because they resist the flow of current, they are used as insulators. Some of these are: dry air, shellac, paraffin, ebonite, porcelain, rubber, glass, mica, silk, paper, wood, slate, celluloid, distilled water (not tap water) and alcohol. Because they conduct practically no electricity, these are used to separate adjacent electrical conductors, such as one turn of wire from another in a wire coil, or for the cover of electrical wires, condensor plates, etc.

We have learned that a comparison of water and electrical currently shows that we measure water in quantity in gallons; electricity in *coulombs*. Water pressure is measured in pound per square inch; while electrical pressure is measured in *volts*. The flow of a current of water is measured in gallons per second. In electricity, this flow is measured in *amperes*.

One gauge peculiar to electricity is the resistance or impedance to a current. This resistance is measured in *ohms*. The knowledge of the nature or measure of a resistance to an electrical current is of great importance and assistance to a watchmaker who works on electric watches or clocks.

OHM'S LAW

Ohm's Law is a simple formula that anyone can learn. It requires only elementary math. With it you can gauge the amperes, volts and ohms of any electrical circuit or device. With this knowledge you can detect flaws in the electrical circuit, coils, contacts and general efficiency of a watch or clock.

FIGURE 31 — OHM'S LAW MAY BE EXPRESSED IN THREE WAYS

IN TERMS OF:	MEASURED IN:		FORMULA EXPLAINED:	SIMPLIFIED FORMULA:
CURRENT	AMPERES	=	$\frac{\text{PRESSURE (VOLTS)}}{\text{RESISTANCE (OHMS)}}$	$\text{AMPS} = \frac{\text{VOLTS}}{\text{OHMS}}$
RESISTANCE TO FLOW OF ELECTRICITY	OHMS	=	$\frac{\text{PRESSURE (VOLTS)}}{\text{CURRENT (AMPERES)}}$	$\text{OHMS} = \frac{\text{VOLTS}}{\text{AMPS}}$
ELECTRICAL PRESSURE	VOLTS	=	CURRENT (AMPERES) X RESISTANCE (OHMS)	VOLTS = AMPS X OHMS

Figure 31. A simplified explanation of Ohm's Law. In electrical terminology, the symbol for volts is "E." Amperes is expressed as "I" and ohms as "R." Standard electrical formulae, such as E=IR and its variations, were omitted for simplicity.

Figure 31 shows us that knowing any of the two values, we can obtain the third.

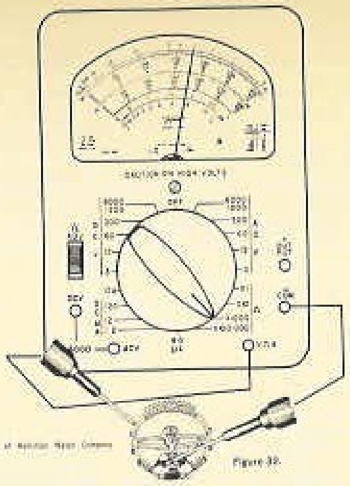
For example, we have a problem deciding how large a current a single cell (1½ volts) will send through a wire with a resistance of 300 ohms. It is solved easily:

Amps = Volts divided by the resistance (300 ohms). In simpler form, $\frac{1.5}{300} = .005$ or five thousandths of one ampere, also termed five *milliamperes* (thousandths of an ampere).

PRACTICAL APPLICATION

Now let's apply this knowledge to the repair and adjustment of an electric watch. The French (Lip) electric watch operates on two connected coils of wire (Figure 29), each containing 5000 turns. From the stated current of six microamperes (six millionths of an ampere or .000006) under a voltage of 1.50 volts, we can find the proper resistance value of the coils.

With a sensitive ohmmeter, we can test whether the coil is defective. Using our formula Ohms = Volts/Amps we substitute our known value or 1.5/.000006 = 250,000 ohms. Should our meter read much less than that number, we can assume that a short exists in the coils. In Figure 32, such a device is shown testing the coil efficiency of a Hamilton electric watch.



Courtesy of Hamilton Watch Company

Figure 32.

WIRE RESISTANCE

The resistance of a piece of metal wire depends not only on the type of metal used for the wire, but also on its length, thickness and temperature.

The longer the wire, the greater resistance. Suppose a length of wire 100 feet long has a resistance of one ohm; the same wire 100,000 feet long would then have a resistance of 1000 ohms. If the same length of wire was substituted for one with a cross section of half the area, the resistance would be doubled, and this wire would have a resistance of 2000 ohms.

For example, let us take again the Lip electric watch with its coils totaling 10,000 turns of wire. The thickness of the wire is .025mm. Since we know the resistance of the coils to be 250,000 ohms, we can divide the 10,000 turns into the 250,000 ohms resistance and find that the wire has a resistance of 25 ohms per turn (approximately — because the inner turns are shorter than the outer layers of wire).

TEST QUESTION

If the Hamilton electric watch has a stated 3100 ohm resistance in its coil, and uses a 1½ volt cell, what is the amperage?

UNDERSTANDING ELECTRIC METERS

Since we are going to use electric meters while testing clocks and watches in our work, we should know the basic principles of their construction and operation.

Electric meters are comparatively expensive. A working knowledge of their construction and principles is necessary to interpret their readings properly, and to avoid "burning out" their delicate mechanisms.

In some ways, the action of a meter is similar to the circuitry of some electric timepieces.

In a meter the indicator hand is impulsed electrically and turns in a pivoted arc. The hand is poised like a balance, has hairsprings which resist an impulse, and then help return it to the zero position. The pointer pivots on jeweled bearings.

THE GALVANOMETER

The galvanometer is a simple, but sensitive, instrument used to make comparisons between quantities of electric current. Voltmeters and ammeters are basically galvanometers—but with some additions.

We can demonstrate the principle of an electric meter with a simple experiment. First, wind a coil of about 25 turns of fine wire around a hollow paper core, so that the coil will fit loosely between the prongs of a horseshoe magnet. Arrange the coil so that its rounded surface is adjacent to the prongs of the magnet, as shown in Figure 33, and suspend it loosely in this position. Connect the ends of the coil to an electric cell for a moment. Watch the action of the coil within the prongs of the magnet. Note that when you complete the electrical circuit by touching the wire to the cell lead, the coil twists to some degree.

Figure 33

Now reverse the leads and observe the action. The twisting motion reverses itself. Should you double the voltage by hooking up additional cells in series, the twisting action of the suspended coil will be more pronounced.

The action of the coil within the magnet is principally that of a simple galvanometer. Earlier we learned that when a current is sent through a coil of wire an electromagnetic force is created. This force has the same characteristics as a magnet, including polarity.

Thus, when a current was sent through the small coil, it assumed the properties of a magnet and its poles attempted to align with those of the permanent magnet. It did this by twisting to approach the opposite poles of the horseshoe magnet, and was simultaneously repelled by the magnet's similar poles. The degree of twisting depends on the strength of the electromagnetic force created by the electric cell or cells.

If we could mount an indicator hand on the twisting coil and arrange some scale or dial, we would have a simple means of comparing different electrical values.

In effect, we would have a simple galvanometer.

Figure 34 shows a simple horseshoe magnet. A "split-ring" magnet may be used as well. Fasten the magnet to a housing. The magnetic field supplied by this magnet has a fixed polarity. The lines of force are represented by dotted lines.

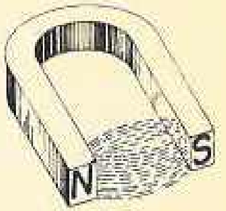


Figure 34

Figure 35 indicates that a soft iron core has been mounted in a stationary position between two soft iron pieces attached to the prongs of the magnet. Their purpose is to concentrate the lines of magnetic force. Earlier we learned that soft iron has this ability.

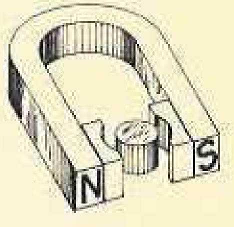


Figure 35

In Figure 36, the core piece of cylindrical soft iron and the soft iron attachments cause the lines of magnetic force to become radial, like the spokes of a wheel, and flow from the north to the south pole.

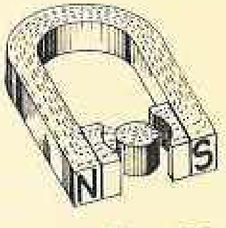


Figure 36

Instead of the round coil used in our experiment as shown earlier in Figure 33, a square type of coil is wound on a form and held by an adhesive or shellac (Figure 37). The square form will closely fit around the core of soft iron, since the profile of a cylinder is rectangular or square. Most coils are either wound around a paper form, or the coils are their own form, held together with shellac.

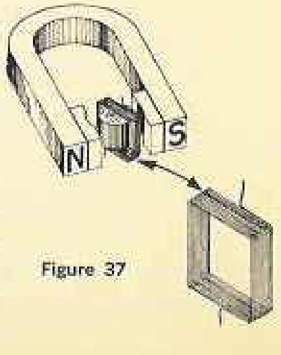


Figure 37

The coil is intentionally light and delicate so that it responds quickly and easily to electrical stimulus, although its delicate construction makes it susceptible to damage. When the two ends of the box-like coil are attached to a source of electric current, the current produces a magnetic field of its own. (The coils are pictured in this position for clarity only.)

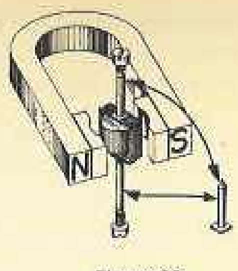


Figure 38

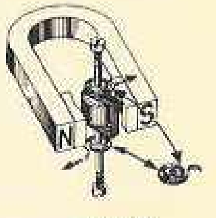


Figure 39

In Figure 38 two pivots have been attached, one above the coil and the other on line below it. The pivots are attached to the surface of the coil by shellac, or a similar substance. The pivots are carried by two cup-jewel bearings, much like the pivots of a clock. The cups are usually sapphires. This permits the coil, when in circuit and containing a flow of current, to attempt magnetic alignment with the permanent magnet.

To combine the elements of a meter we start with a horseshoe magnet (Figure 34), add a soft iron core (Figure 35) which causes the lines of magnetic force to become radial (Figure 36); add a delicate coil (Figure 37), two pivots (Figure 38), and two hairsprings (Figure 39) to restrain the coil.

The alignment of the coil's field with that of the permanent magnet is restrained by two hairsprings, as shown in Figure 39, situated on each shaft of the pivot.

The springs also carry the current to be measured in and out of the coil. The two hairsprings serve as a restraining force —they return the coil to the zero position after the electrical stimulus has been removed. The ends of the box-coil are attached to the hairsprings and carry the current to be metered to the coil. The hairspring ends are generally soldered to the terminals on the meter casing.

Now that we have the elements of an electric meter, we must place an indicator-hand on the upper pivot-shaft, as shown in Figure 40. This hand is usually made of aluminum or other light alloy to maintain the sensitivity of the coil and in case of an over-charge in the meter, are not so heavy or rigid as to cause the pivot to be dislodged from the coil.

Notice that the hand-indicator is poised. Poising is effected by winding a short length of wire around the tail of the indicator. Sliding the little wire along the indicator's tail alters the poise. Sometimes the tail itself is bent up, down or sideways to achieve a precise adjustment.

Under the indicator-hand a scale is placed, calibrated to the meter and its task. Banking pins prevent excessive angular motion of the indicator.

So far we have pictorially constructed a simple electric meter. A cursory study of the coil and its hairsprings shows that if the meter were subjected to large currents of electricity, the coils, springs and connections would melt from the excessive heat. Do not use a meter without first understanding how it operates and its limitations. Every electrical device, whether a toaster or an electric watch, carries a definite current. Subjecting it to current beyond its limit will destroy it; often an expensive loss.

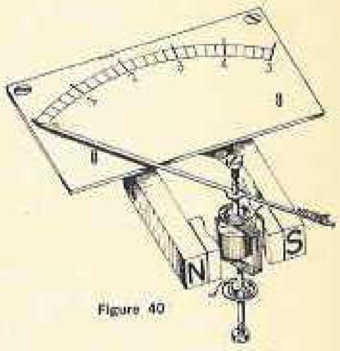


Figure 40

For example, a flashlight uses two cells in series (three volts). The resistance of the filament in the little bulb is six ohms.

Using Ohm's Law, we find that the flashlight will use .5 amperes. The bulb's filament will burn white hot, producing a beam of light. Should we use this bulb on a four-cell flashlight the amperes will double, causing the filament to melt and burn out. Conversely, using the bulb with a one-cell flashlight will permit the filament to become only red hot, not bright enough to produce the desired beam of light.

The Ammeter

We said before that ammeters and voltmeters are basically galvanometers, but with specific variations.

If we take a galvanometer and place a piece of wire across the leads, it would register less than it would without the wire. The galvanometer can be likened to a water meter where *all* the water must go through the meter.

Add a by-pass to this water meter, as shown in Figure 41, and this same meter can handle larger quantities and greater water pressure.

To do this, a small portion of the water going through the pipe is diverted by the same pressure that moves the main stream. This small stream motivates a meter which records the comparative amount of the small stream. Since the same pressure is moving both streams, the gauge's dial can be calibrated to reflect the actual quantity of the entire stream.

In this way only a small amount of water need be sent through the meter at one time, and it can be used to gauge many different degrees of water pressure. All you have to do is change the size of the shunting pipes and vary the dial markings.

Similarly, the galvanometer can be designed to indicate amperes or volts. For the ammeter a shunt is used as pictured in Figure 42. While most of the current goes through the shunt, a small but comparative amount goes through the meter, to register on an appropriate scale.

The quantity of current going through wires *A* and *B* is in direct multiple proportion to the current going through the meter at *C*. Thus when the meter is supplied with a series of shunts it reads the value in amperes.

It is possible then for one meter, supplied with a multiple switch which connects with shunts of different values, to be able to gauge many ranges.

The Voltmeter

A coil of wire resists the flow of electricity like a hose resists the passage of water. The force of a current of electricity, expressed as volts, is measured by the voltmeter. Once again, too much voltage will burn out the coil and hairsprings. Just as the shunts diverted the main flow of current in the ammeter, a resistance is used to measure comparative pressures of electricity with the voltmeter.

THE AMMETER

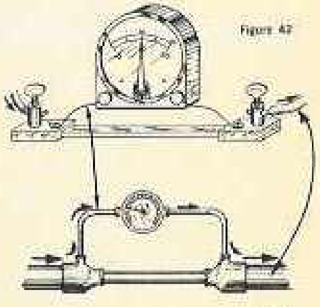


Figure 42

Figure 41

Unlike the ammeter, which is connected in parallel as illustrated in Figure 42, the voltmeter must take the direct force of the current because the connections are in series.

To gauge this force without destroying the meter, a resistance is placed between the gauge's terminals and the source of current. A form of voltmeter is shown in Figure 43.

To measure the voltage of a cell, the meter's leads are attached across the leads of the cell. Do not, of course, use a meter with a limit less than the potential of the cell or battery.

Water doesn't flow directly through the gauge to measure pressure. The gauge only judges the pressure through the pipes. With a voltmeter, practically no current passes through the meter. The meter merely gauges the electric pressure. The resistance coil limits the flow of electricity through the meter.

Suppose a meter has a dial with a maximum reading of 30 volts. Should we attach a coil which resists the flow of electricity by five times, the 30 volt reading can be transcribed to read 150 volts without harming the meter.

By connecting a coil which decreases the resistance to a fifth of the 30 volt coil, the maximum true reading on the dial will only be six volts.

By supplying the meter with a few resistance coils of different values, it is possible for the meter to have many limits.

THE MULTIMETER

If a galvanometer is supplied with a series of shunts and resistances and switches to connect them to the meter, in parallel for the ammeter and in series for the voltmeter, it is possible for one instrument to read not only volts and amperes but volts and amperes in a wide range. Such a device is called a "mutimeter."

USING ELECTRIC METERS

Much of the testing of electric and electronic watches and clocks is observing the condition of the timepiece's various coils and sections of wire.

These coils, which make up the electromagnetic system, are designed either to resist or limit a flow of currnt or to create electromagnetism. But regardless of its primary purpose, the coil always acts as a resistor.

A longer, thinner wire resists the passage of current more than does a shorter, thicker wire (See Figure 30). Thus, a longer section of wire will create a greater resistance, whether it be a mile long or wound up in a neat coil less than a cubic inch in size.

If a bare length of wire were wound tightly, it would act more like a solid piece of metal than a coil, since there would be no protective insulation to prevent the electrons from taking a shortcut through the coil. This is termed a *short-circuit*. When this occurs, there is little resistance to the current.

Most wire coils are made of copper dipped in an insulating material such as shellac, varnish or plastic, which provides thin but effective insulation and allows the coils to be closely wound. The result is tighter formation of the electromagnetic lines of force.

If some of the insulation is accidentally scraped off or the coil broken by abrasion or heat, a short-circuit results and the electromagnetic qualities of the coil are severely impaired. In an electric clock this results in a weak magnetic impulse and rapid deterioration of the batteries. In a watch, the voltage is diminished or disappears, and either causes a poor balance motion or complete stoppage, with possible deterioration of the batteries.

MEASURING RESISTANCE

If we suspect that a coil is faulty, we can test it by comparing it with figures supplied by the manufacturer which indicate what a coil in good condition should register.

Where there are twin coils in a watch or clock, such as the Lip watch or Swiss clocks, you can compare the two coils in the same timepiece.

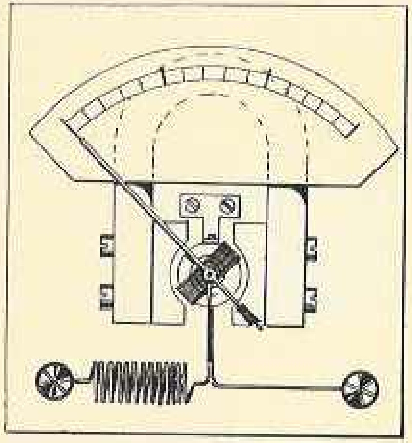


Figure 43

The voltmeter is much like the galvanometer. Because it will be subjected to varying voltages that might burn out the meter, a high resistance coil (lower left) is placed in series with the meter. By supplying this meter with an assortment of calibrated coils, a varied range of voltages may be gauged.

There are many methods of gauging the resistance of a coil. Ohm's law will give us the value in ohms (*electrical symbol-R*), amperes (*electrical symbol-I*) and volts (*electrical symbol-E*). If we know the value of any two of these, we can find the third by using the formulae.

Therefore, if we can measure the voltage drop across the resistance and the amperes, we can discover the resistance in ohms by the formula:

$\text{ohms (R)} = \dfrac{\text{volts (E)}}{\text{amperes (I)}}$. If we have an ammeter and a voltmeter, we can obtain the two of these values needed to discover the third, resistance expressed in ohms.

Suppose we suspect the coil of a battery-operated clock to be faulty. We connect our ammeter in series with an electric cell as shown in Figure 44, across the two ends of the coil, and the voltmeter across the winding of the coil. Of course, you must use meters capable of carrying the necessary current. The readings on the ammeter will give you the *intensity* (I), another term for current or amperes; the voltmeter will gauge the *electromotive force* (E), the electrical term for volts. Knowing these two, we can learn the third; *resistance* (R) or ohms.

Assume the voltmeter reads 3 volts and the ammeter indicates a .20 ampere reading. Using the formula:

$$\frac{E}{I} = R\text{; we see that } \frac{3}{.20} = 15 \text{ ohms.}$$

Most clocks have their correct electrical values stamped on the clock or coil spool. If your figures match those of the maker, the coils are in good condition. Should the ammeter read .5 amperes, the formula:

$$\frac{E}{I} = R \text{ tells us that } \frac{3}{.5} = 6 \text{ ohms.}$$

This would indicate that 3/5 of the coil is inoperative.

Another example: If the maker of this clock had stated that the coil's resistance value is 15 ohms, our formula checks out similarly by

$$\frac{E}{R} = I \text{ or, } \frac{3}{15} = .20 \text{ amps.}$$

THE OHMMETER

While it is possible to obtain resistance values (ohms) by hooking up both a voltmeter and an ammeter, this method is awkward. Today, meters expressly designed to measure resistances alone are available. To understand the working principle of an ohmmeter, assume that you have a galvanometer with a scale reading up to .005 amperes, or 5 milliamperes.

Connect this galvanometer in series with a one-cell battery of 1½ volts and a 450 ohm resistor, as shown in Figure 45. By using Ohm's law again, we find $I = \frac{E}{R}$ or, $\frac{1.5}{450} = .003$ amps, which measures the current flowing through the coil.

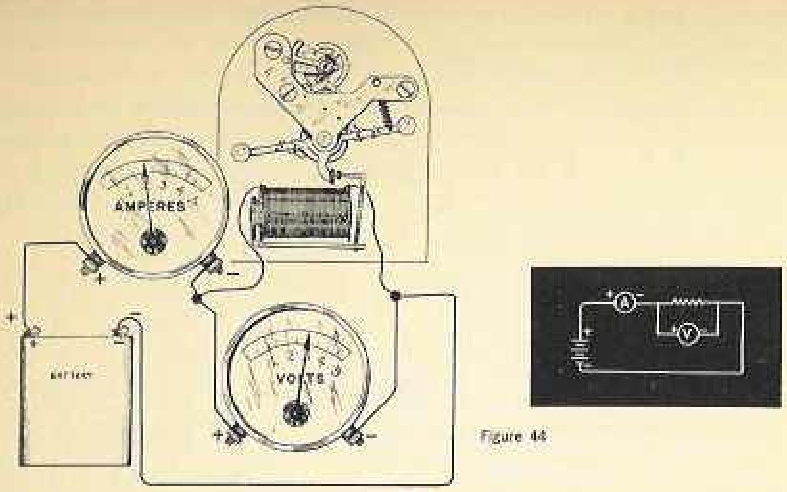


Figure 44

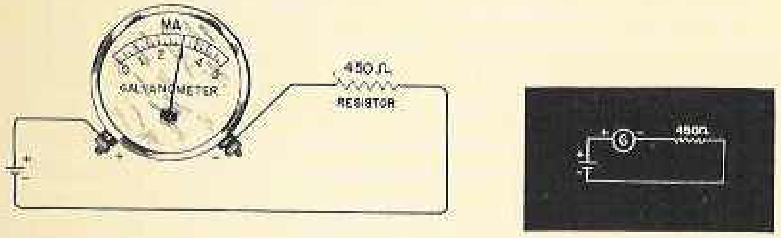


Figure 45

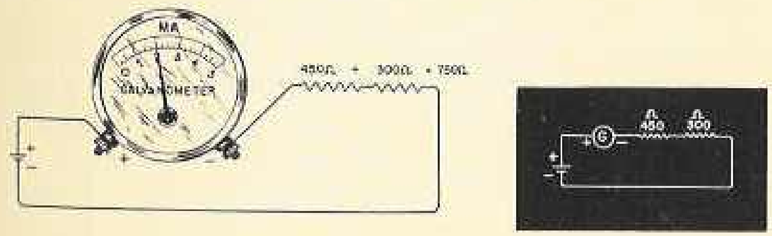


Figure 46

Figure 44 shows the ammeter, voltmeter method of testing the resistance of a clock coil. A galvanometer arranged in series with a battery and known resistor will supply a reading, as shown in Figure 45. An additional resistor is added in Figure 46. The white on black drawings at the right are the same figures expressed solely in electrical symbols.

With the same idea, let us add to the 450 Ω (*The Greek letter omega, Ω, is often used as the symbol of ohms*) resistor another of 300 Ω in series with the first one. The total of resistance in series is the sum of the values of each. Or, in this example, 750 Ω, as shown in Figure 46. Again using Ohm's law, $I = \frac{E}{R}$ or, $.002 = \frac{1.5}{750}$.

This shows a lower reading on our instrument. By using various resistors, in addition to the 450 Ω resistor in the circuit, it is possible to obtain different readings on our instrument. Even if the instrument had no known scale, we still could calibrate a scale upon it from our known values.

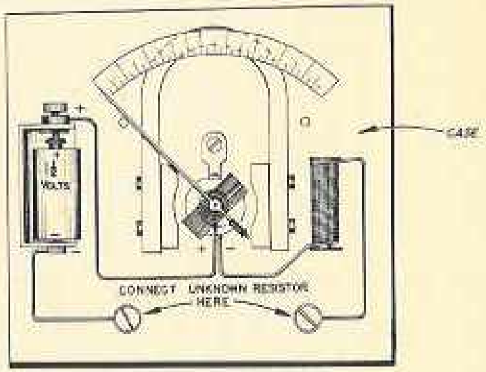


Figure 47

In essence this is the design of an ohmmeter. It is shown in Figure 47. In this illustration we have as our basis the galvanometer hooked up in series with a one cell battery and a resistor of known value. The instrument already knows the value of the reading of the cell it contains (½ volts) and its internal resistor (450 ohms). Connecting the two as it produces a scale reading of .003 amperes. Should we connect a resistor of unknown value across the connector points where indicated the scale will read the additional resistance of our newly connected coil. Of course, the instrument could be calibrated to read zero when no additional coil is connected. It would then show only the value of the resistance of the connected coil. Since the strongest current in such a set-up will be indicated if the connections shown are bridged by a short, thick piece of wire, any additional coil in series will show *more* resistance and the instrument's hand will move accordingly to indicate higher resistance and thus weaker current.

Figure 48 shows a multimeter in use. This instrument is a voltmeter, ammeter and ohmmeter combined. It can be used to gauge a number of values in a very wide range. This is possible because it is primarily a galvanometer, that simple device discussed earlier, with some refinements built into it, (Figures 34 to 42).

To use the galvanometer as an ammeter, we placed shunts across its leads. By using many thicknesses of properly stationed shunts, many ampere values can be gauged by providing a suitable switching arrangement to hook the desired shunt to the instrument. To use the galvanometer as a voltmeter, we provided a resistance coil in series with the galvanometer. By using a number of resistance coils of known values and a means of switching the desired resistance to the galvanometer, any range of volts can be safely read on the same galvanometer.

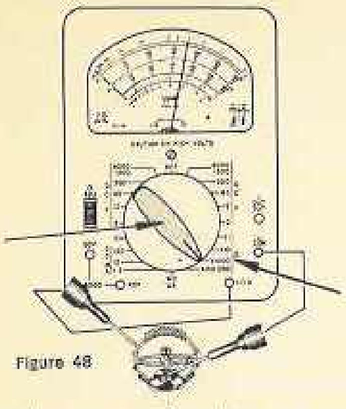


Figure 48

Figure 47 shows the basic principle of an ohmmeter. It has an internal resistance and its own power source, a 1½ volt dry cell. Note that it provides for convenient attachment of an unknown resistor. Study the multimeter shown in Figure 48. Note the many switch adjustments to read amps, volts and ohms of various values.

ometer as a voltmeter, we provided a resistance coil in series with the galvanometer. By using a number of resistance coils of known values and a means of switching the desired resistance to the galvanometer, any range of volts can be safely read on the same galvanometer.

As an ohmmeter, the galvanometer uses its own power source, a dry cell in series with a known resistor adjusted so that its dial reads zero resistance. Switch the unknown resistance in series with the built-in resistor, and the dial reading indicates the value of the unknown resistor. By providing the same galvanometer with a number of different known and calibrated resistances and a switching arrangement to connect any one of them in series with the instrument, a wide range of resistances can be read. It is thus possible to design a galvanometer to read amperes, volts and ohms of various ranges, by providing it with a number of shunts, resistors and a system of switching electrically through the galvanometer's pivoted and moveable coil so that the attached indicator-hand will read the scale.

Let us again examine the multimeter shown in Figure 48. Notice that the contacts are shown touching both ends of the coil of the balance. Such an instrument contains its own energy source, usually a 1½ volt cell switched into the instrument when ohms are gauged. Notice also that the switch is turned so that its pointer is turned to X1000. The "X" in front of the 1000 indicates that any reading on the dial above must be multiplied by 1000.

If the switch were turned to X1, the scale is read directly; that is, multiplied by one. Should the switch be turned to X10 the scale reading is multiplied by 10.

Thus this meter is capable of indicating 100,000 X 200, or 20,000,000 Ω.

In the reading above, in which the leads are connected to the ends of the coil on the Hamilton balance, the switch is multiplying the reading by a thousand. The scale reading points to 3; therefore the reading is 3000, within the tolerance of Hamilton's 500.

When the switch is turned to DVC, the meter can measure volts supplied by direct current from batteries or generators. The coil at the left is for adjusting the instrument, perhaps to read zero should a new battery be used with voltage in excess of 1.50 volts. For example, the energy cells used in the Hamilton 500 electric watch produce 1.57 volts when new. Adjusting to read zero and the volts 1.50 will bring in a required 200 ohm resistance.

ELECTRIC TIMEPIECES — HOW AND WHY THEY WORK

An electric timepiece can use many methods to produce the mechanical impulse needed to move its regulating unit—either a balance, pendulum, tuning fork or others. Most electric watches use a balance and hair spring; while in many small electric clocks, and one early experimental watch, a spring is tensed periodically to move the conventional train of wheels and escapement.

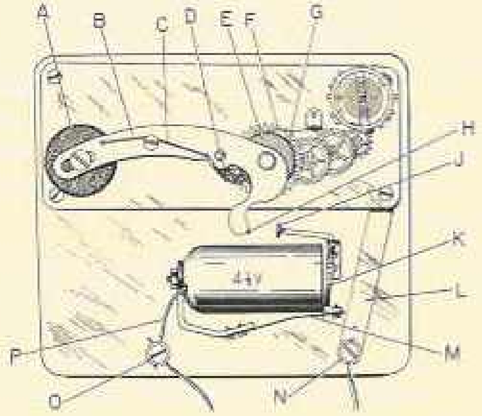


Figure 49—A weighted arm acts like a crank lever to activate the train of wheels and escapement. Arm A is lifted by a "kick" from J when K is magnetically attracted to the coil encased in its metal housing. The circuit is completed when the weighted arm descends and H contacts J. The electric circuit follows leads O and N, through the metal connector L, into the movement. The movement is insulated from the other electrical elements.

Lifted Weight or 'Kick-Type'

In the latter timepieces the impulse or tensing of a helical spring is accomplished by periodically completing an electric circuit. The circuit activates a strong electromagnet which attracts a soft piece of iron. The iron in turn either kicks an arm upon which the spring is mounted, tensing it, or moves a weight upwards, using gravity to power the train of wheels.

Figure 49 shows this arrangement in simplified form. The movement is mounted on a plastic base which insulates it from the electromagnet. The magnet is encased in a metal housing. The coil needs 4½ volts to energize it properly.

The mechanical system is simple—and will help you to understand more complicated units to be explained later.

At *A* is a weight situated on the extreme left of the arm (*B*). The lever arm is loosely mounted and pivoted over the center arbor. The center arbor is the same as those used on the standard mainspring type of small clock. Solidly mounted on the center wheel at *G* is a ratchet wheel (*E*). Attached to the weighted lever arm (*B*) is the click (*D*) and its clickspring (*C*), which keeps the click engaged with the ratchet (*E*).

At *F* is a retaining spring, which is constantly engaged with the ratchet wheel.

If we lift the arm and weight at *A* with the fingers, the click will slide past the ratchet teeth without moving them, because the ratchet is held in position by the retaining spring (*F*). As the weight is released it tries to drop. The click, pushing on the ratchet attached to the center wheel, causes the train of wheels to turn, activating the escapement and balance.

This is how it is done electrically:

The weight (*A*) descends. Its contact piece (*H*) approaches the kicker arm button (*J*). *H* and *J* make a solid contact, and the circuit is completed.

The 4½-volt battery is connected to the leads *O* and *N*. Lead *O* travels up this junction through *P* into one end of the coil. The other end of the coil is attached to its metal casing. The casing acts as an extension wire leading from that part of the coil. The casing is connected by the metal arm extending from the rounded rear of the casing into the spring (*M*) and soft iron disc (*K*). The disc's extension is bent and terminates at the silver button (*J*). When *J* and *H* are touching, the electric circuit continues through into the movement. The movement, being made of metal, is an electrical conductor.

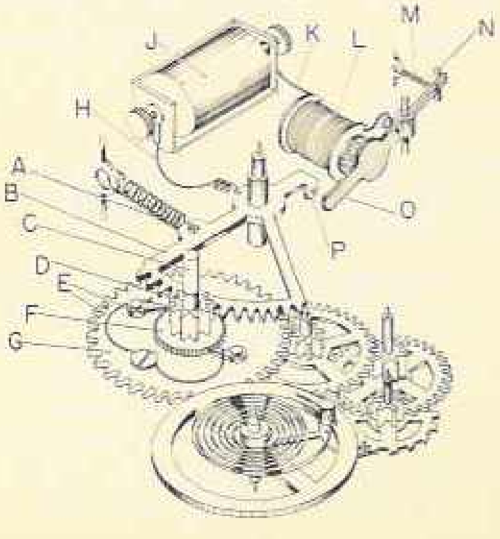
The circuit continues through the movement and, since electricity generally takes the shortest path to complete a circuit, follows the metal tab or canal (*L*) to the lead (*N*) and the other battery terminal.

When the circuit is completed, the coil within the metal casing becomes energized and attracts the soft iron disc (*K*) with a violent motion.

This causes the button (*J*) to impart an equally sudden kick to *H*, and the arm and weight fly upwards. As the metal disc is drawn to the coil and cannot go further, *H* separates from the button and breaks contact. This broken contact interrupts the circuit, releasing the magnetic attraction. The soft iron disc is forced back to its rest position by the spring (*M*).

In most cases where the contact is the "kick-type" illustrated, the actual contact is a rubbing or wiping motion of the rounded nose (*H*) upon the button (*J*), so that carbon which may accumulate from sparking is wiped away by the action of the contact and impulse.

"Kick-type" clocks are better suited for wall or table where the gravity arm will not be disturbed. This type of clock is advantageous in that the weight, being constant, allows better time-keeping—except for the brief moment when the weight is being lifted. Some of the more expensive clocks have a system of maintaining power while the arm is being lifted so that motion to the train is continuous.



Battery Powered Portables

A system by which electromagnetic impulses are used in portable timepieces is shown in simplified form in Figure 50. Here the motive power is supplied by a helical spring (*A*) pulling on a sector gear (*B*). The sector is pivoted, and its teeth enmesh with the center pinion (*D*), which is separated from the center wheel and mounted loosely on the center post (*C*). Attached solidly to the center pinion is the ratchet wheel (*F*). The ratchet's teeth engage the diametrically opposed clicks (*E*), which are held by a common clickspring against the ratchet teeth. The center wheel (*G*) is mounted solidly on the center post, and separated from the pinion and ratchet. The clicks and clicksprings (*E*) are mounted on center wheel (*G*) and move with it.

While the helical spring (*A*) is pulling on the sector (*B*) it is moving clockwise, causing the center pinion (*D*) to turn counterclockwise. Since the ratchet wheel (*F*) is part of the pinion, it too moves counterclockwise against the beaks of the clicks (*E*). Because the clicks are attached to the center wheel, they cannot move unless the center wheel moves. The center pinion and ratchet, through the clicks, causes the center wheel to turn counterclockwise and activate the train of wheels and escapement.

The electrical circuit has been simplified as follows:

The electric cell in its housing (*J*) has one end, at the lead wire *H*, grounded to the movement at the rack. The other battery terminal has a lead wire (*K*) attached directly to one end of the coil (*L*). The other end of the coil's wire is attached to the pivoted soft iron disc (*O*). As shown, the circuit is incomplete or "open." As the tensing of the coiled helical spring moves the sector closer, the opposite end of the sector arm (*P*) contacts the extension of the soft iron piece (*O*), completing the circuit.

With the circuit completed the coil becomes an electromagnet, designed so that a strong and sudden magnetic pull is exerted at (*O*), towards the coil's core. This sudden, strong pull causes the extension to thrust the arm (*P*) counterclockwise. The sector's teeth also turn counterclockwise. Because the pinion is enmeshed with the sector's teeth, it turns in a clockwise direction. The pinion's attached ratchet wheel (*F*) skips past the beaks of the opposed clicks (*E*).

This motion continues until the initial force of the magnetic impulse and momentum equal the tension of the extended helical spring (*A*). The spring again takes over, causes the sector to move clockwise, and the train revolves.

While this system is more versatile than the lifted-weight system, the spring causes a variation in balance motion. When the spring is fully tensed at the beginning of the impulse it is strong and the balance motion is great. When the spring is almost run down and contact is near, balance motion falls off. Many clocks using this system employ a long spring, and design it so only its middle portion is used. But even then the motion variation is present if the impulse is not delivered frequently. Frequent impulse, on the other hand, reduces a battery's life expectancy.

A system such as the one illustrated in Figure 50 was miniaturized by Dr. A. L. Rawlings in his experiments to make an electric wrist watch in 1954. The movement used was a 5½ ligne. It worked well, although the watch had to be housed in a 12-ligne case.

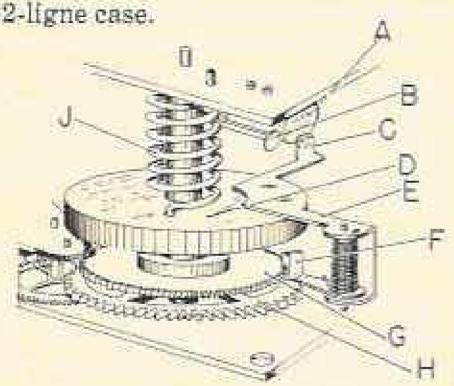


Figure 51. In this system the electromagnetic impulse is similar to that shown in Figure 49 and 50 last month, except that the helical spring is subjected to torque winding instead of being powered by gravity or a flexed spring. *Flywheel* D helps to wind helical spring J. The flywheel is separated from the wheels below, and attached to the hollow tube around which the helical spring is twisted. The rachet and center wheels move as one unit.

Another type of electric timepiece in which a helical spring supplies the motive power to turn the train of wheels is illustrated in Figure 51. Instead of the spring being pulled in the usual manner, however, it is subjected to torque tension and wound similarly to a conventional mainspring. To simplify this example the number of turns in the helical spring has been reduced.

A is the coil casing and *B* the soft iron piece. *B* is attracted to the far end of the coil when the coil is energized by the completed circuit.

The button on the soft iron piece (*B*) kicks the tab (*C*). The tab is positioned upon a heavy disc (*D*) which serves as a flywheel. *E* is an extension of the metal piece. It is fastened to the flywheel (*D*) and acts as a bridge for the pivoted click (*F*). The clickspring is a very weak helical spring. The click (*F*) engages the ratchet (*G*), which is solidly mounted on the center wheel (*H*). The helical spring (*J*), which supplies the power, has one end fastened to the upper plate; its other end terminates at the flywheel.

The flywheel (*D*) is mounted on a hollow tube which is loosely fitted on the center post. The ratchet and center wheels are one unit riveted to the center post. Thus the flywheel can turn independently of the rachet and center wheels.

When the electric circuit is completed as *B* contacts *C*, *B* thrusts *C* clockwise. Since *C* is mounted on the flywheel (*D*), the flywheel also moves clockwise, winding the helical spring (*J*) around its hollow tube. While the flywheel is being thrust clockwise, the click (*F*) trips past the teeth of the ratchet wheel (*G*). The helical spring takes over, pulls the flywheel counterclockwise and the click (*F*), butting against the ratchet teeth, moves the attached center wheel with it, activating the train of wheels. In this sequence the flywheel is moving as one unit with the center wheels and ratchet. Tab (*C*) again approaches *B* until contact is made, and the cycle repeated.

Third-Wheel System

In some clocks employing this principle the helical spring is mounted on the third wheel instead of the center wheel. When this is done a weaker and longer spring can be used to achieve better timekeeping, due to a minimum variation in balance motion. Mounting this arrangement on the third wheel permits the use of an electromagnet requiring only one dry cell. While this method requires more frequent impulses, it does not drain the electric cell or battery; and noise made during the sudden and strong mechanical impulse is kept to a minimum. Of course such a system is used only where the thickness of the movement is of no importance.

When this third-wheel system is used, the helical spring and click-rachet reverse their direction.

Some clocks which use this system have an auxiliary spring that maintains power to the train of wheels while the electrical impulse is imparted to the mainspring in the opposite direction. The use of a coiled spring wound electrically has some advantages over an axially flexed or pulled helix. Aside from conserving height, the power it imparts is generally more uniform and lends itself better to isochronal timing.

Battery-powered timepieces using springs of all types frequently have the springs mounted in conjunction with the third wheel, instead of the center wheel as pictured here for simplicity. With the springs on the third wheel a single electric cell may be used. Other advantages are easier winding, a smaller electric cell and certain improvements. While the contacts are more frequent, they are weaker.

If an electrical system were designed to wind a spring to run a timepiece for a longer time, the number of cells would have to be increased to supply the additonal power. Since the life of each cell presumably would be the same as the cell in a clock using one cell, the cost of batteries would be greater—without providing advantages to offset the cost. In addition, the impulse and coil winding would have to be very powerful to overcome the natural resistance of a spring strong enough to motivate a train of wheels for a long period.

In our next chapter we will show how one manufacturer overcomes these obstacles while using only one energy cell.

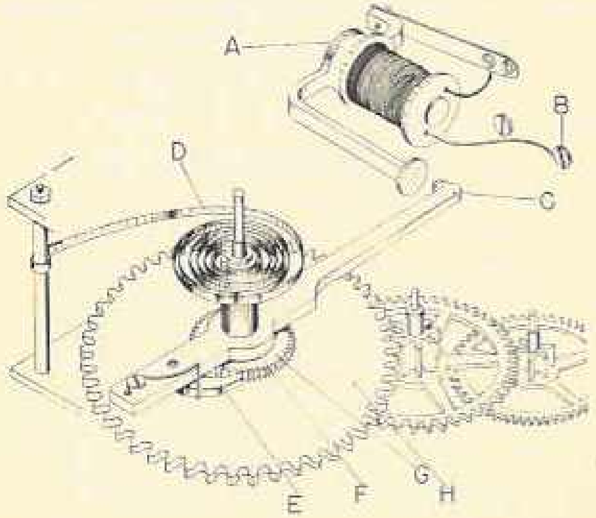


Figure 52. The movement shown here is thinner than the ones illustrated previously. A weak mainspring drives the train of wheels and escapement.

Thinner Movement

A system with a thinner movement is shown in Figure 52. A weak mainspring is used to drive the train of wheels and traditional escapement. Carefully observe the illustration and you will be able to understand this system easily.

A is a soft iron push-piece. It is attached to a thin, flat return spring. *A* serves as an electrical connection to one end of the coil. The coil and all of its attachments are insulated from the movement and battery mounting. *B* is a connection to one terminal of the coil and the battery. The movement itself serves as both the "ground" and a connection to the other lead of the battery.

When the contact button the arm (*C*) touches *A*'s button, the circuit is completed. The energized coil quickly and energetically draws the soft iron piece (*A*) to it. This causes the arm (*C*) to be "kicked" clockwise, pivoting at *F*. The click (*E*) ratchets past the teeth of the ratchet (*G*) and winds the mainspring (*D*) until the momentum of the electromagnetic kick is overcome. The mainspring takes over by moving the hollo warbor counterclockwise. The arm (*F*) is riveted or otherwise fastened to the mainspring arbor, which is hollow and rides easily on the center post.

The impulse arm (*F*) is attached to the lower post of the hollow arbor; and the click and spring (*E*) are attached to it. The rachet wheel (*G*) and the center wheel (*H*) are attached to each other and move as one unit.

When the rachet is pushed counterclockwise by the beak of the click (*E*), the train is also moved counterclockwise until the arm (*C*) again makes contact with the coil's soft iron piece (*A*).

A MOTOR-WOUND ELECTRIC CLOCK

This German clock uses a toy-sized direct current motor, energized by a single small battery, to power its escapement.

We said that one manufacturer had overcome the obstacles inherent in powering a clock with only one cell. The manufacturer, Diehl, of Schramberg, Germany, uses a "toy-sized" direct current motor. The motor shaft is geared low enough to wind the spring so that power can be stored and applied for a long period of time. The Diehl movement is pictured in Figure 53.

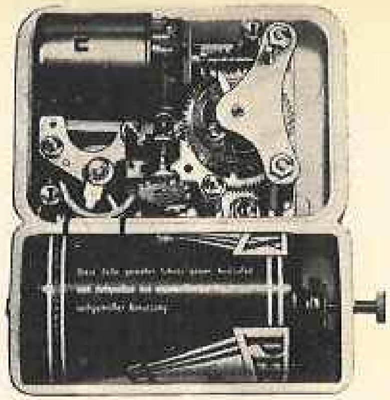


FIGURE 53

The motor which powers the movement uses only 105 milliamperes per second on 1½ volts, yet winds the helical spring enough to allow a full turn of the third wheel, to provide a running time of eight minutes. The motor requires 1½ to 2 seconds to wind the helical spring, allowing the battery to recover for eight minutes before the next drain on the cell.

Should the battery's voltage drop below 1.5 volts, it would take a bit longer for the motor to wind the helical mainspring, perhaps two seconds instead of the 1½ needed with a fresh battery. The use of a helical mainspring, that is, using a wire with a round cross-section, virtually eliminates the need for lubrication and is said to be practically breakproof.

Infrequent use of the battery's power for winding and the short period during which the battery is used guarantees it a long life. The motor is meshed with the clock by a worm gear, which requires one full motor turn for each tooth. There are 48 teeth, so the motor must revolve 48 times to wind the helical wire in a complete winding sequence. The torque is lower than that ordinarily required by a motor geared to a pinion and wheel, where the ratio is larger. The worm gear also provides quieter winding.

How It Works

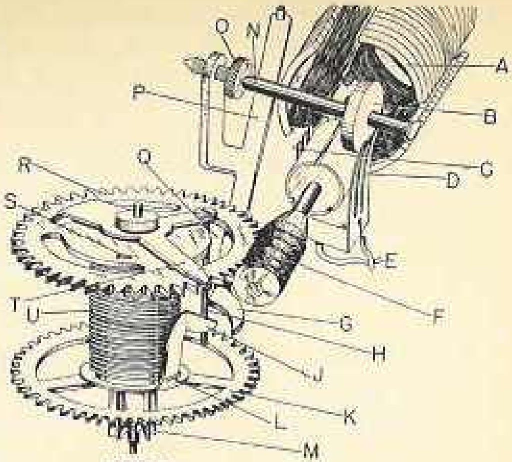


FIGURE 54

Figure 54 shows the principles of this system. The motor's rotor (*A*) has the worm drive (*F*) on its shaft, which is enmeshed with a nylon worm wheel (*R*). This plastic wheel is mounted loosely on the third wheel arbor. A helical wire mainspring (*U*) is fastened to the bottim of the third wheel at one end (*L*), and connected at the top of the nylon worm wheel (*R*) at *S*.

The motor turns clockwise, and the worm (*F*) turns the worm wheel (*R*) clockwise. The helical spring (*U*) is tensed and supplies power, through the third wheel (*K*), to the train of wheels. The pinion (*M*) is enmeshed with the center wheel and dial train.

A switching sequence turns the motor on and off either at each eight-minute interval or as soon as the mainspring is wound. If the motor were to continue to wind the mainspring tight on its cylinder, rebounding off the balance as well as undue drain on the battery would result.

Electrical Contact

The electrical connection to the motor is made as the brushes (*C and D*) contact the segmented commutator. The brushes are made of a spring metal which is a good electrical conductor. Brush *D* is taller than brush *C*. Brush *C* is on the left in our illustration. Mounted horizontally above the brushes is a metal rod (*N*), which rests in bushings (*not pictured*). Near the right end of the rod is a plastic disc (*B*). The edge of the disc intersects the tips of brush *D*. The disc is frictioned to the rod (*N*). The springy brushes are nearly always on the plastic disc (*B*), applying pressure to the left in an attempt to force contact with the commutator.

However, in the sequence shown in Figure 54 the locked position of the rod (*N*) is keeping brush *D* from making contact with the commutator—thus the motor is not working.

The pressure on the rod's rounded end by the flat screw-head (*O*), which is threaded into the elbow of the pivoted locking lever (*P*), keeps the rod (*N*) and disc (*B*) locked and the motor at rest. The pivoted locking lever (*P*) is kept in position so that its elbow's screw (*O*) presses to the right to keep the brushes from electrical contact with the motor's commutator. The pin (*H*) reaches downward through the concentric slot in the wheel (*R*). It remains in this position until the vertical extension (*J*), attached solidly to the third wheel (*K*) and moving with it, makes one full revolution. As it comes around, almost completing a full circuit, its flat extension (*J*) makes contact with the pin (*H*). Although the pin is mounted firmly to the three-armed floating piece (*T*), the floating piece is mounted loosely on the third wheel arbor and is free to turn. The face of the extension (*J*) makes contact with the pin (*H*). The pin continues to move until it leaves the corner of the lock lever at *G* and enters the curved, concentric surface at *G*. *J* continues to move *H* until *H* is past the beak of *G*.

At this point the pressure of the spring-brush (*D*) on the disc (*B*) moves the disc, its rod (*N*) and the lever (*P*) to the left. An electrical contact is made and the motor turned on.

The motor turns at about 1900 revolutions per minute, or about 48 turns in 1½ seconds, using a 1½-volt cell. The worm (*F*) turns clockwise which moves the worm wheel (*R*) clockwise.

When contact is first made as the pin falls past the beak *G*, the pin (*H*) has been pushed in a circular path in the concentric slot (*Q*) by the extension piece (*J*). At this point of electrical contact, the pin (*H*) is near the forward end of the slot (*Q*). When the worm wheel (*R*) is being turned by the worm (*F*), the pin is motionless until the back end of the circular slot catches up with it and carries it along, together with the three-armed free piece (*T*).

Movement continues until the pointed extension at *T* enmeshes with the worm and is carried along with the worm wheel (*R*). The pin makes contact with the flat end of the lock lever (*P*) and forces it to the right. This movement in turn causes the button-head screw (*O*) to push the horizontal rod (*N*) to the right, and the plastic disc (*B*) pushes back the spring-brush (*D*). The electrical contact is broken and the motor stops.

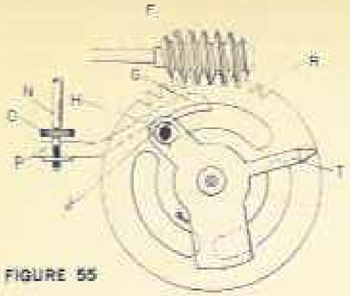


FIGURE 55

Figure 55: The concentric slot (Q) provides latitude of movement for the pin (H). T allows the pin an extra margin of movement during winding.

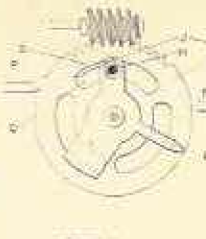


FIGURE 56

Figure 56: The pin has moved almost half the length of its slot, and is shown near the end of the beak (G).

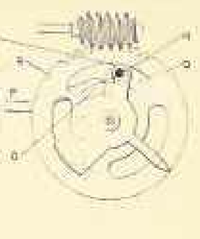


FIGURE 57

Figure 57: Now the pin has passed the beak (G). Under pressure from the commutator springbrush, the entire piece (P and G) falls downward.

A Closer Look

In Figure 55 the position of the extension (*J*) is practically where it was when it caused the pin (*H*) to trip off the beak of *G*.

The concentric slot (*Q*) provides additional latitude of movement for the pin (*H*). The pointed toothshaped piece at *T* provides an extra margin of movement for the pin during winding, when *J* makes one complete revolution and moves it. Figures 55, 56 and 57 show the sequence in two dimensions.

Each part bears the same identifying letter in all of the drawings. In Figure 55 the pin (*H*) has come to a stop after being forced around by the worm wheel (*R*) and the end of the slot. The pin (*H*) has forced the lever (*G*) upward. The lever (*G*) exerts pressure at *P* to move the screw (*O*), which moves the rod (*N*) and pushes the springbrush away from the commutator of the motor. This breaks the circuit, and the motor stops.

The third wheel has run for about seven minutes. Its extension piece (*J*) has almost completed a full revolution and is against the pin (*H*).

In Figure 56 the flat extension piece (*J*) is moving the pin freely in its slot so that the pin rides along on the curved surface of the locking lever's beak (*G*). It is shown here almost at the end of the beak. Note that the pin (*H*) has moved almost half the length of its slot (*Q*).

In Figure 57 the pin has moved a bit more, past the beak (*G*) which, through the pressure of the commutator springbrush has caused the piece (*P* and *G*) to fall downward. An electrical contact is made as the brush touches the commutator. The motor turns. The worm moves the worm wheel (*R*) clockwise until the rear of the slot (*Q*) in which the pin rides comes against the pin (*H*), and moves it until it is again positioned as shown in Figure 55.

The extension of the third wheel (*J*) is in about the same position as shown in Figure 57, since it moves only with the third wheel. The pin (*H*) appears as in Figure 55, except that it is behind the extension piece (*J*).

No restraint is required as the worm gathers up the wheel since the gear ratio of wheel to worm is too high to move it backwards, regardless of the strength of the mainspring. This is an advantage because it reduces friction during winding.

A SIMPLE ELECTRIC MOTOR—how it works

Because repair of motor-wound timepieces requires attention to their motors, knowledge of a direct current motor's principles of operation is important to the watchmaker.

Direct current motors and the balances of electric watches have much in common. Both contain electromagnets pivoting on axes, which are attracted or repelled by permanent magnets when polarized by a battery's current.

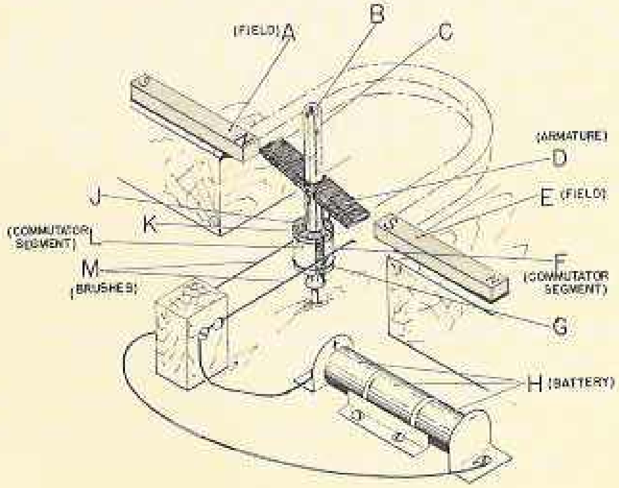


Figure 58

This simple device, easily fabricated from materials available in the home or shop, demonstrates the basic principles of operation of the motors used to power an electric timepiece.

Unlike balances, which oscillate back and forth, motors turn continously in one direction. You can make a simple experimental motor, shown in Figure 58, to help you understand more about them and how they work.

Obtain a glass tube or a thin test tube (*C*), a flat piece of soft iron about 2 inches long and ½-in. wide, and a bottle cork about an inch in diameter (*J*).

Drill a hole through the center of the cork, and force the test tube into it to about ½ above the tube's mouth. Drill a hole through the iron's flat center, and shellac the tube in place about an inch above the cork. Remove the insulation from one piece of insulated copper wire and position it against the cork's side. Bring the wire up the outside of the tube, along the underside of the bar to its outer end, and wind a neat clockwise coil of wire around the bar, past the test tube to the other side. Turn the end of the wire back so that it doesn't unravel. Bring it back to the test tube, and position it so that it remains against the cork. Scrape the insulation from both ends of the wire.

Cut two squares of copper or tin foil (*L* and *F*) and position them around the cork so that the distance between them is equal, and there is about ¼-inch clearance on each side. Place rubber bands over the exposed ends so that the ends are pressed firmly on the square plates. Make sure that each plate is facing one side of the coiled wire on the bar (*D*).

Use a large board as a base. Drive a long thin nail upward through the bottom of the board so that the hollow tube rests and pivots on it. Cut a small block of wood, about the thickness of the cork and high enough to be level with the top of the cork (*J*).

Scrape the insulation from the ends of two pieces of springy copper wire. Twist the wire to give it more "springiness." Secure the wires to the small block of wood so that they are parallel to each other on opposite sides of the wood block at the same height and length. Use two screws for each wire; position them as shown. The wires should be long enough to make contact with the plates. The loose ends of the wires (*M*) can be connected to a large dry cell or a group of cells (*H*). A convenient way to make contact with the batteries is to use scraps of sheet metal. Do not connect the wires to the battery yet.

The core of the motor is finished. To complete the motor, we need either two bar magnets (*A* and *E*) resting on blocks of wood to provide height, or a horseshoe magnet (shown by the dotted lines) placed on a block of wood of the correct height. The horseshoe magnet must be wide enough to embrace the coil without its ends touching. In the absence of either bar or horseshoe magnets, magnetize a couple of files in your watch de-magnetizer and position them on the wood blocks close to the coil (*D*), being careful not to interfere with the rotation of the pivoting, coil-wound bar. Before connecting the battery to the loose ends of the wires (*M*), spin the bar (*D*) by hand and assure that it clears both magnets, and yet passes close to them. Assure that the wires leading from the coil are in solid contact with the plates. Check to see that the wires are free of insulating lacquer and oxides. Finally, make certain that the wires (*M*) begin to make contact with the plates *after* the coil-bar (*D*) has *passed* the point where it is on-line with the long axis of the bar magnets. Adjust the plates to make sure the sequence is correct.

If you have followed directions accurately, the wires (*M*) will be resting on the cork between the plates (*L* and *F*) when the bar (*D*) is on line with the magnets. Of course the magnets should be positioned with opposite poles facing each other.

Connect the battery leads and your motor should start turning clockwise. If it doesn't move, give it a nudge in either direction. If it turns, but again positions itself opposite the magnets, there is probably an open circuit. Check the wires' contact with the plates. If there is current flowing through the wires and into the coil, there will be an electromagnetic surge—but the leads may be crossed. Change the leads so that the wires end at opposite terminals of the battery. The "motor" should now turn.

Current and Polarity

The current flows from the battery through the positive terminal. It travels through the wires (*M*), or *brushes*, to the plates, which are called commutators. The wires (*K*), making contact with the commutators from above, bring the current into the coil wound around the iron bar, which becomes an electromagnet. This part of a motor is called the *armature*. The electromagnetic polarity is such that the north pole of the armature is adjacent to the north pole of the permanent magnet. Since like poles repel, the north poles move away from each other and cause the armature to spin clockwise. At the

same time, the brush on the right makes contact with the other commutator (*F*), causing the coil to become polarized with its south pole adjacent to the south pole of the permanent magnet (*E*). This too causes the pivoting armature to be pushed clockwise.

When the armature has made a 180° turn, the brush at the right makes contact with the other commutator segment, with its attached wire (*K*). The polarity is reversed and the clockwise motion maintained.

If the armature were turned counter-clockwise by hand from the position shown in Figure 58, the brushes (*M*) would touch the cork sections between the commutator segments when the armature is on line with the magnets. Move the armature a bit further and right brush makes contact with the edge of the commutator. (*L*) and causes this section of the armature to act as a north pole, because its wire lead from the commutator starts at the left wing of the armature. This results in an attraction of the armature, and it returns in a clockwise direction. As it does, the armature again approaches a position opposite the magnets. The brushes contact the insulating cork. The momentum carries the armature past the center line of the bar magnets, and the brushes again make contact.

Repulsion of like poles again results, and the motor continues to turn clockwise.

Thus, such a motor turns in one direction only. The direction depends on the winding of the coil and the connections to the battery. If the battery were reversed, the motor would turn in the opposite direction.

Electrical Terms

In learning the names of the motor parts—whether the motor is the balance of an electric watch or one supplying power to wind a clock—the names indicated in Figure 58 are generally used. The magnets, which are part of the stationary housing of the motor, are called the *field*. Sometimes the field is called the *stator* (meaning *stationary*). The turning electromagnets, and in some cases a pivoting permanent magnet, are called the *armature* or *rotor*. However, it is more apt to be called a *rotor* when the turning part contains permanent magnets, as in the Secticon, made by Universal Escapements Ltd., and in synchronous electric clocks.

Where the armature is an electromagnet, current must be supplied to energize the moving coil. One end of the coil's wire is soldered to a segment which "commutes" current from an electrical source to the armature. This segment must be made wide enough to carry current through most of the armature's turn. This part is called the *commutator*, shown in Figure 58 as *L* and *F*. As an electric train receives current from a third rail through "shoes," the wires (*M*) conduct current to the commutator.

In a watch like the Hamilton 500, the contact wires become the brushes and the gold pin becomes the commutator. The balance is the armature and the permanent magnets under the balance together with the shunt pieces comprise the field.

In the Swiss electric watch, too, the contact wires serve as brushes. The contact tab is termed the commutator and the balance, containing a permeable alloy rather than a coil, is called the rotor.

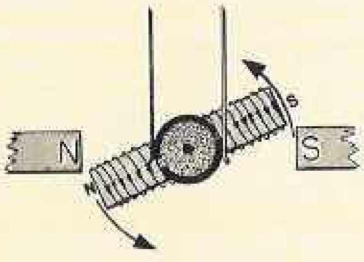


Figure 59

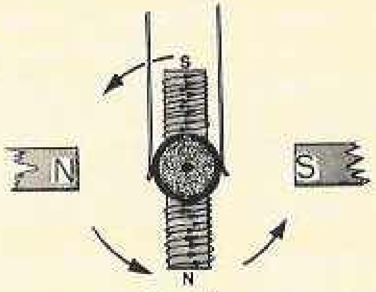


Figure 60

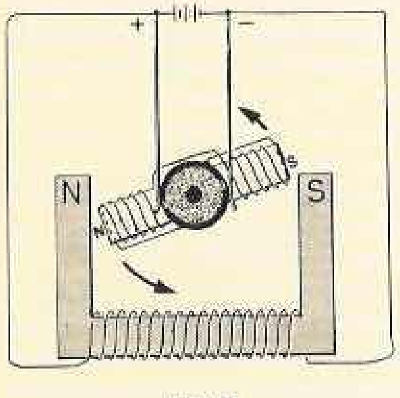


Figure 61

Figure 59 is a simplified schematic of the motor in Figure 58. Note the careful winding of the coil and the direction of current. **In Figure 60** the armature is approaching the opposite polarity of the nearest magnet's field and attraction begins. At the greatest position of attraction the commutator segments will feed current from the opposite terminals of the battery and repulsion will again take over. **Figure 61** shows the motor using an electromagnet instead of permanent magnets.

Figure 58. The coil on the armature is wound a bit more carefully and shows the clockwise direction of winding and the direction of the current. In Figure 59 the armature is being repelled by the similarity of adjacent poles. As it reaches the position shown in Figure 60, the armature is approaching the opposite polarity of the nearest magnet's field and attraction, rather than repulsion, begins. As soon as they are at the greatest position of attraction, the commutator segments feed current from the opposite terminals of the battery, and as it passes beyond this point, repulsion again takes over.

The field can be an electromagnet as well as a permanent magnet. This is shown in Figure 61. Soft iron is used here as a permeable metal core for the electromagnet. An electromagnetic field can be adjusted to the quality desired, although permanent magnets are used in practically all clock motors.

Obstacles

While the simple motors shown in Figures 58-61 work and are easily understood, they have obvious drawbacks. If current was cut off and the motor came to a stop so that the brushes touched the sections between the commutator segments and rested upon the insulating core, the motor couldn't start by itself. Or, as shown in Figure 60, the armature's magnetic influence may be too far from the field's attraction to overcome inertia and friction and get the motor started.

Next, will be described how battery-powered clock motors overcome these obstacles.

We learned the prinicples of operation of a simple electric motor. But we concluded with the disconcerting thought that once the motor stopped it might not start again without help.

Now we examine an inexpensive direct current motor that will start automatically from any position. The motor is shown in Figure 62.

Figure 62 is a photo of our self-starting direct current motor. It is compact and efficient.

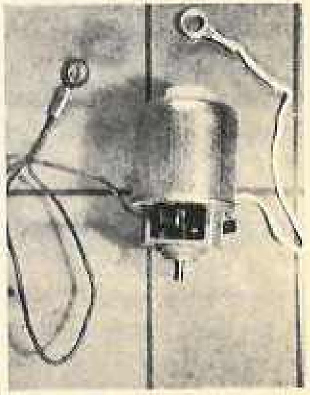


FIGURE 62

Three sections to the armature and two permanent magnets in the field are necessary components.

The Field Magnets

The North pole of one curved magnet faces the South pole of the opposite magnet. As we have already learned, it is possible to orient the poles of a magnet to any position.

In order to conserve space, as well as obtain a better motor action, the field magnets appear as in Figure 63, with the North pole of one curved surface facing the South pole, which is the inner curved surface of the other magnetic field.

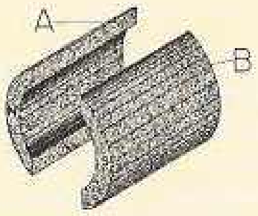


FIGURE 63

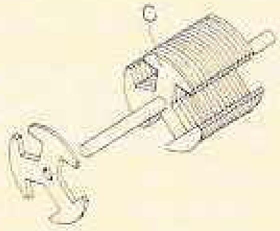


FIGURE 64

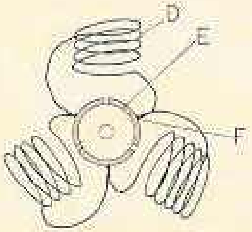


FIGURE 65

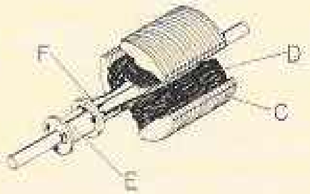


FIGURE 66

Since the field magnets are designed with their curved surfaces of opposite polarity, the electromagnets situated on the rotor or armature must exert a magnetic push, or pull, in conformity with the field magnets. The electromagnetic coil is wound in a flat loop, long enough to allow its magnetic lines of force to interact with those of the field magnets.

Laminated Armature Core

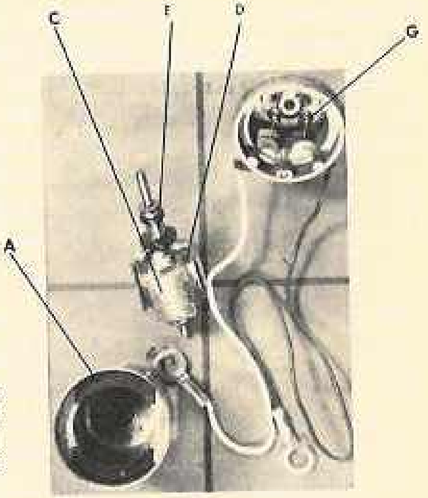
An electromagnet functions more efficiently if its coil is wound on a soft iron core. Efficiency is increased even more if the core is made of laminations or thin layers of iron. The armature core—around which our armature coil will be wound—is made of three-finned plates (*C*), packed together and aligned upon an axle as shown in Figure 64.

Direction Determines Polarity

The coils are wrapped around each section with a continuous length of copper wire, each connected to the next in series length of copper wire, each connected to the next in series (*Figure 65*). *D* is the coil. It is soldered to the commutator segment (*E*). With the coil wound as shown, a positive current fed to the upper part of the coil causes it to become an electromagnet, with the North pole at the top and South pole at the the bottom.

The lower part of each coil is connected to the commutator segment at *F*. Note that the coil is wound upwards and around, to assure the proper polarity when current flows through it.

Figure 66 shows how the three coils appear when wound around the armature core. The beginning of one coil and end of the next coil are joined together at *F*. Point *D*, Figure 65, shows that the coils are wound in the same direction. To insulate the commutator segments from each other, a plastic sleeve is placed over the forward part of the armature axle. On the axle is the commutator with its three separated metal segments, each insulated from the other (*E, Figure 66*). They are made of silver, which is a good electrical conductor. The commutator segments transfer electrical energy from the battery to the coils.



This is our motor broken down into its three main sections. Note that the field magnet (A) is positioned by lead shims in an iron casing. This construction concentrates the magnetic lines of force and protects steel parts from them.

FIGURE 67

PARTS IDENTIFIED

Figure 67 is a photograph of the motor with its three chief sections dismantled. *A* is a field magnet, positioned by lead shims inside an iron casing. The construction concentrates the field magnet's lines of force and protects nearby steel parts from their influence. *C* is the armature. *D* is the wire coil wound around one of the sections. *E* is one of the three silver commutator segments and *G* one of the brushes which will rub against them.

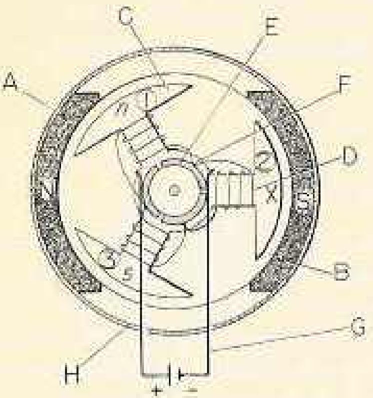


FIGURE 68

There are four phases to the sequence of operation of our motor. This is phase one of the motor sequence. Phases two, three and four will be illustrated and explained next month.

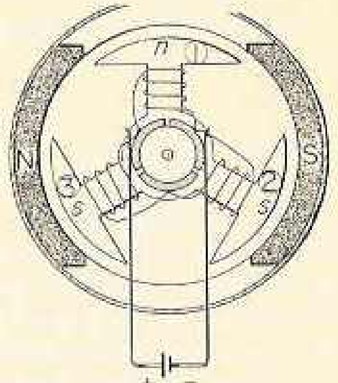


FIGURE 69

netic changes that occur during a single partial revolution. Figure 68 shows the first phase. Note that one coil is inactive. In Figure 69 a fraction of a second has elapsed and the arma-

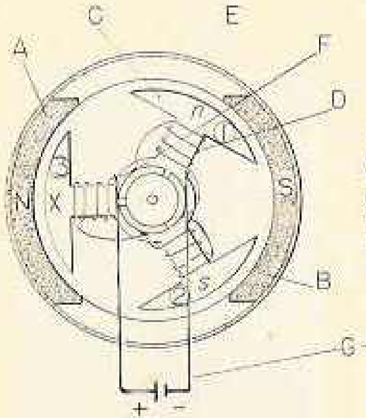


FIGURE 70

ture has turned 30° or 1/12-turn to the right. For the only time during the motor's four phases of operation all three armature sections are energized. Another 30° has been added in Fig-

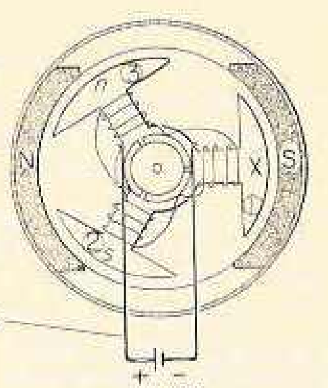


FIGURE 71

ure 70. Again, one coil is inactive, this time the one on armature section three. After another partial turn the motor appears as in Figure 71, and armature section one is "dead."

The motor sequence is shown in four phases in Figures 68-71. *A* is the North pole magnet, situated between lead shims contained in the iron shell casing (*H*). *B* is the South pole magnet. *C* is one of the three armature sections. For simplicity we show an abbreviated winding of the armature coils

around each armature section (*D*). *E* is one of the three silver commutator segments. At *F* the end of each coil makes contact with the commutator and the beginning of the next coil. *G* is one of the two brushes; the one leading to the negative side of the energy cell.

MOTOR SEQUENCE—PHASE ONE

In Figure 68 the positive brush contacts a commutator segment. Positive current flows into the coils, one of which is wound around armature section one and the other around armature section three. However the current enters the two coils from different directions. When the positive current enters the coil on section one, it causes an electromagnetic field with its North pole at the top, as indicated by *n*. This same current, entering the coil on section three from the bottom, causes the North pole of this section to be at the bottom and the South pole to be at the curved, outer part of the armature section (*s*).

A COIL "SHORTS OUT"

What is happening to armature section two? If we examine the brush feeding negative current to the commutator, we find that the brush is contacting two commutator segments. Follow the upper right commutator segment to the lead at *F*, and we discover that one coil connected at that point leads to the end of the coil of armature section one, thus completing the circuit in that coil and causing armature section one to become an electromagnet with the North pole at the top. Follow the brush at the right as it contacts the commutator segment at the lower right, and we find that a coil connected to it goes to armature section three, thus completing the circuit and placing the South pole at the outer, top section of the armature.

Again, follow the contacts made by the negative brush (*G*) and the two leads from the contacts to the coil on armature section two. By following the lead at *F* as the wire goes to the top of the coil on section two, we can see that this would ordinarily cause a South pole at the top of this armature section. However, the same brush contacts the commutator segment at the lower right. Following the wire leading to the coil on section two, we find that the same negative current is being drawn into the bottom of the coil. With negative current being fed through both ends of the same coil, the coil "shorts out" and becomes temporarily inactive.

FOUR MAGNETS

We now have four magnets in this little motor. *A* and *B* are permanent *positive* and *negative* field magnets. Armature section one acts as a North pole and section three as a South pole. We know that like magnetic poles repel and unlike magnetic poles attract each other. In the first phase (*Figure 68*), section one is repelled by permanent field magnet *A* while at the same time it attracts South pole armature section three. Section two, marked *x*, has been shorted out and is idle.

In phase two of our motor's sequence of operation (*Figure 69*), the armature has moved clockwise 30° or 1/12 turn, and each brush contacts only one commutator segment. The positive brush at the left still makes contact with the same commutator segment as in the first phase of operation (*Figure 68*). Thus the polarities of armature sections one and three are the same as in Figure 68.

The negative brush now contacts only the upper right commutator segments. This sends negative current through the wire leading to the coil on armature section two. To complete the circuit on this armature section, the positive brush contacts the commutator segment at the left and sends positive current through the bottom of the coil on section three.

The current continues to the top of the coil, onto the lower commutator segment and then to the wire leading to the bottom of the coil on armature section two. The inner, lower part of armature section two becomes a North pole and the outer, top portion a South pole.

FIVE MAGNETS

Now we have three electromagnets and two permanent magnets. Armature section one is mid-way between the North and South field magnets while armature section three is below the center of the North field magnet and section two is past the center of the South field magnet. The result is a clockwise motion.

The North field magnet, attracts armature section three, which has become a South pole, strengthening the clockwise motion. Armature section two, also a South pole, is repelled by the South field magnet, adding more impetus to the clockwise motor action. Armature section one is, of course, repelled by the North field magnet and attracted by the South field magnet.

PHASE THREE—MOTOR SEQUENCE

Now, let us consider the third phase (*Figure 70*). Another 30° has been added to the clockwise motion of the motor. Armature section one is within the influence of the South field magnet (*B*), armature section three is directly opposite the North field magnet (*A*) and armature section two is leaving the area of the South field magnet.

The positive brush touches two commutator segments. Positive current is fed into both ends of the coil around armature section three, and it "shorts out" and becomes temporarily inactive.

The positive brush contacts the upper left commutator segment, sending positive current through *F* to the top of the coil around section one (*D*). To complete the circuit on this section of the armature, the negative brush touches the commutator segment at the right, which supplies a path for the current to complete its circuit.

TRACING THE CURRENT

Once again, let's trace the flow of current into armature section one. It starts at the positive lead of the energy cell, flows through the left brush into the upper left commutator segment, through the coil, down into the upper right commutator segment and out through the brush leading to the negative side of the energy cell. The result—a North pole at the outer part of this armature section (*n*).

Armature section two is a South pole. Follow the flow of current from the positive lead of the battery through the left brush, which also makes contact with the lower left commutator segment. The lower left segment supplies current to the inner end of the coil on armature section two. This positive current continues to flow out of the outer end of the coil to the right commutator segment, and then into the right brush (*G*) and the negative terminal of the battery.

This circuitry causes a North pole at the inner portion of armature section two and a South pole at the outer end of the armature section (*s*).

FOUR MAGNETS AGAIN

Thus, in the third phase we have four magnets, two being field magnets and two being armature-electromagnets. Armature section one is attracted to the South field magnet while armature section two is repelled by it. Clockwise motion is thus maintained. There is neither "pull" nor "push" on the third armature section because it has "shorted out" and remains idle (x).

Of course, after a partial turn the positive brush will touch only the lower left commutator segment, and positive current will flow through the top of the coil on section three, causing a North pole on its outer surface. The circuit will be completed as the current flows through the negative brush, and the North field magnet will repel the North pole of this armature section.

PHASE FOUR—MOTOR SEQUENCE

For the final phase of this motor action, examine Figure 71. Armature section one is in exactly the same position occupied by armature section two in the first phase of motor action (*Figure 68*).

Armature section one and its coil are inactive because the negative brush contacts two commutator segments which supply current to it. Again, a double dose of negative current "shorts out" the armature section (x). Armature section three has a positive polarity at its outer end because the brush at the left transfers positive current along the upper part of the armature section. The circuit is completed as the current travels outward into the commutator segment at the upper right, through the negative brush which contacts the commutator segment, and down into one negative terminal of the energy cell.

Armature section two has a negative polarity because positive current enters from the bottom of the coil, goes through the top of the coil and into the lower right commutator segment, and then into the right brush, terminating in the negative part of the battery.

Thus, the field magnet repels section three and attracts section two. A split second later the motor turns slightly. Armature section one becomes a South pole at its outer end, because the right brush only contacts one commutator segment and the circuit to section one is completed through the coil of section two. The South pole in section one is repelled by the South field magnet.

The stronger the energy cell or voltage of the battery, the stronger the electromagnetism and hence the more powerful the motor action. The more powerful the motor action, the faster the motor will go.

At this point the entire four-phase sequence begins again. If the motor were stopped during any of the four phases of operation it would start again automatically, since two of the three coils are energized whenever current is applied to the motor.

CHANGING MOTOR DIRECTION

Should we reverse the battery and make the right brush positive and the left brush negative, the direction of the motor, too, would change. In direct current motors a change in direction is accomplished by switches which reverse the battery leads connected to the brushes.

There are some variations of this motor principle, and some larger motors work on different winding—but the basic principle is much the same. The brushes in some small motors are made of a group of short, fine copper wires bunched together to resemble a small brush. This is said to provide better commutator contact.

Some motors have no permanent magnets in the field. Instead they have separate windings which supply electromagnetism of the desired polarity and power; thus both the field and armature rely on electromagnets. Larger motors use electromagnets exclusively because it is difficult to make large permanent magnets of the desired strength and polarity.

SPARKING: ITS CAUSES AND CURES

A current of electricity, like a flow of water, has momentum. When it is shut off suddenly, a spark may "leak" across contact points causing wear and inefficiency.

Electric timepieces use switches or contacts to turn on a current. Often, these contacts are of very simple design and construction. A circuit is completed, say, when one metallic tab on the balance staff or pendulum makes passing contact with another tab anchored to the movement. This releases energy from a cell or battery which energizes an electromagnetic coil. This in turn attracts or repels the balance, pendulum or tuning fork.

The efficiency of the timepiece and the length of its carefree maintenance period to a large degree depend on these switches and their condition.

Most often, these contact switches are made of gold, silver or platinum to resist wear due to friction and sparking.

Sparking occurs at switchpoints when a contact or circuit is broken, and is less pronounced in watches with a hollow coil, then in those which have a solid or permeable core. Carbon deposits form on the contacts because of the spark. These deposits insulate the tips, prevent good electrical contact and cause poor motion. Eventually the timepiece stops. Furthermore, sparking burns away metal at contact points until the contacts cannot meet, and the watch mechanism stops running permanently.

EXPERIMENT PROVES IT

A simple experiment will prove that sparking is caused by the coil, and that it takes place when the circuit is broken rather than when it is closed.

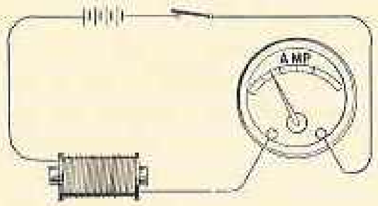


FIGURE 72A

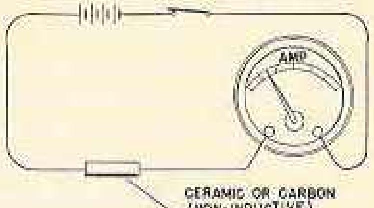


FIGURE 72B

When an electric circuit with one solid coil (72A) is broken at the switch, a spark results. When the coil is replaced by a resistor of the same resistance as the coil (72B) no spark occurs when the switch is opened. Coil, therefore, must be the cause of sparking.

Hook an ammeter into a circuit which includes an energy source and a coil of many turns, as schematized in Figure 72A. Start a current through the circuit and notice that while the switch is closed there is no sparking. Also, read the value of the ammeter.

Now, break the cricuit by opening the switch. A strong spark should occur there. Repeat this, replacing the coil with a carbon or ceramic resistor of the same resistance as the coil (*Figure 72B*). This time there should be little or no sparking, but the current reading on the ammeter will be the same.

Since the coil is the only thing that has been changed, it must have been the cause of the strong sparking in Figure 72A. Specifically, it is the destruction of a magnetic field in the coil which causes the spark.

SIMILAR TO PLUMBING

It is possible to understand the causes and cures of sparking by a simple analogy from hydraulics.

When we open a faucet, a flow of water begins and continues to flow until it is shut off or the supply is exhausted. In an electrical circuit the same is true: electricity continues to flow until a switch is opened or the energy source is exhausted.

Sometimes, in a hydraulic system (your home's plumbing, for example), a loud report somewhere back in the pipes will result when the water is shut off suddenly. This condition is called "water hammer." When the faucet was open, water flowed as a long line of traffic would. When the faucet was shut off, all of the moving water as far back as the source piled up. To this pressure was added the force from the momentum of the water, and a loud "ping" resulted when this flow "bounced back" into the system. In some cases, this bounce may have been sufficiently great to burst the pipes.

Roughly, this happens when the current in an electromagnetic coil is terminated suddenly, as it is in electric watches. The current has inertia and will tend to continue and to "bounce back" in somewhat the same way. Because it cannot either continue or return, a spark leaks off, burning and reducing the contacts, with the resulting damage we have already described.

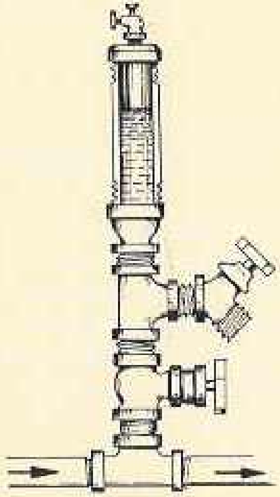


FIGURE 73

In the hydraulic system, plumbers overcome "water hammer" by providing an air chamber (*Figure 73*) to absorb and dissipate the shock of increased pressure. Water under extra pressure enters this appendage and compresses the air in it until an equilibrium is attained between the two forces. Then, slowly, the water distributes its pressure along the entire length of the pipe system.

In electrical systems, extra voltage which would burst off as a spark is channeled into a condenser or a capacitor of some sort. The resistance of a condenser to the backsurge of current is lower than the resistance of the air gap between the parted contacts, and the energy goes to the condenser where it is stored. Finally, it is dissipated along a small path from the condenser to the movement, or to the intake end of the coil. This all takes place in the smallest fraction of a second, but it is slow enough by electrical standards.

USED IN SWISS ELECTRIC

An instance of spark suppression can be seen in the Swiss electric watch, Landeron cal. 4750. Figure 74 is a schematic diagram of the watch's electrical system. In this case, the spark-suppressing parts are a resistor (*G*) and a diode (*H*).

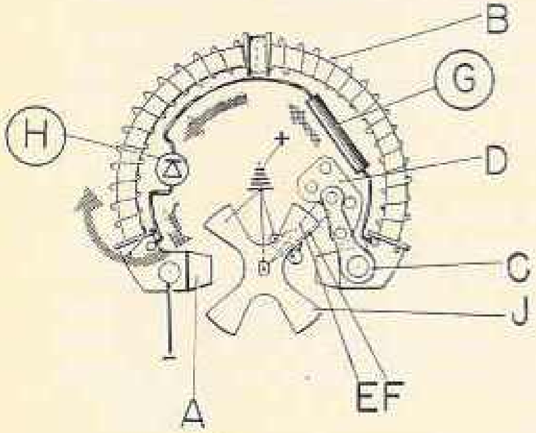


FIGURE 74

Schematic diagram of the electrical system in the Swiss watch. The normal flow of electricity through the coil is clockwise. A back-surge current, which results when the circuit is broken, tends to flow counter-clockwise through the coil, but is diverted through the resistor (G) and diode (H) to enter the coil in the normal direction, from the left. The current is absorbed and dissipated without sparking at contact points.

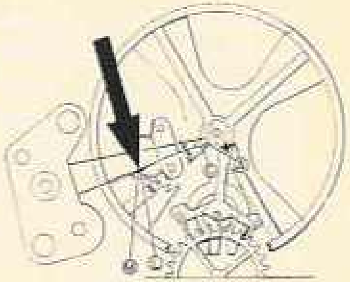


FIGURE 75

Contact points in the Swiss electric. When tab A parts from tip of spring C, plate M will spring away from beak L, breaking circuit. A spark would occur at this point (arrow) if resistor and diode were not present.

When the balance is in the position shown in Figure 75, the contacts are about to part. The metallic tab A on the balance will move past the tip of spring C in the counter-clockwise direction. This spring will break the circuit when it springs back from contact beak L at point M. Because of the coil and core, a spark would occur at the gap between M and L. But, as indicated in Figure 74, the surge of voltage is diverted through the resistor, which absorbs some of the back current, and into the diode.

A diode, of which we will learn more later, is an electronic valve to permit electricity to flow in one direction only. In Figure 74, the diode permits the current to flow in the direction shown by the arrows. This surge of current flows into the left hand side of the coil, where the energy is dissipated.

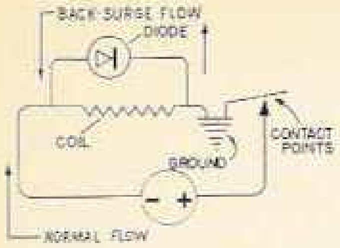


FIGURE 76

The Lip watch. The back-surge flow, which tends to enter the coil in the counter-clockwise direction, is diverted instead through the diode and re-enters the coil in the normal direction, where it is dissipated.

The Lip electric watch suppresses sparking by a "contact diode." The system is schematized in Figure 76. As the balance revolves after energizing the electromagnets and receiving an impulse from them, certain contact points are parted. This opens the circuit, and a back-surge of current takes the path of least resistance through the contact-shielding diode instead of going through the coil. This diode is biased so that it allows current to flow in the direction shown by the arrow above it. The voltage then pushes the current along into the left part of the coil, where it is dissipated. The sparking that would have occurred at the air gap between the contacts is greatly suppressed.

In the Hamilton and German electrical watches, sparking is minimized because the electromagnetic coil is hollow.

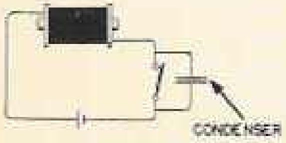


FIGURE 77

Use of a condenser is another way to suppress sparking. Extra current is temporarily absorbed by the device, and released at a rate slow enough to avoid a spark buildup.

Another way to reduce sparking is by means of a condenser or capacitor. Such a device stores an electric charge. It may consist of two thin electrical conductors side by side, separated by a thin insulating layer, and hooked up in parallel with the contacts, as shown by the arrow in Figure 77.

The energy that would result in a spark is led into the condenser. Sometimes, one of the conductors is grounded to allow a slower path for this surge current to dissipate.

RELAY CIRCUITS & GENERATOR PENDULUMS REDUCE WEAR AND TEAR

Using relays, a balance or pendulum can swing without mechanical hinderance or electrical deterioration

We have seen that sparking and deterioration occur when contacts part. And we learned how to suppress this sparking.

One important implication of all this is that the secret of good electrical timekeeping is through a watch that can open and close circuits using no mechanical contacts whatever.

Many clocks (Kundo, Junghans-Ato-Hatot, etc.) operate this way. The only watch at present without mechanical contacts is the Accutron electronic timepiece. All of these use transistors in their circuits.

Timepieces with transistors and contact-less switching have one thing in common, generally missing from other clocks and watches. They use permanent magnets in conjunction with electromagnetic coils.

Long ago, it was predicted that since electricity can create magnetism, then perhaps magnetism can create electricity. It can.

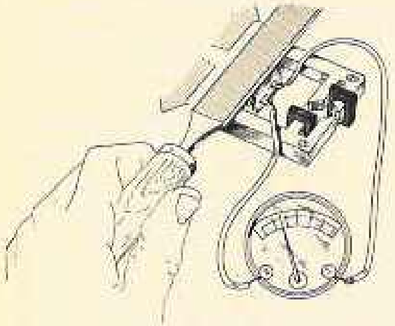


FIGURE 78
A simple generator may be constructed from a large magnetized file and the coil of a synchronous clock. When the file is passed over the coil, a galvanometer registers the quantity and direction of current.

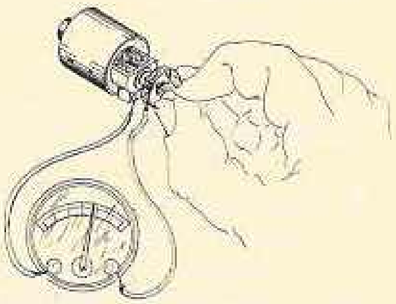


FIGURE 79
Even a toy motor can become a generator because it contains the necessary elements: a coil and a magnet. By spinning the axle, a current registers on the meter.

MAKING A GENERATOR

To prove this, the watchmaker can set up another simple experiment, using an old, large file. Magnetize this in the hollow of a "demagnetizing" coil. Then, obtain the stator and coil of a synchronous clock, such as a Sessions or General Electric. Hook up the leads from this coil to those of a galvanometer or voltmeter as shown in Figure 78.

By moving the length of the magnetized file over the coil with rapid to-and-fro strokes, you will see a coincident movement of the meter needle, indicating a flow of electricity. The flow will be great if the file's movement is rapid, barely perceptible if the motion over the coil is slow.

We say that the magnet "generated" this current by passing over the coil. The speed and direction of the file's movement, the strength of the magnet and the type of coil determined the kind of current generated.

MOST GENERATORS SAME

Almost all electric generators work on the principle of magnets passing through or near to coils, or coils passing through or adjacent to magnets.

If we were to hook up a small direct current toy or clock motor, similar to that shown in figures 62-69, to a meter and spin the axle with our fingers, the meter would register a current (see figure 79). The direction and quantity of current would depend on the direction and strength of the spin. In one of the directions of spin, the meter will surge against the zero banking.

Thus, the direction of physical movement in our generator determines the direction of current. Specifically, the coils of wire cutting across magnetic lines of force generate the electricity, the direction of flow depending on from which direction the coil cuts these lines.

Instead of a meter, a flashlight bulb can be hooked up to our motor-become-generator. When spun, the generator will cause the tiny bulb to glow.

A CONTACT-LESS SWITCH

Now, if a current can be generated by a magnet passing near a coil (or a coil passing near a magnet), why can't a balance or pendulum containing a coil pass over or through a magnet generate electricity? Or, which is the same thing, a magnet mounted on a balance or pendulum, might pass over a coil and generate a current.

Such a current could operate a tiny switch or "relay" to make a quick momentary circuit, which might be used to maintain the motion of the pendulum or balance.

The term relay is often used in electricity. It describes a system by which a small current triggers or releases a large stored voltage. A knowledge of the relay is important to an understanding of the electronic trigger—the transistor.

An example of the relay is the sending of signals over long distances by telegraph. The original electrical impulse needed to send a dot or dash across the country in one jump would use a tremendous amount of electricity and heavy equipment. An easier and simpler way is to have the small original impulse travel a number of short distances.

At way-stations along the route, this gradually-weakening impulse closes a second circuit which contains its own battery or energy source. This circuit sends out a fresh impulse to the next way-station, and so on.

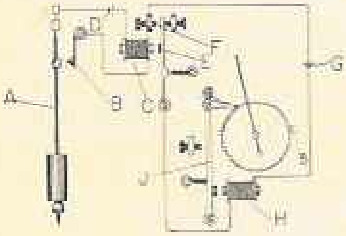


FIGURE 80

Another use of a relay system is the operation of many secondary clocks in a school, factory or public building by a single master clock. Figure 80 shows how this might be done.

The half-seconds pendulum *A* for a fine precision regulator is weight-driven or electrically impulsed. Its suspension has an electrical connection with battery *D* and electromagnetic coil *C*. Tab *B* is a contact.

CIRCUIT COMPLETED

When the pendulum swings from the left to right and touches contact *B*, a circuit is completed which energizes coil *C*. This coil magnetically attracts the contact button mounted on armature *E*, normally held back lightly by a helical spring.

When contact *E* moves to coil *C*, the space between *F* closes and completes a secondary circuit powered by cell *G*. This energizes coil *H* which pulls arm *J* toward it. The beak atop arm *J* moves over the racheted index wheel by one space. This wheel has 60 teeth, so that every movement of the half seconds pendulum indexes the wheel one unit, or one full second.

By providing additional relays to such a master clock, it is possible to impulse many secondary clocks, or rather, clock dials. On a smaller scale, a system of relays can be used in small clocks or watches.

It is even possible to propel the balance or pendulum itself without any visible physical contact, switching or wear. The coil or magnet could be situated on the balance or pendulum, and by passing over respectively, a magnet or coil, it might generate a relay, complete a circuit and release energy stored in a battery to further propel the balance or pendulum.

It might also be possible for such a relay system to trigger an independent or secondary circuit to move the indexing or dial train. In these ways, a balance or pendulum would be able to oscillate without mechanical interference from any part of the timepiece. It would be able to do its chronometric job and have no distracting influences or duties.

A PENDULUM GENERATOR

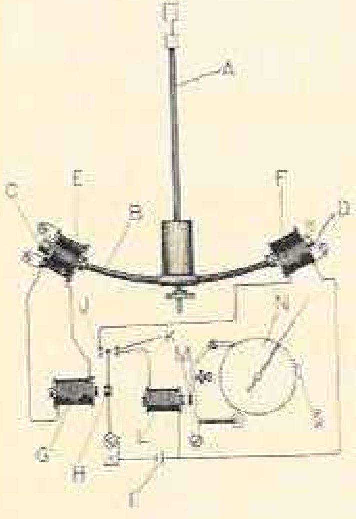


FIGURE 81

A set-up to achieve this is depicted in Figure 81. Pendulum *A* has a bob *B* of non-ferrous material, curved concentrically upon its point of suspension. Each end of this bob has a permanent magnet, *C* and *D*. The bob and magnets swing through hollow coils *E* and *F*, stationed at either side. This movement generates electric currents in the following succession:

As the penudulum swings to the left, it is travelling at its highest rate of speed when rod *A* is dead center, as shown. At this point, the left-hand permanent magnet has enough speed entering coil to generate a current sufficient to energize coil *G* and attract armature *H*. *H* is also a permanent magnet, normally too weak to be drawn to the coil's core at *G*. With the added electromagnetism generated by the pendulum's swing, however, it does move toward *G*, at the same time causing the contact above *H* to touch the contact *J*.

This completes the circuit through battery *I* and energizes coil *F* in such a way that its polarity is the same as magnet *D*. This repels the magnet in the right-to-left direction, implementing the swing of the pendulum.

At this point, the pendulum has swung as far left as it will go and begins to return in the left-to-right direction. It picks up speed, until again its greatest speed is at the dead center position. The magnet *C* enters coil *E* again, but from the opposite direction, creating a current in the opposite direction.

CURRENTS REVERSE

This current energizes coil *G* with the opposite polarity from before. The coil, therefore, repels magnet *H* and causes its upper point to make contact with *K* instead of *J*. This completes the circuit through coil *L*, battery *I*, and back to the spring contact upon which *H* is mounted.

While energized, coil *L*, draws armature *M* to it. A split second later, the generated current at *G* and *H* is terminated and the magnet *H* returns to the "open" position, allowing armature *M* to be drawn back by its helical spring. When *M* does go back, the beak mounted at its top will index the sixty-toothed rachet wheel *N*, causing the seconds hand mounted on the arbor of *N* to move one second of time forward.

Thus, with a half seconds pendulum the seconds hand is moved with every other swing of the pendulum, while the pendulum is impulsed once a second.

The important thing in such a system, however, is that the pendulum has no work to do, and makes no mechanical contacts. It swings freely, just keeping time.

ELECTRONIC VALVES PROVIDE THE ANSWER TO SPARK SUPPRESSION

The diode, key element in a transistor, allows current to flow in one direction only, removing the danger of short circuits

In discussing electricity and electronics, the term "amplify" often comes up. It refers to the use of an auxiliary or outside source of energy to make a weak electrical signal stronger. It's important to note that the outside source is set in action and controlled by the original weak impulse.

For example, the electrical relay shown in the diagram of the magnetic pendulum (Figure 81) allowed a weak, induced current to close the circuit. As a result, a stronger current from a separate source (batteries) was tapped, augmenting the original impulse and thus "amplifying" it.

In electronic horology, a weak signal generated by a pendulum, balance, tuning fork or other oscillating device can be amplified by controlling the electrical power stored in a battery.

Previously, the sequence of events which caused the relay in a circuit containing a battery to produce amplification was spelled out in some detail. It was shown how the magnet-pendulum could induce a current (induction) by moving in a coil of insulated wire and how this current, although weak, could close a circuit in which a stronger impulse source (a battery) is present.

Figure 81 showed how a pendulum or any other oscillating device could be kept in continuous motion without any physical impulse-contact and how a dial train also could be indexed. However, in examples discussed previously, sparking would occur when electrical contact was broken. While spark suppressors could diminish this arcing they would not eliminate it entirely.

Mechanical switching is eliminated by using a transistor as an electronic escapement. In a conventional escapement, a larger power such as a spring or weight is stored and held in check by the lock of the escape tooth on the side of the pallet (jewel). Only a slight movement of the balance is needed to unlock the mainspring's power and impel the balance further.

The mechanical "transistor" or escapement thus consists of a stored power source, the mainspring, which is held in critical check by the escapement lock. The mainspring is released by the comparatively weak unlocking force of this balance.

In the electronic circuit, a large source of ready-to-release power, generally a battery, is held in check by an open "switch." Earlier, it was explained how it's possible for a small amount of electrical energy to close a switch and release a greater (stored) surge of electrical energy. In horology, the transistor is the valve, gate or escapement which allows this chain of events to take place without any visible moving part making or breaking electrical contacts.

DIODE: AN ELECTRONIC VALVE

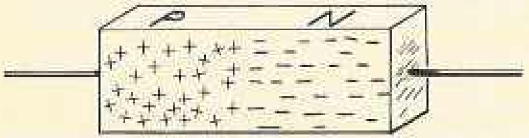
Before attempting to explain how this is possible, it's as well to examine the basic principles of the transistor and how it works. Transistors will be used more and more in horology.

We will attempt to explain the principles in simple terms so the watch maker may understand what the transistor can be expected to do and, in general, how it is done. A good text on transistors is — "Transistors, Information, Experiments, Applications, Bureau of Naval Personnel. NAVPERS, 92387A, March, 1962. Supt. of Documents, U. S. Govt. Prtg. Office, Wash. 25, D. C.

The basis for the transistor is the diode, an electronic device or valve which allows current to flow in one direction only. It is composed of materials such as silicon or germanium.

In their pure state as crystals, no electrical current can flow through these materials. In fact, when these crystals are pure, they make excellent insulators. To permit them to conduct a current, small amounts of "impurities" are added. These impurities produce a condition which makes positive (+) or negative (—) charges available to carry current. Specific quantities of impurities are added to the crystals depending on the type and amount of current they will carry. If, for example, antimony is added to the crystal, negatively charged current carriers are made available.

The diode consists of two sections. Impurities introduced into one section produce negative current carriers; different types of impurities introduced to the other section produce positive current carriers.



Different types of impurities introduced to the two sections of a pure crystal diode allow one side to carry only positive current (P) and the other to carry only negative current (N)

Figure 82

Figure 82 shows a diode in simplified form. The left-hand section contains impurities which will produce carriers of positive current. Thus, it is marked P. The right-hand section contains impurities producing negative current carriers. Thus, it is marked N. For further identification, the positive and negative sides may be marked plus (+) and minus (—) respectively. Connected to the sides of this diode are wires which could be connected electrically to a power source such as a battery.

AN EASY TEST

Suppose we try a simple experiment, using a diode (either an F-2, General Transistor or an International Rectifier S.D. 91A type with ratings, approximate 100 V, 750 m/a), a 1½ volt flashlight bulb and a one-cell battery.

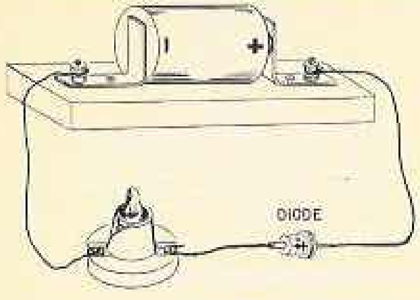


Figure 83

When the plus side of the battery is joined to the minus side of the diode and the minus side of the battery to the plus side of the diode the lamp does not light, indicating lack of current

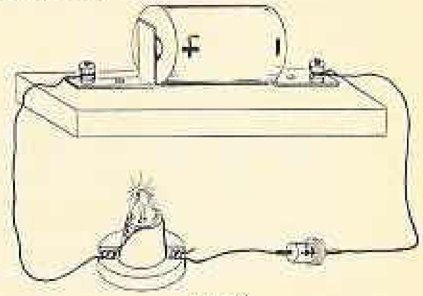


Figure 84

Reverse the battery position shown in Fig. 83 so that plus sides of battery and diode are joined to plus and minus sides to minus. The lamp then lights, indicating a flow of current

These are connected in series with the diode (Figure 83) so that the plus side of the battery is connected to the negative side of the diode and the positive side of the diode is connected to the flashlight bulb. The wiring should then continue from the bulb to the negative side of the battery.

The bulb does not light up. This indicates that when connected in this manner almost no current passes through the diode. Now, reverse the battery in its holder (as in Figure 84) so that the plus side of the battery is connected to the bulb and through it to the plus side of the diode, the negative side of the battery is connected to the negative side of the diode. The bulb now lights up, proving that current will pass through the diode in one direction but not the other.

To understand this movement of current examine Figures 85A and 85B, remembering that like polarities repel and unlike polarities attract. When we connected the negative side of the battery to the positive half of the diode, the positive current carriers in the diode were attracted by the negative charge on the battery and rushed to the edge-end of the diode.

Likewise, on the other half of the diode, the negative current carriers were attracted to the positive terminal of the battery. This is shown in figure 85A in which a meter instead of a lamp indicates current flow. Thus, there were no current carriers in area *A* to serve as a conduit for the passage of current and so the current was blocked.

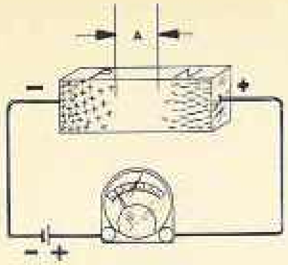
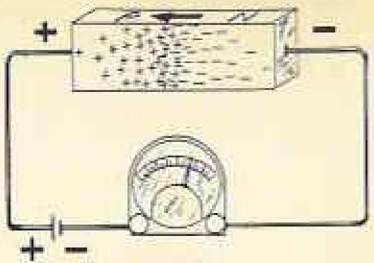


Figure 85A

Like polarities repel, unlike polarities attract. The battery's plus and minus charges, in effect, attract unlike current carriers in the diode to its outer edges eliminating carriers from area A (Fig. 85A), thus blocking the circuit.



85B

By reversing the battery, carriers in the diode are forced towards each other to form a continuous current flow through the diode that establishes an electrical circuit (Fig. 85B)

Next, in Figure 85B, the battery was reversed so that its positive lead was connected to the half of the diode containing positive current carriers and the negative lead connected to the diode section containing negative current carriers.

In this condition, the positive current from the battery caused the positive current carriers in the diode (section *P*) to be repelled toward the junction between the two halves of the diode. On the other side of the diode (section *N*), the negative current carriers were being repelled by the battery's negative current.

In this condition, the junction between the two halves of the diode was "soaked" with current carriers of both polarities and the positive current from the battery thus could pass into the *P* section through the junction and continue in an electrical circuit. The negative carriers likewise had an uninterrupted path through the junction and could also complete the circuit, as shown in the meter reading.

SPARK SUPPRESSOR

The same test or experiment can be conducted using an ohmmeter instead of a light bulb. The ohmmeter will register a high resistance in one direction and a low resistance when the diode is reversed, proving that the diode can serve as a valve which allows current to pass in one direction and not the other.

Now it should be easier to understand the diode's role as a spark suppressor. Examine again Figures 74 and 76. When the current reverses itself and its polarity, the diode will allow this current to pass through and dissipate itself through the energizing coil. But, when the current is required to go through the energizing coil, the diode blocks any attempt by the current to take a short-cut (circuit) from the battery to the contact.

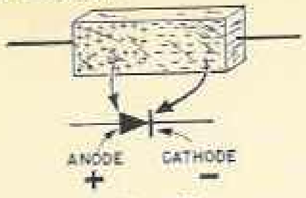


Figure 86

Identifying symbols of the diode are an arrow, the anode, and a black bar, the cathode. Electrons flow towards the anode (P) and flow from the cathode (N)

The electronic symbol for the diode is shown in Figure 86. The symbol is composed of an arrow head touching a short black bar. These two parts of the symbol represent the two parts of the diode. The arrow is called the *anode* and the black bar is called the *cathode*.

The anode is the electrode *towards* which the electrons flow. It is also called the positive electrode and corresponds to the P section. The cathode is the negative electrode *from* which the stream of electrons flows. It corresponds to the *N* section of the diode.

THE TRANSISTOR—HOW IT WORKS AND WHAT IT DOES

Without sparking, this minute device can be used as an electronic switch to turn on or off the current which drives the watch mechanism

As explained earlier, the basis for the transistor is the diode, an electronic device or valve which allows current to flow in one direction only. Now, we want to consider in detail the transistor itself.

The transistor must be used when we want an electronic escapement capable of triggering an auxiliary source of current. In essence, the transistor consists of two diodes placed end-to-end and sharing a common center section. This is shown in figure 87.

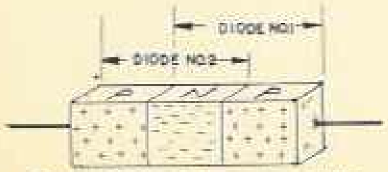


Figure 87: The PNP transistor has outside positive sections and a negative center. In effect, unit is two overlapping diodes.

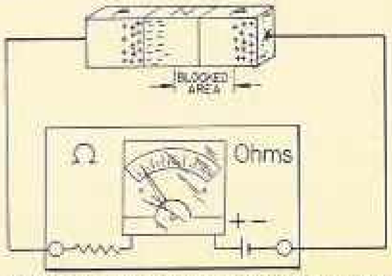


Figure 88: Repelling and attracting forces of ohmmeter's positive (left) and negative (right) leads draw current carriers from transistor's center, causing a circuit blocking void.

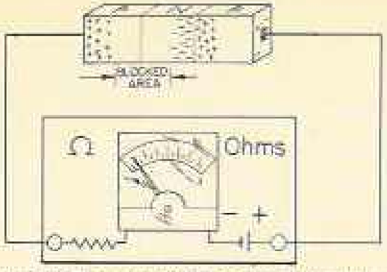


Figure 89: Even if the ohmmeter's leads are reversed a void still must be created because the outside transistor sections are of the same current carrying polarities.

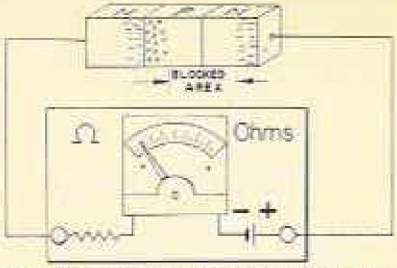


Figure 90: The same situation exists if a NPN (negative-positive-negative) transistor is substituted for the PNP. A void through which current cannot pass again is created.

There are two types of transistor: (1) the PNP with two outside P (positive) sections and an N (negative) center section and (2) the NPN in which these outside sections contain negative current carriers and the middle contains positive current carriers.

Here we repeat another key statement which should make it easier to follow the electrical circuits described in this article: like polarities repel and unlike polarities attract. This basic fact cannot be repeated too often.

A NEW EXPERIMENT

If we connect an ohmmeter (an ammeter with its own internal battery) to a PNP transistor (Fig. 88) so that the positive lead (+) from the ohmmeter is connected to one position (P or +) section of the transistor and the negative lead (—) of the ohmmeter to the other positive (P or +) section of the transistor, there is no flow of current.

A study of the diagram should make the reason apparent. When the connection was made, the positive (+) charge from the ohmmeter repelled the positive current carriers in the left-hand section of the transistor toward the junction with the center section. Then, in turn, these positive carriers attracted the negative current carriers in the transistor's center section.

At the same time, the ohmmeter's negative charge attracted the positive current carriers in the right-hand section of the transistor to that section's outer edge. As a result a void through which no current could flow was created in the transistor. That area now is considered an insulator.

Even should we reverse the ohmmeter leads (Fig. 89), feeding a (+) charge from the ohmmeter battery to the contacts we had previously fed a (—) charge and vice versa, the same situation would exist since both outside transistor sections are of the same current carrying polarity. Hence, the empty section of the PN junction would be void of current carriers necessary to provide a path for a current. Thus current would be blocked.

Now let us try the same procedure with an NPN transistor as shown in figure 90. The outside sections of such a device contain some current carriers of negative polarity. When the negative side (—) of the ohmmeter is connected to one of the N's of the transistor, the current carriers in the transistor will be repelled by the like polarity of the ohmmeter's battery charge and crowd the area of its junction with the center P section. This part would normally be good for the passage of a current.

However, when the (+) lead of the ohmmeter is connected to the other N part of the transistor, current carriers here will be drawn away from the right part of the transistor's PN junction and a void, insulating area will be created. This is shown in figure 90.

Therefore, the transistor as it is pictured here cannot conduct a current through it. The difficulty lies in the fact that part of its junction (center section) develops an area void of current carriers when it is connected as shown.

AUXILIARY POWER

It becomes clear that if current is to flow through the transistor this void area must be filled with current carriers derived from an independent source.

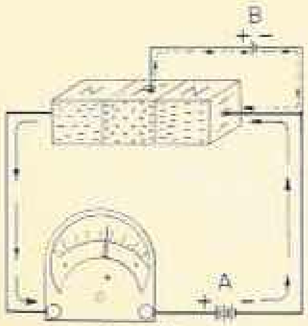


Figure 91:

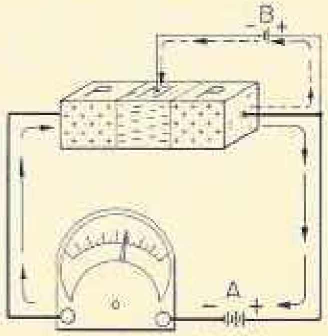


Figure 92:

Figure 91 shows how the unblocking is accomplished by connecting a small, *outside source of current* (battery B) to the blocked area and completing a circuit as though part of the transistor were a diode. In other words, applying a small voltage across the right two-third section (diode part of the transistor) so that the polarities of this battery would repel the current carriers towards the void areas.

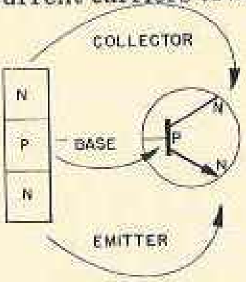


Figure 93: Schematic drawing of transistor's symbol. When arrow points away from base and toward circle, this identifies NPN transistor.

In this case, the positive terminal of the small battery (B) is connected to the section of the transistor containing P carriers, and the N part of this battery is attached to the section with N carriers. In this instance, the P carriers are driven into the mid-section of the transistor and provide a path between the other two sections. The other terminal of the small battery B repels the N carriers in the N section of the transistor to which it is connected and a path is provided for the current from the larger battery A to pass through all sections of the transistor.

Introduction of a small outside power source would be equally effective in completing an electrical circuit with a PNP transistor (Fig. 92).

To assist passage of a current through the mid-section of the transistor, this section generally is made narrower than the outside ends, thus providing a shorter path through the area once the flow of electricity is started.

This description of the transistor and the diode does not go deeply into the theory of these devices, but it should be sufficient to enable the watchmaker to understand what they do and, to some extent, how they do it. The use of transistors in horology should become clearer.

THE TRANSISTOR AT WORK

This ability to hold in check a large source of energy until a small current is applied to the mid-section of the transistor is important. It allows the transistor to be used as a switch to turn on and off a larger, stronger electrical impulse without involving sparking or any moving parts.

For example, when a pendulum is composed of a magnet, (Fig. 81), and this magnet-pendulum swings close to a coil, it could generate a small current. Although this induced current would be weak, if fed into the mid-section of a transistor it could distribute enough current carriers to unblock a void area in the transistor.

With the void unblocked, current then could pass through the transistor from the main battery and complete a circuit. This circuit could energize a coil to impel further the oscillating device used—whether it was a pendulum, balance, tuning fork or other device. In fact, this basic principle is used in modern transistor clocks as well as in the Accutron.

FACTS TO REMEMBER

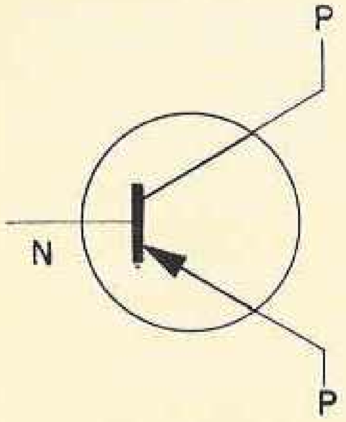


Figure 94: In this symbolic drawing, the arrow points to and touches the base, identifying PNP transistor.

The transistor's symbol in schematic drawings is shown in figure 93. The mid-section to which the auxiliary triggering current is fed is called the *base.* The other two leads are called the *emitter* and the *collector.* The following facts and definitions also should be noted:

The emitter is so called because it emits current carriers.

The emitter part of the transistor symbol always is identified with an arrow.

The collector is so called because it collects the current carriers which emit from the emitter.

When the arrow points away from the base and toward the circle (Fig. 93) this identifies an NPN transistor.

When the arrow points to and touches the base (Fig. 94) this identifies a PNP transistor.

Instead of a symbol, the letters EBC (emitter, base and collector) sometimes are used.

Transistors come in many shapes, sizes and ratings for electrical capacities and performances. Larger ones, logically, are built to handle stronger electrical currents. Tiny ones, engineered to handle smaller signals, are used in watches. However, regardless of their size, all transistors have three leads, one each for the emitter (E), base (B) and collector (C) connections.

The transistor has fairly standard features to identify these three leads. For example, in a transistor of the type shown in

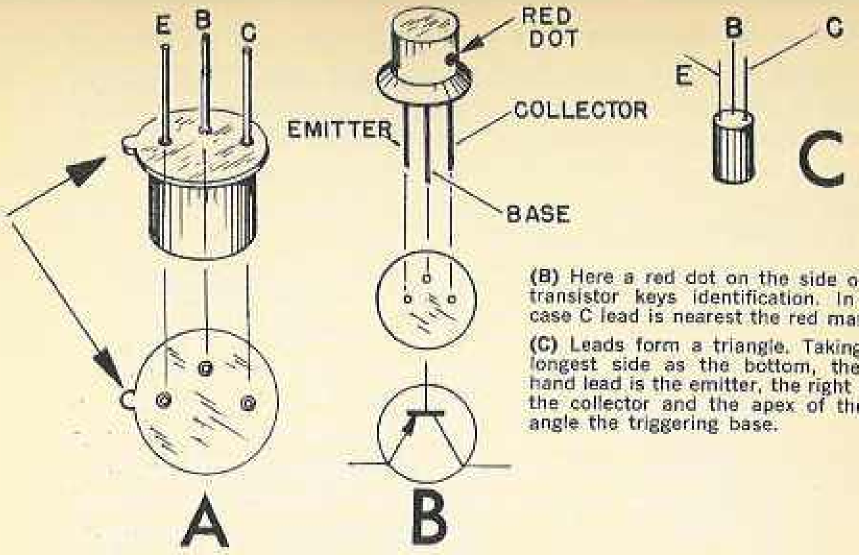
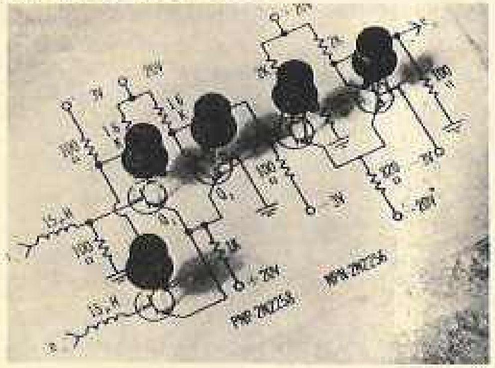


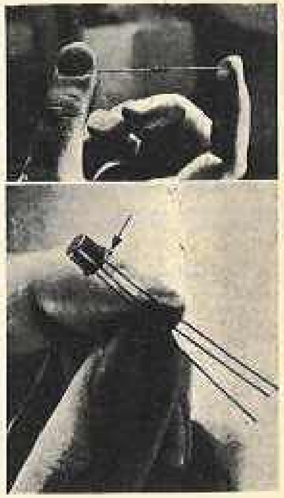
Figure 95: (A) Letters E, B and C denote emitter, base and collector. In Fig. A a small tab on the side of the transistor establishes identification. The E lead always is nearest the tab.

(B) Here a red dot on the side of the transistor keys identification. In this case C lead is nearest the red mark.

(C) Leads form a triangle. Taking the longest side as the bottom, the left hand lead is the emitter, the right hand the collector and the apex of the triangle the triggering base.

figure 95A a slight tab extending from the flange indicates that the pin nearest to it is the *emitter*. Continuing the sequence, the center pin is the *base* and the pin farthest from the tab is the *collector*.





Transistors come in many shapes, sizes and ratings for electrical capacities and performances. Shown here (right and below right) are tiny ones engineered to handle smaller signals of type needed in watches.

MARKS OF IDENTITY

In figure 95B another method is used to identify the leads. Where design of the transistor prohibits use of an extending tab on the flange a red dot is placed on the cylindrical portion of the transistor casting.

In this case, the dot identifies the nearest pin as the *collector*. Thus, the pin farthest from the dot is the *emitter* and once again the center pin is the *base*.

Notice that a triangle is formed by the placement of the pins (Fig. 95C). Taking the longest side of the triangle as the bottom, the left pin is the emitter, the right pin is the collector and the pin at the apex of the triangle is the triggering base.

Included earlier, was a section on relays, spark suppressors and the induction of a current by passing a magnet over a coil. The section was illustrated with diagrams. With the additional information provided last month and this month, perhaps now you can change these diagrams to eliminate all contacts and substitute diodes and transistors for sparkless, contactless switching of currents.

A TRANSISTORIZED CLOCK

Now that we know something about the transistor, we are ready to examine a timepiece which uses this tiny switch. Let's find one that uses a transistor in its simplest application.

Clock and transistor. This photo shows clock and cylindrical housing that surrounds the curved pendulum rod. The housing contains all elements necessary to propel the pendulum yet, because it is transistorized, this source of power never contacts the rest of the clock. The 1.5 volt battery will last at least five years.

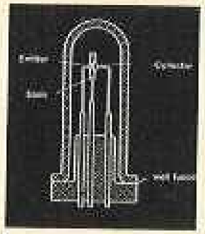
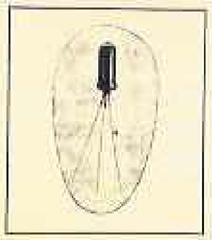


Figure is a cross section of the clock's transistor.



Bottom photo shows the transistor. It is 5 mm in diameter, 15 mm long.

The Kundo transistor clock (see photograph), imported by Fred J. Koch, 1115 Broadway, New York, is such a timepiece. Figure 96 diagrams the clock before it was transistorized; figure 97 shows it incorporating a transistor.

The main part in either clock is the pendulum, suspended in the usual manner with spring and chocks. The pendulum rod is Invar and is threaded to support the adjustable regulating weight *J*. This can set the clock to an accuracy of a few seconds per day. A yoke cradles curved rod *F* and is fastened by set-screws in the rear. The curved rod swings freely through hollow coil *G*. The right side of rod *F* is hollow and carries a short rod magnet of high intensity.

Battery *H* supplies power. It is flat, fastened to the underside of the clock case platform.

In figure 96 the negative (—) terminal is connected to coil *G*, and the positive (+) terminal is grounded to the movement to complete the circuit when the proper contact is made.

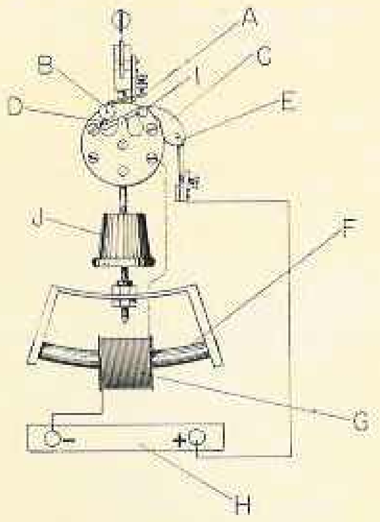


FIGURE 96

Electric clock without transistor must have a circuit breaking mechanism. Sparking, "leakage" and deterioration result at point E as a circuit "makes" or "breaks."

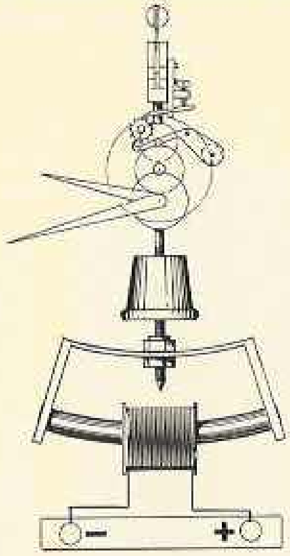


FIGURE 97

Same clock, transistorized, has fewer moving parts, no sparking. All electrical components except the battery are contained in the coil unit, as shown in figure 98.

A CIRCUIT WITH CONTACTS

Completion of the circuit in this older model is accomplished by electrical contacts when the pendulum swings in the clockwise, right-to-left direction. Indexing lever *A*, near the top of the pendulum, intercepts a tooth atop index wheel *B* and moves it one division.

Nestled between two of the lowest teeth on the index wheel is a little roller *D* mounted on the contact lever *C* which is pivoted at *I*. When the index wheel turns, its lowest teeth push roller *D* down and cause the right side of lever *C* to see-saw up. A small pin on the lever's tail touches contact spring *E* to complete the electrical circuit.

The current now flows from the battery into coil *G*. The coil becomes an electromagnet and its magnet further in the right-to-left direction.

As the pendulum swings further along, the contacts are broken after roller *D* drops into the next recess between teeth and the pendulum swings back freely until the cycle repeats i.e., when the pin on lever *C* again touches contact spring *E*. The screws on *E* provide the contacts with a fine adjustment.

In figure 97 the clock is much simpler. There are no electrical contacts, and both battery leads are connected directly to the coil. Lever *C* is also somewhat simpler. Its tail is weighted to supply just enough pressure for roller *D* to remain between the lower two teeth of the index wheel. This roller, and lever *C*, now serve only to position the index wheel and to provide a "jump" action when a tooth passes the crest of the roller.

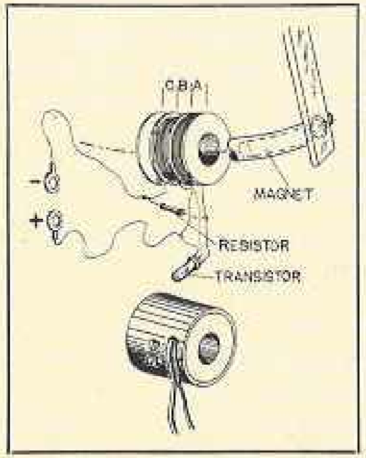


FIGURE 98

Coil unit is essentially the stator (fixed) part of a generator with its own off-on switch (transistor). Compartment **A** houses the transistor-triggering coil, **B** holds the main, pendulum-impulsing coil, **C** the transistor and a resistor. Current is created in coil **A**, then **B** as magnet in pendulum passes through in one direction. Lower sketch shows how three elements appear in brass shell.

TRANSISTOR TRIGGERS CIRCUIT

The pendulum is impulsed electronically. All components for this are sealed in the coil unit's outer shell. They are the transistor, a transistor-triggering coil, an impulsing coil and a resistor. There are three sections to the coil unit (figure 98): the triggering coil *A* allows the transistor to release current from the battery; the strong impulsing coil *B* propels the bar magnet in the pendulum; compartment *C* houses the transistor and resistor. The whole unit is encapsulated in a brass shell and appears as shown in the lower sketch of figure 98.

The pendulum is started by hand. When it swings from the left to the right, no electrical action occurs. The polarity of the induced current, generated by the magnet moving through the triggering coil, happens to be opposite that required to trigger the transistor.

THE CIRCUIT COMPLETES

When the pendulum re-enters the coil in the right-to-left direction, its encased magnet enters the trigger part of the coil (*A*) and induces a weak current of the proper polarity and intensity. This goes to the base of the transistor. The transistor releases the large battery current to the impulsing section of the coil (*B*), which further attracts the magnetic part of the pendulum bar. As the pendulum continues in this direction, the magnet leaves the coil and current ceases to flow to the transistor's base. This terminates the transistor's operation for the cycle and thus shuts off the large battery current. Since there are no mechanical contacts, no sparking takes place.

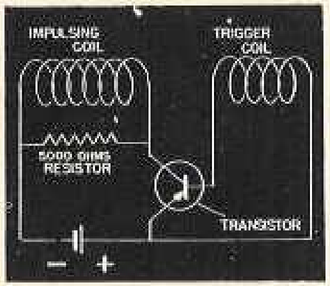


FIGURE 99

Resistor is placed across impulsing coil to absorb back-surge EMF when impulsing coil switches off.

When the battery current ceases abruptly, the magnetic field in the coil collapses and a back EMF (electro-magnetic force) arises. To avoid any back-surge towards the transistor and to dissipate this EMF so that the termination of the pendulum impulse is sudden and complete, a resistor is placed across the impulsing coil. It is a refinement of the electronic action and is schematized in figure 99.

INDEXING

The mechanical action is rather simple, all of it directed to moving the hands. Each clockwise movement of the pendulum indexes a tooth which is enmeshed with a train of wheels (actually, a part of the dial train). The 1/3-second pendulum oscillates 180 times per minute and indexes 90 times per minute.

The indexing mechanism is shown in figures 100 and 101. *A* is the indexing wheel, *B* the indexing lever, *C* a retaining pawl and *F* the roller at rest, nestled between two teeth of the indexing wheel. The pawl is weighted at *C* to provide the necessary tension for roller *F*. *C* pivots at its center. Adjusting screws *D* and *E* regulate the depth and arc of indexing lever *B* as it engages index wheel *A*. The half-arc of the pendulum necessary to index the wheel is represented by *G*.

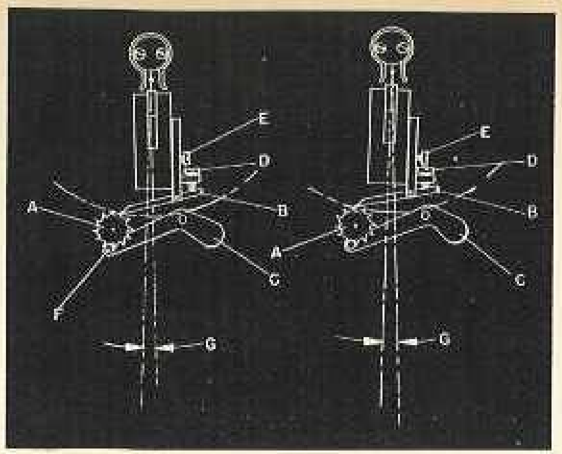


FIGURE 100 FIGURE 101

Indexing adjustment. Raise or lower screw **D** so that indexing lever **B** gathers but one tooth. Depth of lever's arc is changed by turning screw **D** or loosening screw **E** to raise or lower chock upon which **D** and **B** are mounted.

To adjust the clock's indexing mechanism, raise or lower screw *D* so that indexing lever *B* gathers but one tooth, regardless of the pendulum arc's width. The roller beneath provides part of the indexing as the tip of a lower tooth pushes past the crest of the roller. The depth of the arc should be such that lever *B* barely misses the tooth in front of the one being intercepted. The arc of the indexing lever can also be adjusted by loosening screw *E* and lowering the chock upon which *D* and *B* are mounted.

LUBRICATION AND CHECKING

Little can go wrong with the clock mechanically since there are few wheels. These are driven in reverse compared to wheels in mainspring clocks; therefore, there is practically no pivot or bushing hole wear. The main pivot holes are jeweled. Oil should be used sparingly and no oil should be placed on the index wheel or roller, or on the indexing unit.

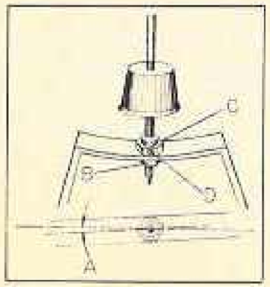


FIGURE 102

Lock pendulum for carrying by tightening spring-loaded screw in hole of nut **D**. Bird's-eye view of pendulum yoke reveals it is off center **(A)**. Adjustment is made by loosening nut **B**, aligning yoke, retightening.

The pendulum adjustment is shown in figure 102. When the clock must be moved, raise the pendulum by hand a few milimeters and thread the spring-loaded screw, located on the back stand of the clock, into the hole of nut *D*. This locks the pendulum for carrying and prevents damage to the vulnerable suspension spring.

The clock must be stationed upright, using the four uprighting screws in the corner of the base. The pendulum's curved bar should swing straight through the center of the coil. Should it not, loosen nut *B* below the pendulum yoke, and straighten the pendulum. Be careful not to kink the suspension spring; Grasp nut *C* firmly to loosen nut *B*. Be certain that threaded hole *D* is in the front position as it must be square to the axis of the spring-loaded locking screw.

Make certain that all electrical connections are tight and that all contacts have been checked. The consumption of this clock is about ¾ of an ampere-hour annually. The circuit permits this cell to be used long after the same cell on electric clocks would have become useless, because in a transistor clock the current is turned on only when needed.

Power source of the Kundo clock is a single battery, more properly termed a monocell. It is designed to run the clock for a full 5 years.

FIGURE 103

Measure the battery (a monocell of 1.5 volts) with a high-impedance voltmeter. As soon as the pressure falls below 1.1 volts, the battery should be changed.

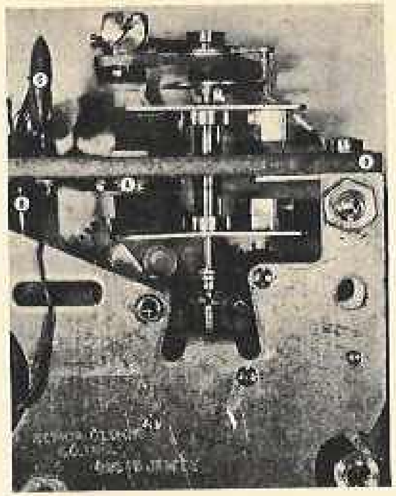
THE SEMCA TRANSISTORIZED BALANCE CLOCK

Our study of transistors in timepieces continues, using a balance clock as an example

We learned that a pendulum containing a magnet, by passing through a stationary, hollow coil, can 1) generate a small current to trigger a transistor, which 2) releases a strong electrical current stored in a monocell, in order to 3) impulse a pendulum without switches or sparking.

In this article, and the one which follows, we will see that this same sequence can impel a balance.

Our model is the AN transistor clock, a product of France's La Generale Horlogere (JAZ) and imported by the Semca Clock Co., 30 Irving Place, New York. Its movement is shown in figure 104. The unit is small and light; in its transparent casing it measures about 2¼ in. square and weighs less than 3 oz. It is recognized by the disc-shaped coil, a condenser and a transistor fitted to a removable, fiber plate. We may refer to such a self-contained assembly as an electrical "module." It is designed to be replaced as a unit if only one of its components breaks down.



The movement. A is the coil combination, **B** the transistor, **C** is a condenser and **D** is the fiber plate on which all stationary electronic parts are fastened.

FIGURE 104

ELECTRICAL COMPONENTS

Figure 105 is a drawing of this module. It is easily taken from the movement without disturbing the balance by removing two screws. The module is pulled out past the long neck of the balance via a channel in the fiber plate. This is indicated by a dashed line.

The coil (*A*) measures 10.5 mm by 3.5 mm and consists of two separate windings, not differentiated in this drawing. One is the transistor-triggering coil; the other is the balance-im-

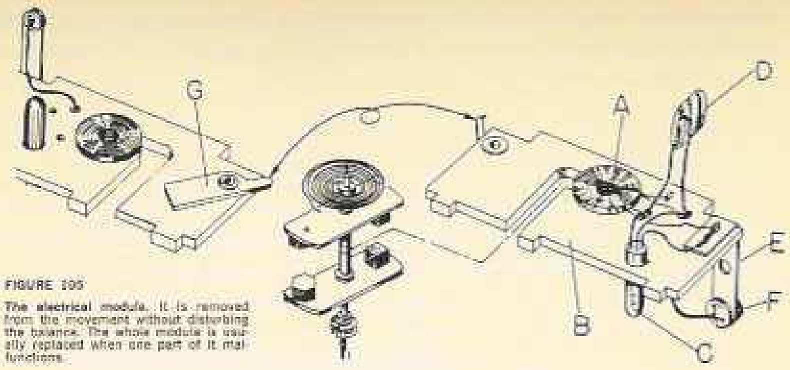


FIGURE 105

The electrical module. It is removed from the movement without disturbing the balance. The whole module is usually replaced when one part of it malfunctions.

pulsing coil. The transistor (*C*) measures 5 mm by 15 mm. Item *D* is a condenser and *E* the hole through which one of the screws fastens the module to the movement. Tab *F* is the electrical contact to a battery lead.

The top drawing in figure 105 shows fiber plate *B* in the downside-up position. This reveals amplitude control piece *G*. The hole in the eyelet of this piece positions the other movement-fastening screw.

In the Kundo clock, a permanent magnet, mounted on the pendulum, generated a small voltage when it passed through the coil. This neutralized the "blocked" area at the base of the transistor and released a major current through the circuit. The current pulsing through another coil, magnetizing it. Finally, this magnet pulled against the permanent magnet in the pendulum and kicked the pendulum along in its arc.

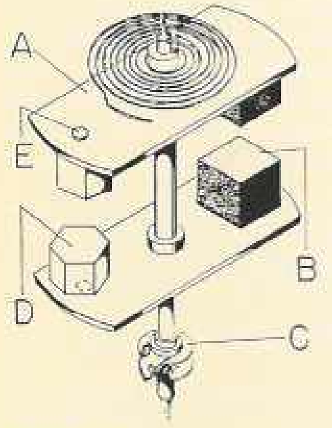


FIGURE 106

Balance and staff. The balance swings back and forth, straddling the stationary coil (not shown here).

BALANCE DOES SAME

The Semca clock also uses permanent magnets, but they are on a balance.

The balance is shown in detail by figure 106. It is basically a long staff on which are mounted two aluminum plates (*A*). On the inside of these plates are two strong alnico magnets (*B*) of opposite polarities.

Counterpoising these magnets are two eccentrically mounted hexagonal nuts (*D*), friction-fastened by rivets (*E*). Poising the balance is accomplished by twisting these nuts so that they are, in effect, closer or further from the center of the staff. "Escapement" (*C*) indexes an escape wheel and a train of gears.

Start the clock by twisting the balance. A push-button arrangement or a twist of the whole clock does this. The motion causes the magnets which straddle the coil to induce a light voltage in the coil's transistor-triggering winding. This small voltage causes the transistor to release the larger battery voltage to the coil's impulsing winding and turns the coil into an electromagnet strong enough to attract the permanent magnets on the balance.

Notice that the coil is hollow. When the magnets pass over this area, no current is generated in the transistor-triggering winding. The transistor base is again deadened and this terminates the current from the battery through the impulsing coil. The balance now continues by momentum until arrested by the resilient hairspring. The balance then reverses its direction. When its magnets approach the flat coil the cycle repeats. The magnetic sequence works in both directions.

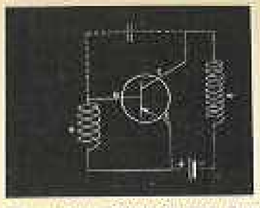
SCHEMATIC EXPLANATION

The electronic sequence will be made clear by schematic drawings (figures 107 and 108). In figure 107, *M* represents the impulsing winding of the coil. One end of this coil connects with the negative (—) battery terminal and the other end connects with the collector (*C*) of the transistor. The emitter (*E*) of the transistor connects with the positive (+) terminal of the battery.

No current can pass between the emitter and the collector (to complete the circuit through coil *M*) because of the blocked area of the base (*B*) of the transistor. To neutralize the base at the right moment and allow current to flow between *E* and *C*, coil *R* is connected between *E* and *B*. (Figure 108 shows how coil *R* is sandwiched in with coil *M*. *R* is represented by the dotted line.) When the magnets pass over the edge of this coil, an induced current is created which then flows between *E* and *B*. This small current "unlocks" the base of the transistor which then permits the large, stored battery current to flow between *E* and *C* and through coil *M*.

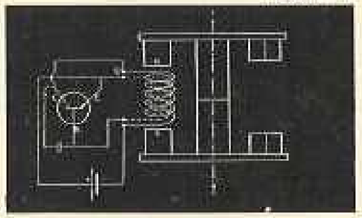
Coil *M* becomes a magnet with poles opposite in charge to the permanent magnets on the balance (*N* and *S*, figure 108). Thus the balance is attracted once the circuit completes.

FIGURE 107

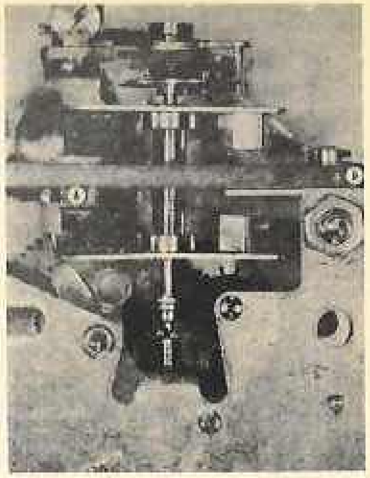


Schematized circuit. Current flows through coil M after coil R generates enough current to "unlock" the base (B) of the transistor, allowing battery current to flow between E and C. Dotted line hooks into a condenser to make current build-up sudden and uniform.

FIGURE 108



Coil M and coil R are sandwiched together. The magnets (N and S) on the balance straddle the coils inducing current in coil R (dotted line) and receiving an electromagnetic impulse from coil M (solid line).



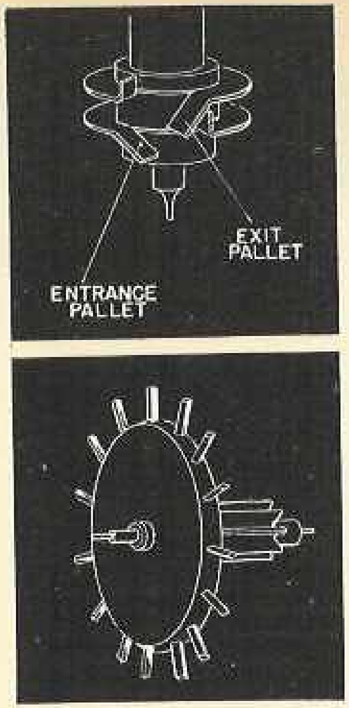
CONDENSER HELPS OUT

The condenser is a device to store electrons. It is also called a capacitor. When the balance magnets pass over the triggering coil, current is built up too gradually for isochronal purposes. The electromagnetic impulse to the balance should be sudden and uniform. When properly charged, therefore, the condenser sends the full charge through the transistor base and this allows the transistor to unleash the battery's power in a business-like manner.

Figure 108 shows how the two coils are wound together, one within the other, each performing its own job independently. As you study the drawing, try to see how, as the balance arms pass through, coil *R* triggers the transistor and coil *M* delivers a magnetic impulse to the balance assembly.

The indexing unit of the Semca clock is a kind of reciprocating worm drive, reminiscent of the Jaegar auto clock devices. This process differs from the indexing of mainspring timepieces in that the pinions drive the wheels. Such an arrangement results in little torque or side friction. Motion is translated from the balance wheel through collar-like pallets which index the teeth of an escape wheel, setting off a train of gears.

INDEXING MECHANISM



FIGURES 109 (top) and **110** show the escape mechanism: the pallets collaring the lower part of the balance staff, and the escape wheel which is indexed by the pallets.

The main components of the unit, illustrated in Figure 109, are the pallets, set in grooves around the lower part of the balance staff. They are essentially two thin discs, each with a downward slanted ramp at one end and a bent up tab at the other. The two ramps face each other, positioned to receive the tooth of the adjacent escape wheel, which is shown in Figure 110. These teeth radiate from the wheel like diamond-shaped pins. The wheel is made of a teflon-type plastic, requiring no oil. The pallets work at right angles to the plane of rotation of the escape wheel.

The sequence of motion is illustrated in Figure 111. The tooth to be indexed stands out here in solid black. In 1, as the balance shaft turns in the direction of the arrow (counter-clockwise), the tooth is gathered by the lower, or entrance pallet and lifted up the inclined plane of the ramp until it rests on the flat surface,

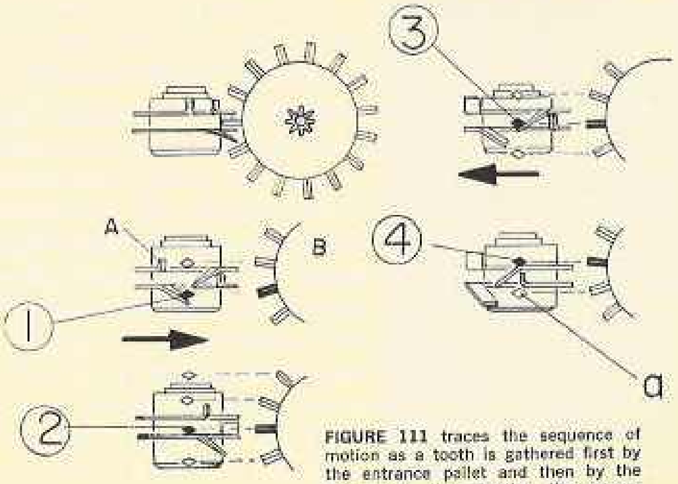
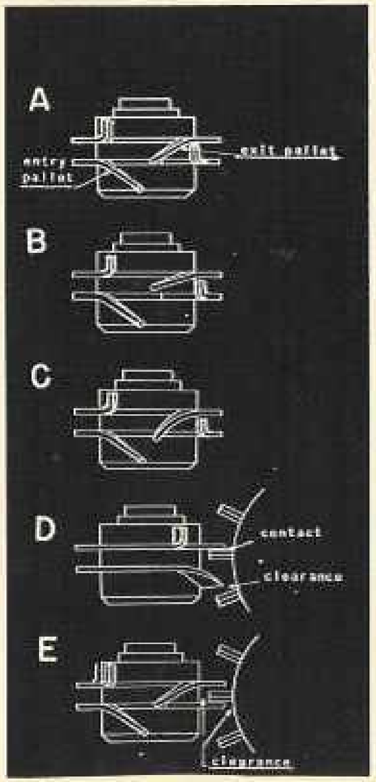


FIGURE 111 traces the sequence of motion as a tooth is gathered first by the entrance pallet and then by the exit pallet, thus turning the escape wheel.

as in 2. The tooth remains at this level while the balance continues to turn by momentum until the hairspring arrests the balance and returns it in the clockwise direction shown by the arrow in 3. This same tooth is now gathered by the upper, or exit pallet and lifted up the ramp until it again rests on a horizontal surface, as in 4. Notice here that the next tooth (*a*) is in the same position as the black tooth in 1. As the balance reverses once more and travels counter-clockwise, the entrance pallet will gather up tooth *a* in the same manner. The escape wheel teeth will in turn revolve the gears of the movement.

Overwinding is prevented by tabs *A* and *B* (Figure 111, *1*), which act as precautionary backstops for the teeth. The escape wheel has no loose, free motion—only that initiated by the slanted ramps. The wheel is controlled by the light pressure of a brake plate upon the escape wheel arbor, much like that of a friction spring upon the sweep second pinion of a watch.

PRECISION ADJUSTMENTS



While the escapement is a simple mechanism, the position and angle of each pallet and its relationship to the escape wheel must be precise or butting and jamming will result. Examine the drawings in Figure 112. The exit pallet should be adjusted so that its lower tip is exactly aligned with the flat part of the entry pallet, as shown in *A*. If the tip of the ramp is too high (*B*) or too low (*C*) it will bump against a tooth, impeding the regulation of the movement and even stopping the balance. Bend the inclined ramp so that it coincides with the path of the escape tooth and gathers it up. Although these ramps are made of tempered steel, they can be manipulated easily with tweezers. To test the alignment, turn the balance slowly by hand until the ramp of the entrance pallet meets a tooth. Turn the balance about one-eighth of a revolution further to bring the tooth to the top of the slope. Then turn the escape wheel in the opposite direction to make sure that this same tooth touches the bottom of the exit pallet (*D*).

There should be a clearance of about .10mm between the tip of the entry ramp and the next tooth on the escape wheel (*D*). If the pallet interferes with the tooth, its tip should be gently bent upward.

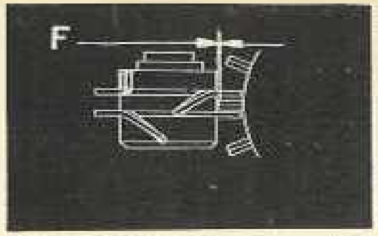


FIGURE 112 illustrates the need for precision adjustments to assure adequate clearance between pallets and escape teeth.

A minimum clearance of .10mm is needed between the balance and the escape wheel at the points shown in *E*. Check all 15 teeth for this measurement in case the wheel is mounted eccentrically. If the clearance is too small, as in *F*, adjust the cambered bracket (potence) on the back plate which carries the lower bearing of the balance.

The balance magnets should be free of any dust particles. These could interfere with the motion of the balance assembly when it passes through the narrow space around the coil. Also make certain that the wires to and from the coil are secured to the mounting plate with epoxy resin. The magnets should clear both sides of the coil by .2mm.

The brake plate, which prevents backlash of the escape wheel, should be adjusted so that its contact with the escape wheel arbor is sufficient but not too strong. The plate should contact the escape wheel pinion over a length of 2mm. Grease this area but keep escape teeth dry.

If the amplitude of the balance is too great, rebanking may cause the upturned tabs of the pallets to strike the escape teeth (Figure 109, A). Consequently an electrical brake is needed to keep the balance revolving in a 270° arc, which is most advantageous for isochronism. This device is a flat copper tongue, held fraction tight upon the screw-hole eyelet. (See *G* in Figure 105). When the magnets pass over the tongue during their arc, they induce eddy currents in the piece of copper. These currents momentarily block the magnetic field between the magnets, thus inhibiting the motion of the balance. This braking effect is proportional to the extent that the tongue projects into the magnetic field. The tongue should be rotated until it allows the balance three-fourths of a turn.

If the balance amplitude diminishes, however, another automatic control compensates. Since the balance moves less, the transistor remains in a conducting state longer and the period of time during which the current flows through the coil increases.

Once the balance system and the indexing unit are checked for precision, the movement can be adjusted for isochronism. If the movement gains when connected to a 1.3 volt battery, spread the regulator pins apart. If it loses time when tested with a fresh battery of 1.6 volts, move the hairspring toward the inside pin of the regulator. Always test the movement regulation at the 1.6 voltage after each adjustment. A new clock will keep time between 1.6 and 1.3 volts for two years, and, according to manufacturers, should remain accurate until the voltage falls to 1.2.

Some of the technical data concerning this movement are listed here:

Electrical consumption: Average 120 microamps.
Balance swing: 230° to 270°.
Temperature limits: Minus 20°C to 90°C (—22°F to 194°F).
Operating voltages: 1.6 down to 90 volts.
Coil M (Impulse coil, Figure 106): 2000 turns.
Thickness of impulse coil wire: 0.04 mm. (.0015 in.).
Resistance of impulse coil: 650 ohms.
Coil R (Triggering coil, Figure 106): 2000 turns.
Thickness of triggering coil wire: 0.04 mm. (.0015 in.).
Duration of current pulse of impulsing coil: .12 to 15 milliseconds.
Condenser: 0.025 microfarad.

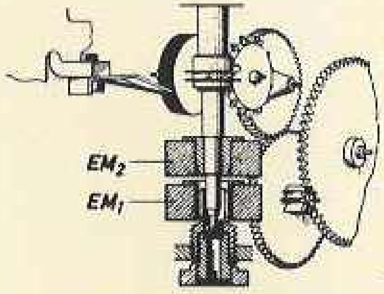
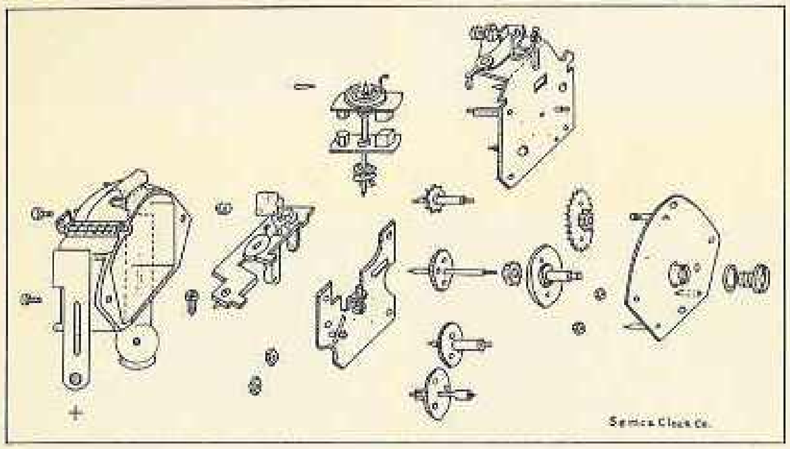


FIGURE 113. A German version of the Semca uses opposing magnets (EM_1 and EM_2) to force the weight of the balance off the lower pivots.

A movement made by the Junghans Company, in Germany, similar to the one we have been discussing, appears in Figure 113. However, we notice in this latter movement that attached to the balance shaft below the escapement is a collar magnet, EM_2. Facing this is another magnet, EM_1, attached to the lower pivot bushing, situated in the plate. These magnets repel each other, effecting a floating balance with no strain or weight upon the lower pivot and lower cap jewel.

FIGURE 114 (below) shows an exploded view of the Semca balance movement to facilitate assembly of parts.



THE CAPACITOR'S ROLE IN TIMEPIECES

A tiny reservoir for electricity helps maintain an even impulse in the electronic clock or watch

Many electronic timepieces contain capacitors, which perform various necessary functions. Here, we shall discuss the capacitor, its principles and characteristics, in preparation for the final installment in our series which will deal with the Accutron circuit and its use of the capacitor.

In its simplest form, a capacitor is composed of two electrical conductors separated by an insulator called a *dielectric*. This insulator may be waxed paper, mica, ceramic, air, or even certain chemicals which will oppose the passage of an electric current.

AIR AS A DIELECTRIC

Let us consider as an example two thin metallic plates, closely facing each other. They are separated by an air gap which provides insulation, acting as the dielectric in this case. The plates are connnected in series with a battery, a switch, and a *galvanometer*, or device to measure electric current, as shown in Figure 115. The middle point on the dial of the

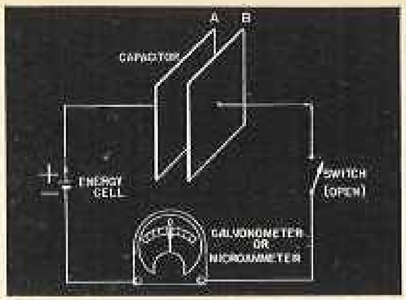


FIGURE 115

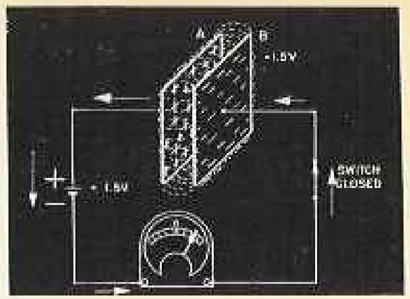


FIGURE 116

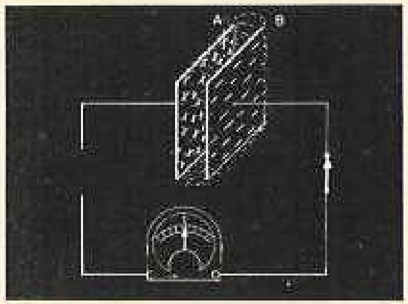


FIGURE 117

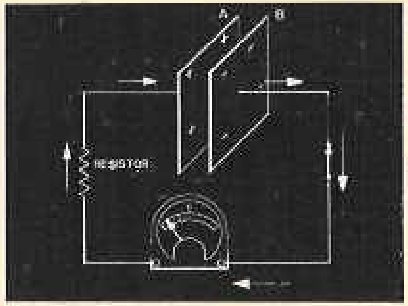


FIGURE 118

Figure 115 illustrates the circuit of a typical capacitor, plates A and B. **Figure 116** shows the switch closed and the battery charging the plates. The charge is maintained in the capacitor, **Figure 117**, even when the battery is removed. When dielectric strain is relieved in **Figure 118** by connecting the circuit without pressure exerted by the battery, the capacitor discharges.

galvanometer is zero; if current flows through this meter in one direction, the hand will deflect to the right, and if current flows in the opposite direction, it will point to the left.

By closing the switch, as in Figure 116, we cause current to flow from the negative pole of the battery around the circuit to plate B, which receives a negative charge. This places a strain on the dielectric, in pushing electrons against and off plate A and back to the positive terminal of the battery. Plate A thus has positive polarity. As the current flows from the negative to the positive pole through the circuit in Figure 116, we see the galvanometer pointing its hand to the right. The plates of the capacitor are being charged so that an electrostatic field is set up between them, as shown by the dotted lines. The opposite polarities of the plates store energy in the dielectric material between them.

PRESSURE SEEKS TO EQUALIZE

This action is similar to that exchanged between a bicycle tire and a small tank of compressed air. *Air is transferred from the source to the capacitor until the pressure of each is equalized.* When the air in the tire reaches the same pressure as the tank, air stops flowing between the two. Similarly, when the voltage (or pressure) stored in the capacitor becomes equal to that in the battery, current flow ceases. The galvanometer registers zero again and the capacitor is charged.

In Figure 117, the battery has been disconnected, opening the circuit. The capacitor will maintain its already charged voltage. But should we complete the circuit by substituting a resistor, coil, or other conductor in place of the battery, the negative charges on plate B would rush through the galvanometer back around to positive plate A, since the strain of pressure against the dielectric would be relieved. This is shown in Figure 118, where the meter is registering to the left side of the dial. The capacitor thus discharges and the current stored in the electrostatic field is exhausted.

QUANTITY OF CURRENT CAN CHANGE

The amount of electrical energy that the capacitor can contain depends on three things: the surface area of the plates, the distance between the plates, and the type of dielectric or insulating material separating the plates. If the surfaces facing each other are made larger, they will be able to store a greater amount of current for a given voltage. Furthermore, if the plates are closer together, they are akin to two magnets—their electrostatic attraction for each other is stronger and they are able to hold a larger charge. If the plates are so close that they touch, they will discharge. Therefore, insulating material is used.

Air is taken as a standard, with a *dielectric constant of 1.* Mica, waxed paper, and ceramic make better dielectrics and so have higher constant values. Since waxed paper has a dielectric constant of 6, changing a capacitor from one with air to a comparable one with waxed paper means that the unit will hold six times as much charge. This is due to the fact that electrical energy is stored in the dielectric's atomic structure.

We compared a capacitor to a bike tire accepting air from a compressor. The smaller the tire is, the more quickly it will fill to capacity, or, in the case of a capacitor , the faster it will charge. On the other hand, should too much pressure be applied, the tire would burst, and, a capacitor subjected to too great a voltage would cause a spark to jump between the plates, burning through the insulating dielectric and ruining the capacitor. The maximum voltage of the unit, beyond which sparking will occur, is called the *breakdown voltage*. This value sometimes appears on the unit and warns not to purposely exceed this load. The air space capacitor is an exception to this situation, as it would be self-healing.

APPLICATION TO TIMEPIECES

Capacitors for clocks and watches generally are of two types. One is composed of long thin strips of metal foil separated by dielectrics of waxed paper, as illustrated in Figure 119. Wire leads connect to the foil, and the unit rolls up to permit a large surface area to be condensed into a small, sturdy capacitor.

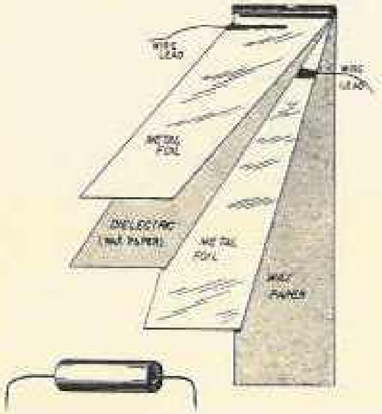


FIGURE 119
An effective capacitor can be made out of strips of metal foil, insulated by waxed paper, rolled up to fit into a timepiece.

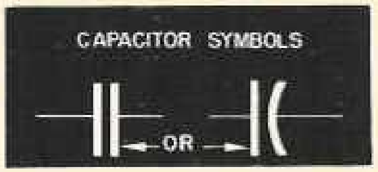


FIGURE 120
The symbols for a capacitor are expressed here, with the one on the right preferred.

The other type is called an *electrolytic capacitor;* the action of a chemical such as a borax solution upon aluminum causes an extremely thin layer of aluminum oxide and oxygen gas to form on the surface of the metal. Thus, the aluminum plate becomes one pole of the capacitor and the borax solution the other. Because the coating of oxygen and aluminum oxide is not an electrical conductor, it becomes the dielectric. The aluminum can be folded or rolled to occupy a relatively small space. Because this chemical dielectric is so thin, the capacitance of the unit is very high. It is important to observe polarities as marked on the case, when connecting battery leads to the electrolytic capacitor, in order to prevent the unit from burning itself out by a wrong connection.

COMPENSATING MECHANISM

Capacitors have the ability to compensate for a change in voltage in the circuit. They are essentially reservoirs of electricity. Referring back to Figure 116, the charge in a capacitor will build up until it equals the charge of its source. As the difference in pressure between the capacitor and the battery lessens, the rate of flow slows down. The capacitor draws the most current when it is void of electricity. If the battery voltage should fall below that of the charged capacitor, part of this stored energy would flow back to the battery, just as a leak in the tire would cause more air to fill from the tank. Thus the capacitor, once charged, helps to maintain a constant voltage in the circuit. It is also able to accept a rise in voltage by being additionally charged.

TIMING MECHANISM

Capacitors can be used to delay or time a charge, for instance to control the energy stimulating a balance or tuning fork coil until the unit is in the proper position to receive that stimulus. If the capacitor is wired as simply as in Figure 116, the charge builds up in the unit almost immediately. However, including a resistor in the circuit impedes the flow of current. This is seen in Figure 121, analagous to a thin tube connecting two tanks of water. The long narrow passage of the tube delays the water, and the tanks take longer to equalize. Because of this same resistance, the capacitor takes longer to become charged to the same value as its "donor."

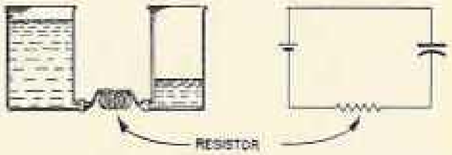


FIGURE 121
A capacitor can be used to time a circuit by inserting a resistor to delay the charge from the battery, much as a thin tube impedes a flow of water from one tank to another.

Previously, we discussed the capacitor and learned something about its characteristics—that it is essentially a reservoir for electricity, that it tends to equalize its source of voltage, and that it can be used, along with a resistor, to delay or time an electrical charge.

IN THE ACCUTRON

As we examine the Accutron circuit, we can learn more about the capacitor's action in a timepiece, as well as understand the Accutron better.

We know the Accutron operates on the vibrations of a tuning fork, rather than by the oscillations of a balance wheel and hairspring. The tines of the fork are equipped with magnetic cups at each tip. Mounted within each cup is a conical magnet, surrounded by insulated wire, which serve as *driving coils.* One of them functions also, as a *phase sensing coil.* Energy provided by a tiny battery sets up an electronic circuit between these coils and magnets, causing the tuning fork to vibrate continuously. To maintain this vibration, the coils must receive a pulse of current from the battery at just the exact instant. As the tuning fork vibrates, an alternating voltage is induced in the two coils. This voltage is a direct measure of the amplitude of the tuning fork's vibration. It is also this voltage which helps the circuit sense the timing and control the amplitude of vibration.

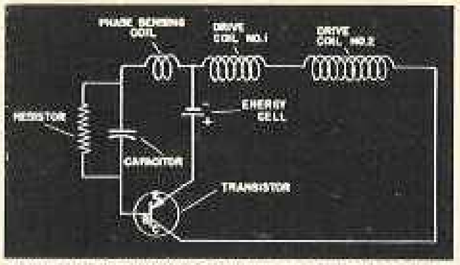


FIGURE 122: In the Accutron circuit, the capacitor, along with its resistor, keeps the transistor in a nonconducting state through most of the cycle operating the tuning fork

As we notice in *Figure 122,* the capacitor lies parallel in the circuit to a resistor. This resistor causes a slight leak in the capacitor's charge; thus the capacitor will be recharged slightly at each peak of the alternating voltage induced in the phase sensing coil by the magnets. These pulses of current cause the transistor to conduct and let current flow into the driving coils to maintain vibrations of the tuning fork. Therefore, we see that the capacitor, with its resistor, is the element which keeps the transistor in a non-conducting state through most of the cycle operating the tuning fork. If the amplitude of the tuning fork's magnets is such that at the instant the transistor becomes conducting, the induced voltage in the drive coil equals the battery voltage, no current will flow, since the two voltages are opposite in polarity and would cancel each other.

The amplitude is controlled by maintaining the induced voltage in the drive coil at 10 per cent less than the battery voltage. The key to this is in the design of the magnet and coil system. In case of shock, a 10 per cent increase in amplitude of the tuning fork tines would cause the driving current pulses to be stopped and the tuning fork would then rapidly return to its proper amplitude. If the tuning fork should decrease its amplitude 10 per cent for any reason, the driving current would then be comparatively doubled, causing the tuning fork to pick up amplitude.

PRESERVING BATTERY LIFE

Another use of the capacitor in a timepiece circuit is to suppress a regenerative current, which would otherwise exhaust the battery. Such a circuit was shown in *Figure 107* and is repeated here.

While a capacitor is composed of one conducting metal separated from another conductor by an insulator, we may even call a coil a capacitor. Multiply a few adjacent turns of wire by the hundreds in a watch or clock coil, and we have a capacitor of noticeable size and electrical value. By placing one coil next to or even inside a similar coil, we have additional capacitance.

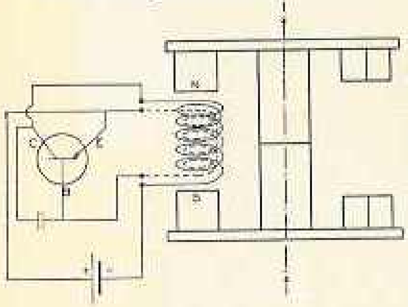


FIGURE 123: A capacitor is inserted in this circuit to save the life of the battery as the relaxed backsurge of current through one coil induces a momentary current in the adjacent coil, constantly stimulating the battery to supply current to maintain the circuit.

Current sent through a coil generates a magnetic field around it. When this current is stopped, the magnetic field collapses back into the coil in the opposite direction. In *Figure 123,* one coil is wound within the other; when current in the first collapses, it induces a current of opposite polarity in the second coil, which, being only momentary, quickly collapses also, inducing a current again in the first coil. This is repeated back and forth. It would eventually die out, but the initial surge of alternating current has sufficient intensity to influence the transistor to conduct. This in turn would cause the battery to supply additional current to overcome the circuit's losses. The electrical oscillation would continue until the battery becomes exhausted. Thus the circuit would drain the battery without providing power to compensate.

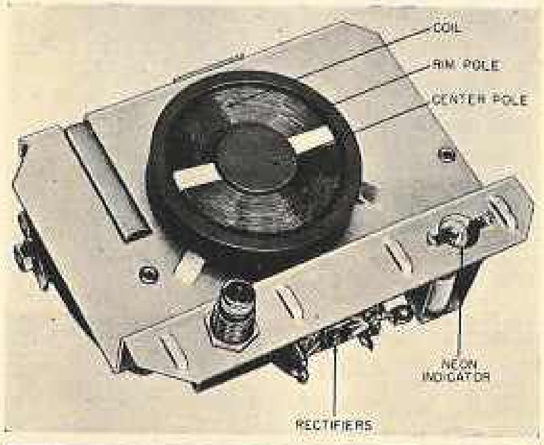
To overcome this difficulty, a capacitor, shown in *Figure 123*, is placed in the circuit. It is charged and discharged by the alternating action just explained. As it discharges, the capacitor bucks the regenerative current, cancelling out the electric oscillation and conserving the battery's life so that it can supply pulses to the coil to stimulate the balance magnets at just the right instant.

TO PREVENT ARCING

Capacitors are used in some cases as spark suppressors. When a circuit using an iron core coil is broken, a spark would ordinarily jump across the contacts or switch points. If a capacitor is connected across these points, the electrical charge caused by the collapsing magnetic field will be used to charge the capacitor instead, preventing arcing.

DISCRIMINATING A CURRENT

Since capacitors allow the passage of AC current but block DC current, they can be used in circuits where the discrimination of one from another is important.



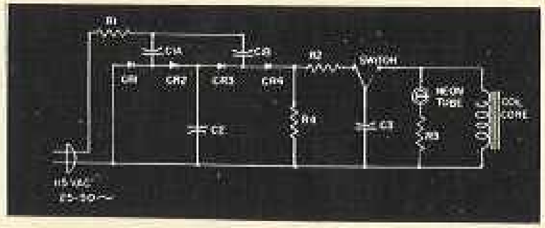
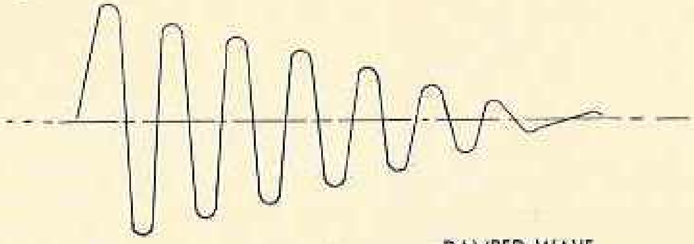


FIGURE 124: Modern watch demagnetizer: inside view. Watch is placed on top in a recess which aligns it with the demagnetizing coil of enamel wire wound on a powdered iron core. With the unit connected to AC current, the pushbutton is depressed. A neon lamp flashes to show the device is working. **FIGURE 125:** Scheme of demagnetizing unit; coil core is connected to the open switch. When not in use, the pushbutton's terminals complete a charging circuit to capacitor C3. When the button is depressed, the charging circuit is opened and the discharge circuit through the coil core is closed. As the capacitor's discharge current flows through the coil core, a ringing circuit composed of the coil core and C3 produces the damped AC wave which does the demagnetizing.

IN AN ELECTRONIC DEMAGNETIZER

Still another use of the capacitor is in the modern electronic demagnetizer. In this device, all electronic action takes place in about 1/20 of a second. Its purpose is to produce electronically and automatically that which old fashioned demagnetizers did by hand. By withdrawing a watch from the demagnetizer's coil, the magnetic influence of the alternating current on the watch gradually diminished. This produced a damped or diminishing wave of magnetic intensity and polarity.

Figure 124 shows the inside of this device with its iron core coil. *Figure 125* shows its electronic scheme. From the regular 60 cycle AC source, the voltage is rectified and multiplied. The circuit to the left is closed and the capacitor is charged to approximately 600 volts.



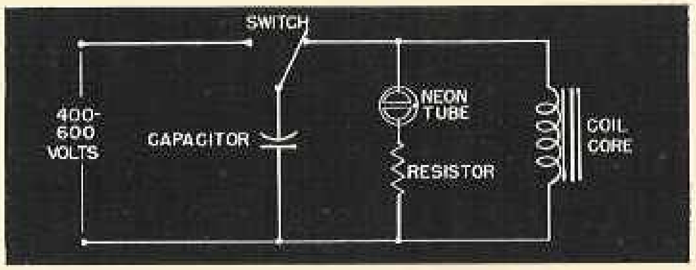


FIGURE 126: The damped wave, produced by a demagnetizer, dies down quickly from its maximum value to zero. **FIGURE 127: The scheme of the electronic demagnetizer** in Figure 125 is summarized more simply here.

When the watch is placed over the iron core coil and the switch turned to the right, the supplying circuit is opened but the right side of the circuit is closed. This allows the already charged capacitor to discharge through the iron core coil.
A strong magnetic field forms around the coil and adjacent watch.

Notice that the energy which was stored in the capacitor as an electrostatic charge is now transferred to the coil as an electromagnetic field. When this magnetic field ends, it collapses suddenly, causing a back surge which recharges the capacitor in the opposite polarity. The capacitor is not as strongly recharged as originally, due to heat loss of energy in the coil windings. Because the circuit is still closed, the capacitor will discharge into the coil core again, more weakly. This repeats for several cycles until, like a freely swinging pendulum, it comes to rest, exhausted. Its wave grows weaker and weaker, like the damped sine wave shown in *Figure 126*, and the magnetism in the watch exhausted.

Figure 127 shows a simplified diagram of the right side of the Elimag's circuit. The switch to the right is closed. The capacitor discharges into the coil core. As the resistor is fed by the discharging capacitor, a small neon lamp flashes to indicate that the circuit is operating. As the magnetic field in the coil core collapses, it travels in reverse, creating a voltage of its own. We know that a capacitor tends to equalize the voltage of its source. In this case it will absorb the charge from the coil's collapsing magnetic field, and, since the coil is "vacant," the capacitor will "feed" the coil. This action oscillates back and forth until all of the energy is dissipated, producing the damped sine wave.

SPECIFICATIONS FOR ELECTRONIC BATTERIES

			MEASUREMENTS					
				INCHES		M/M		
Ref. No.	Factory No.	Type	Voltage	Dia.	Hght.	Dia.	Hght.	Used For
1	RM-312	Mercury	1.35	.300	.124	7.55	3.40	Lucien Picard & Novelty Lights
2	W-1	Mercury	1.35	.305	.133	7.70	3.38	Elgin 725
—	—	—	1.35	.445	.244	11.27	6.20	Timex Old — Use # 6 Washer
3	MC251	—	1.40	.446	.126	11.30	3.20	Epperlein 100 — Hamilton 500-505A
4	W-2	Mercury	1.35	.448	.132	11.40	3.40	Bulova Accutron
5	WD2	Mercury	1.40	.450	.130	11.43	3.30	Lip R27
6	W3 303	Mercury	1.35	.450	.206	11.43	5.33	Timex New
7	RM 675	Mercury	1.40	.450	.203	11.43	5.15	Novelty Lights
8	RM-450	Mercury	1.35	.450	.565	11.43	14.35	Clock — Photo Electric Eye
9	RM-400	Mercury	1.35	.453	.126	11.50	3.20	Novelty Lights
10	WD-4	Mercury	1.40	.593	.154	15.07	3.90	Landeron 4750 Wittnauer 11EW
11	PX 13	Mercury	1.35	.608	.241	15.40	6.10	Polaroid Electric Eye — Exposure Meters
12	RM-625 E625	Mercury	1.35	.610	.233	15.50	5.92	Landeron 4750 Clocks — Hearing Aids
13	RM 630	Mercury	1.40	.620	.233	15.75	5.92	Transistor Radios
14	RM-640	Mercury	1.40	.620	.435	15.75	11.05	Exposure Meters — Transistor Radios — Electric Eye
15	RM-1	Mercury	1.35	.620	.645	15.75	16.38	Clock — Photo Electric Eye — Paging Systems
16	PX-14	Mercury	2.70	.641	.608	16.20	15.40	Photo Electric Eye
17	WD-5	Mercury	1.40	1.003	.110	25.48	2.79	Landeron 4751
18	Swiss	—	—	1.080	.120	29.35	3.00	Tourist Watch Dial Light
19	Swiss	—	—	1.252	.152	32.00	3.80	Tourist Case Back — Dial Light

Part 2
Electric Watch Repair

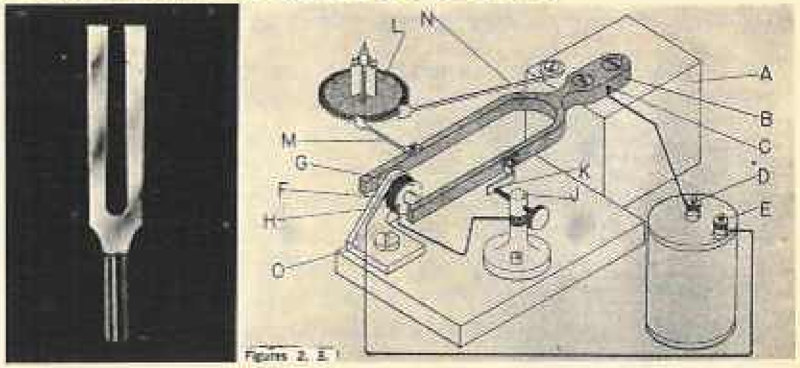
"ACCUTRON"
(BULOVA)

Bulova's "Accutron" (pronounced ac' cu' tron') is an electronic timepiece which eliminates not only the mainspring with its winding mechanism, and the escapement, but also does away with the balance and hairspring. At the heart of the principles which make "Accutron" possible is the tuning fork (Fig. 2).

The Tuning Fork

The high accuracy of the fixed vibration frequency of tuning forks has long been known to students of physics. The rate at which these forks vibrate depends on the material of which they are made, their length, and the body.

If a tuning fork were electro-mechanically (or electronically) activated, engineers discovered, its vibrations could be made to push a wheel. Since the vibrations per second are fixed, steady and unchanging, each vibration would push the wheel at a most regular pace. Such a wheel could then be geared in a series with a train of wheels to move a set of hands.



Figures 2, 3

The Principle Explained

Figure 3 shows a simplified method by which a tuning fork can be made to vibrate continuously and move a gear. This should help prepare the reader for the more technical explanations of the electronic principle of "Accutron" which follow later on.

A is a block of wood upon which the entire unit is mounted. B is the magnetic tuning fork fastened to this step-block by two screws. C is a copper wire connected to the fork and terminating at the positive connection D of the battery (energy cell). At the negative connection E, is another wire which leads to F and is connected to a coil of copper wire G, wound around an iron core. This coil and its core are supported independently by the stand O, and no part of the coil or its core touches the tines of the fork. The other end of the coil of wire at H is connected to the stand J with its adjustable contact screw.

Connected to one of the tuning fork tines is a silver contact piece K, which the adjustable screw in J touches when the fork is at rest.

The circuit produces a flow of current from D to C through K, into the screw through the wire at H, and through the coil G, coming out at F, and then back to E. This causes the coil G to become an electro-magnet; and the coil's iron core attracts both tines of the ferro-magnetic tuning fork.

When the tines are attracted toward the iron core of the coil, the circuit is broken, because K loses contact with the adjustable screw in J. It is this loss of contact that interrupts the circuit; and the tines—because of their resiliency—return to their position of rest. But at the instant that it comes to rest, the tine at the right, through contact piece K, makes contact with adjustable screw J. This completes the circuit again, which causes the tines to move inward, towards the coil core, again breaking the circuit. Thus the vibration continues at its own musical pitch (fixed frequency) as long as the energy cell lasts.

The fork's other tine has attached near its end a thin spring M which engages at near tangency the ratchet-toothed wheel L. As the tine moves outward, the spring moves the wheel L one tooth. To prevent the ratchet wheel and pinion from turning backwards when the spring M and tine are attracted inward, lock spring N (attached to wood block A) is used. Spring N not only prevents backlash, but its slight side pressure against the slanted ratchet teeth positions the wheel for its next impulse by N. This action is similar to the draw in a jewelled lever escapement.

Difficulties Overcome

The preceding is an over-simplification. Such a device would have many drawbacks. One fault is that with each break of the contact between K and the adjustable screw at J, a spark would result. The spark would sap the energy from the battery and

eventually cause the contacts to erode or carbonize. Furthermore, the amplitude of vibration of this type of tuning fork could increase, due to an increase in voltage or from a shock, and these wider vibrations would cause the pusher spring M to move wheel L more than one tooth at a time. Any horological mechanism attached to such a machine would gain time.

On the other hand, if the voltage dropped, the fork vibrations would become weaker. The amplitude would drop a bit, the tine which nudges wheel L would be too weak to advance the wheel, and the timepiece would stop.

Transistor's Function

In Bulova's "Accutron" these problems are eliminated. No sparking is possible because there is no physical contact or "break" to induce sparking. The release of energy from the power cell to the electro-magnetic coils is electronically accomplished through the use of a transistor. This does electronically what other devices do electro-mechanically. (The watch's general electronic system which does this will be described in detail.)

But here is a simplified explanation:

Figure 4 shows the actual tuning fork—the heart of "Accutron"—mounted on the movement plate. Attached to each of the tines of the fork is a magnetic iron cup, which faces outward. In the center of each cup is a thin, tapered permanent magnet. Mounted firmly on the movement case are two stationary hollow coils made of ultra- fine copper wire. They are connected to each other in series (Figure 5).

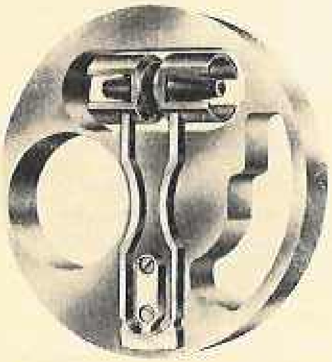


Figure 4. Tuning fork with magnetic iron cups is mounted on movement plate.

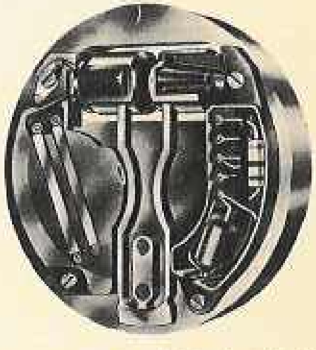


Figure 5. Spacing of magnetic cups at tip of fork around tiny electro-magnets is shown in this cross-section.

The transistor is in series with these coils and the combination is connected to a battery. The coils are precisely fixed so that there is ample clearance between the hollow part of each coil as it fits over the tapered magnet and the iron cup which fits over the coil. Therefore the tines with their outer cups and inner magnets can vibrate within and over the stationary coils without touching them. Figure 5 shows the right coil partially cut away to reveal its relationship to the cup and tine magnet.

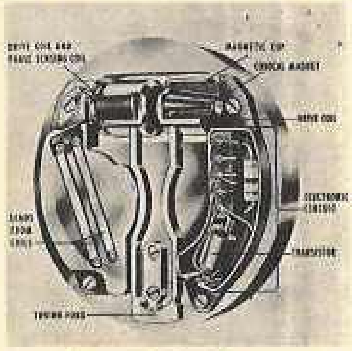


Figure 6. This is the basic mechanism of "Accutron." Tiny striped cylinder at 3 o'clock position is the resistor.

The Transistor-Switch

To follow the action, refer to Figure 6. It is necessary to imagine in ultra-slow motion action which actually takes place 360 times a second. When current flows through the coils, it attracts the tines. However, as we realize from our knowledge of electricity, when a permanent magnet moves through a coil of wire, it induces a current. Therefore, as the iron cup on each tine is attracted to the coil, its inner, permanent magnet moving through the coil induces a voltage. This induced voltage is in the reverse direction from the original voltage coming from the battery, and it cancels out the energizing voltage, causing the field partially to collapse. As the magnetic tines move back to their (original) point of rest, their attached magnets induce a voltage going in the opposite direction. A current travels through the transistor, which acts as a switch and which releases a new surge of current to again attract the tines. In other words, the transistor acts as a switch, allowing current from the battery to flow only when the voltage applied to it is sufficiently high A capacitor with a resistor across it is the element which maintains the transistor in a non-conducting condition through most of the cycle of operation of the tuning fork.

Figure 7 shows "Accutron" with the dial removed. Notice the fixed coils within the iron cups on the tines. The transistor is the cylindrical object near the 5 o'clock dial position. The striped cylindrical piece at the 3 o'clock position is the resistor. The toothed wheel enmeshed with the minute wheel is the hand setting wheel which is depressd into mesh with the minute wheel

for the hand setting operation. This is done by a handle on the back of the watch case.

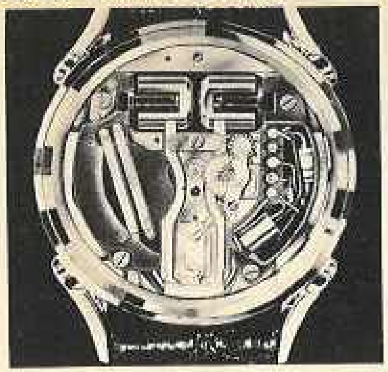


Figure 7. Enlargement of dial side of movement shows electronic circuit at right, tuning fork at center of photo.

Figure 8. Train-side view shows tiny mercury battery as circle at right, the tuning fork cups and coils at top.

Figure 8 shows the movement side of "Accutron." Here the magnetic cups can be seen. The mercury battery is the circular shape at the 3 o'clock position. The driving mechanism, similar to the system shown in Figure 3, is shown in Figure 9, also greatly simplified.

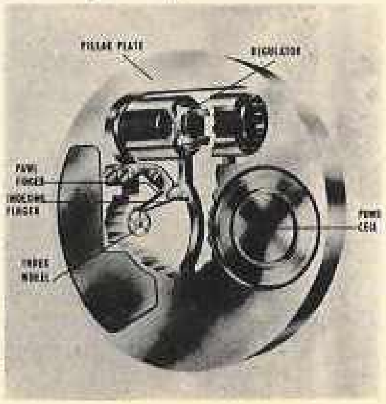
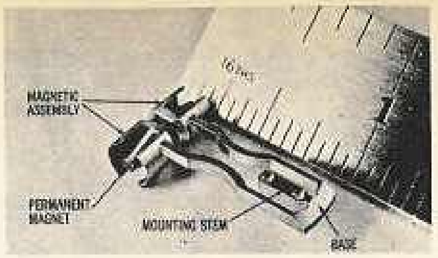


Figure 9. Diagram shows how the tuning fork's indexing finger whirls the index wheel at the rate of 360 teeth per second.

In "Accutron," the fork vibrates 360 times a second. There is no tick, but if the watch is held closely to the ear, a musical hum is heard. The physical pitch of middle C is 256 vibrations a second. The nearest tone to the watch's hum is F sharp (365.8 vibrations a second). Each of the vibrations is made to move a ratchet-toothed wheel by the width of one tooth. The wheel contains 300 teeth. Thus in one second, the tuning fork advances this gear one and a fifth turns. Geared to other train wheels, the speed is reduced to drive a full set of hands. The sweep second hand moves in an apparent continuous motion similar to that of an AC synchronous electric clock.

In an elementary example of the electro-magnetically activated



ACCUTRON Tuning Fork

tuning fork (Figure 3), we also showed that if the voltage increased, the tuning fork tines might vibrate with greater amplitude, and push the wheel a distance of more than one tooth. That would cause any timepiece connected to the mechanism to gain. Conversely, if the voltage dropped, the amplitude might be insufficient to advance the index wheel even one tooth.

Furthermore, a shock might increase or decrease the amplitude, causing erratic timekeeping. However, in Bulova's "Ascutron," the problem has been solved in two ways. First, by the design of the ratchet toothed index wheel and its index and pawl jewels; this arrangement allows reasonable variations of amplitude—and yet the tine indexes only one tooth at a time. Second, by the electronic design (the transistor-electro-magnetic coils, phase-sensing coils, capacitor and resistor arrangement). This design will be explained in detail later in this chapter.

Amplitude Variance

While it might seem advantageous to keep the tines' amplitude to exact limits, this would not be advisable. If the voltage dropped, a diminishing of the amplitude would cause a failure of the index jewel to advance the one tooth required. On the other hand, should the voltage rise, or the watch receive a shock, the amplitude would increase, causing the index jewel to register more than one tooth. The increase would result in the timepiece's gaining time.

The index wheel contains 300 fine ratchet teeth. The diameter of this wheel is .095 inch, or 2.40mm. In familiar fractional inches, it is closest to 3/32-inch. This means that each tooth is .001 inch (.025mm); in other words, there is 1/1000 of an inch between the tips of each tooth. If I were required to make an accurate drawing of this precise and important index wheel so that each tooth would be ½ inch from tip to tip, I would have to draw the wheel four feet in diameter! If a 12-tooth sector of such a large wheel were then to be shown, the arc of such a wheel would appear nearly straight. Therefore, it will be simpler to show the indexing action with a series of enlarged teeth and index and pawl jewels on a straight line. (See Figure 11.)

Purposes of Pawl Jewel

The pawl jewel on the left is attached to the spring which in turn is attached to the plate. Its chief purpose is to prevent the index wheel from turning backward when the indexing jewel moves back in the return direction. Its second purpose is to draw the wheel backwards by the coincidence of its angle and pressure upon the inclined surface of the teeth. This works much in the manner of draw in a conventional lever escapement, keeping the fork against the banking pin.

The index jewel (attached to a finger-spring which is attached to the left tine of the tuning fork) moves the index wheel counterclockwise. The pawl jewel and index jewel are in a position of rest in the first sequence (panel A) in Figure 11. Notice that the pawl jewel is resting snug against the edge of tooth 1 and flat against the surface of tooth 2. However, the index and pawl are positioned about half a tooth apart, so that at rest one or the other (or both) will exert the "draw effect" in the direction opposite from the normal movement.

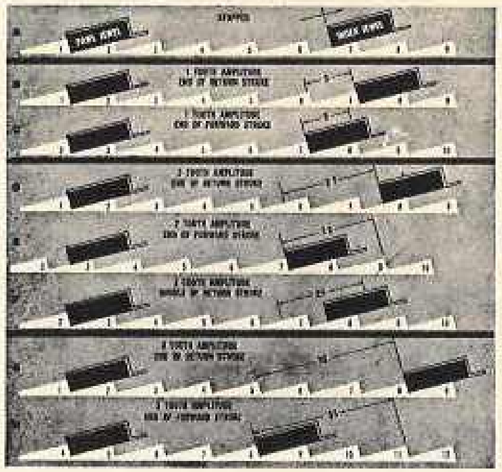


Figure 11. Diagram shows possible variations in index finger's 'push' regulated so ratchet toothed wheel always moves forward only one tooth's width.

When the tines are electro-magnetically activated and the jewel moves to the right on the return stroke (Sequence B), it moves just far enough to drop onto the front of tooth 7. There it rests on the incline of tooth 8. In sequence C the forward stroke (of a one-tooth amplitude), will advance tooth 7 one full position. The pawl jewel will lock tooth 2 and prevent backlash.

When the tine amplitude has caused the indexing jewel to move the equal of a two tooth movement (as shown in Sequence D, 2S), only one tooth of the index wheel will be advanced. Here the width of the return stroke of the index jewel's motion is equal to two teeth. It moves forward one half of this distance and because of the "draw" pressure of the index and pawl springs, the index wheel moves backward to the position midway between teeth 7 and 8.

On the forward stroke of the index finger and jewel with an amplitude equal to a width of two teeth (Sequence E), the index jewel has gathered up tooth 7 (see also Sequence D) and moved it to a point one-half tooth width beyond its position of rest. Notice that tooth 2 is one-half tooth width beyond the pawl jewel.

When the indexing thrust of the indexing finger and jewel are returning as in Sequence F, the torque (draw-pressure) of both pawl and index jewels and fingers on the inclined surface of the index wheel teeth will cause that wheel to recoil slightly until a tooth such as Number 2 in F, C, and A rests against the front edge of the pawl jewel.

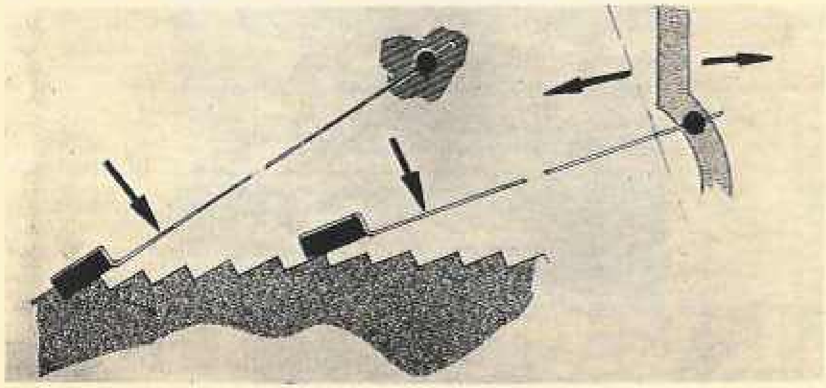


Figure 12

Figure 12 shows how this "draw" angle operates. Imagine the springs which contain the epoxy-bonded pawl and index jewels exerting a slight pressure in a near radial direction. This would cause a recoil of the ratchet tooth. It is this allowable recoil which permits the tines to move the index wheel a distance equal to a limit of almost three teeth amplitude, and yet register only a one-tooth advance. This gives a wide tolerance in the tuning fork amplitude with no gain or loss of time.

However, should the amplitude of the tuning fork exceed these limits, for instance, equal to an amplitude of slightly over three teeth, then the arrangement just explained would be inoperative —and all three teeth would be gathered up. This is shown in Sequences G and H, Figure 11. Here the return stroke of the index jewel starts from a point of rest against tooth 5 and ends three teeth back in front of tooth 8. Notice that the same amplitude on the forward stroke would actually gather up the three teeth which will be "counted" by the dial train. This is shown at the left, at which point teeth 2, 3, and 4 have been gathered and retained.

Despite its small size, the physical principle and action of the index wheel and pawl and index jewel and springs are the same whether the wheel is 1/10th of an inch or 4 feet in diameter.

Amplitude Control, Electronically

To safeguard against such extremes of amplitude in which more than one tooth would be counted with each vibration of the tuning fork, "Accutron" has provided a unique amplitude control system designed into the electronic circuit driving the tuning fork.

Interrelationship of the Electro-Magnetic Elements

Before discussing the electronic circuit in "Accutron," let us examine the interrelationship of the magnetic elements on the tuning fork tines and the coils of wire connected to the electronic circuit. The cup-like part attached to each tuning fork tine (Figure 13) is made of iron as it must be magnetic. Mounted in the center of each of these cups is a conical magnet. Between the cup and its central magnet is a strong magnetic field. The coils of wire wound on the plastic forms extend into the space between the respective magnets and cups and these coils there-

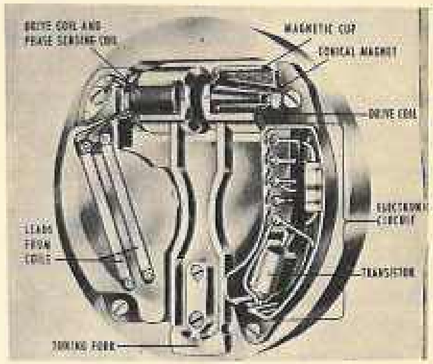


Figure 13. This drawing shows the timepiece's "works" in greatly enlarged detail. Notice the cut-away magnetic cup assemblies at the tips of the tines.

fore lie within the magnetic field without touching the moving parts attached to the tuning fork. These coils are supported by the pillar plate.

If a current is passed through one of these coils of wire, this coil becomes an electro-magnet. It will then either attract or repel the associated magnet and cup assembly, depending upon the polarity of the voltage applied. Conversely, if a magnet and cup assembly is moved within its associated coil, a voltage is induced in this coil. The polarity of this voltage depends upon which direction the magnet assembly is moved. This means that as the tuning fork vibrates, an alternating voltage is induced in the coils. This induced voltage is a direct measure of the amplitude of the tuning fork. It is this voltage which permits the circuit to sense and control the amplitude of vibration.

Dual-Purpose Coil

One other feature of the arrangement of the electro-magnetic parts which can be observed on this photograph (Figure 13) is that there are four wires leading from the coil on the left. This coil is in two sections with one end of each section connected together. The result is that while most of the turns of wire on the left hand coil are used to drive the tuning fork, approximately one quarter are used to form what is termed the "phase sensing coil." It is this coil which initiates the pulses of current into the driving coils at the proper instant to maintain the oscillations of the tuning fork.

The coils and associated magnets shown in this figure therefore serve three functions: first, they convert pulses of electrical current into mechanical impulses which drive the tuning fork; second, they provide the means by which the electronic circuit may sense the tuning fork amplitude; third, they control the instant in the tuning fork cycle during which the driving current pulse is delivered.

Operation of the Electronic Circuit

In the "Accutron," the tuning fork is impulsed electro-magnetically once each cycle. To avoid sparking as in electric watches, the impulsing is accomplished by an electronic circuit. Hence the problems of make and break contacts are avoided. The activation of the electric watches' mechanically operated switch is accomplished in "Accutron" in a trouble-free manner by the phase sensing coil which causes the current in the tuning fork driving coils to be turned on and off. *The transistor is the electronic element which turns the current on and off under the control of the phase sensing coil.* The transistor in "Accutron" therefore functions as a switch.

The transistor in "Accutron" has three leads: the emitter, base, and collector respectively. The base to emitter leads must be supplied with a current in order to cause the emitter to collector circuit to be conducting. In other words, the collector circuit can conduct only when there is current in the base circuit of the transistor.

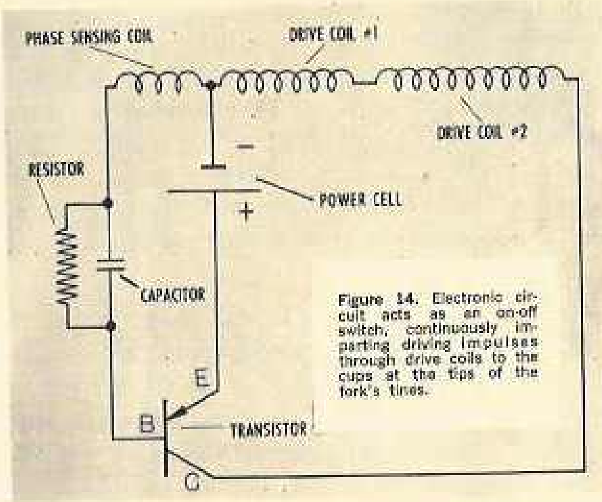


Figure 14. Electronic circuit acts as an on-off switch, continuously imparting driving impulses through drive coils to the cups at the tips of the fork's tines.

Figure 14 shows the schematic wiring diagram with the electrical connections between the various circuit elements. To repeat, the transistor functions as a switch, which can be caused to conduct or to be non-conducting. The *left hand side of this diagram* contains all the elements for turning the driving current on and off. First, let us examine the manner in which this occurs.

The *capacitor*, shown on the left with a *resistor* across it, is the element which maintains the transistor in a non-conducting condition through most of the cycle of operation of the tuning fork. As explained previously, an alternating voltage is induced in the phase sensing coil by the vibrations of the magnet associated with it. In combination with the emitter to base circuit of the transistor, which acts as a diode or rectifier, this voltage is added to the power cell voltage to charge the capacitor. A capacitor functions as a storage tank for electricity. The resistor across the "Accutron" capacitor causes a slight leak with the result that this capacitor will be re-charged slightly once each cycle by the peaks of the alternating voltage induced in the phase sensing coil. It is these recharging pulses of current which allow the transistor to conduct momentarily and cause current to flow in the driving coils to pulse the tuning fork and maintain its vibrations.

The right hand side of this diagram contains all the elements for delivering pulses of current to the tuning fork drive coils and for controlling the size of these current pulses so that proper tuning fork amplitude is maintained. The drive coils are connected in series with the power cell and the emitter-to-collector-circuit to the transistor. The emiter-to-collector-circuit is caused to conduct at the instant when the voltage induced in the drive coils is about at its maximum instantaneous value and is opposite in polarity to power cell voltage. Therefore, if the amplitude of the tuning fork should be such that at the instant the transistor becomes conducting the induced voltage in the drive coils exactly equals the power cell voltage, no current would flow since there would be no net voltage because the drive coil induced voltage "bucks" the power cell voltage.

The magnet and coil system is so designed that at the proper amplitude of vibration for the tuning fork, the voltage induced in the drive coils has a peak value about 10 per cent less than power cell voltage. This is the key to the operation of the amplitude control system. Because of this a 10 per cent increase in amplitude, resulting from a disturbance, would cause the driving current pulses to be reduced to zero and the tuning fork would rapidly return to its proper amplitude. Furthermore, a 10 per cent decrease in the amplitude of the tuning fork would cause the driving current pulses to double and again return the tuning fork very rapidly to the proper amplitude.

In principle, it has been shown that the tuning fork amplitude is controlled by converting it into a voltage, which is maintained at a value about 10 per cent below power cell voltage. This cell is designed to provide a very constant voltage for approximately 99 per cent of its useful life, hence the tuning fork amplitude remains at its proper value. If the amplitude changes due to a shock, it will return to the proper value within a very small fraction of a second because of the amplitude control circuit just described.

REGULATING the Accutron is done by changing the frequency of the tuning fork. As mentioned earlier, this frequency depends upon the effective length of the tuning fork as well as its mass and the material from which it was made. The effective length of the fork can be altered by shifting the center of gravity of the tines. If the center of gravity is moved outward, away from its center, the frequency of vibration will be less and the Accutron will lose time. If the center of gravity is moved closer to the center of the tuning fork, the frequency will increase and the Accutron will gain time.

Such changes are accomplished by the pronged, frictioned, spring-clip which is attached to each of the cups at the tips of the tuning fork tines (Figure 15). These clips are the regulators.

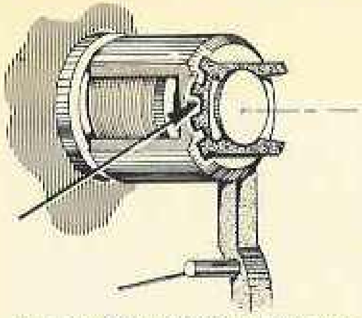


Figure 15. Center of gravity of tuning fork is changed by shifting notched spring-clip.

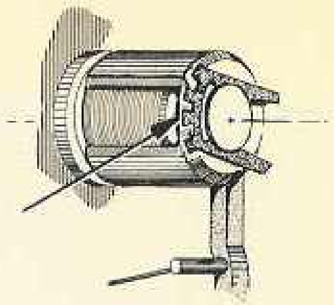


Figure 16

The prongs of these regulator-clips are called "lands" and the notches between them are termed "grooves."

By twisting the clip so that a land occupies the spot formerly occupied by the adjacent groove, a change of two seconds a day can be obtained.

In Figure 16, the regulator has been twisted one "land" in the clockwise direction. This has caused a very slightly heavier mass to be positioned upwards of the tine, causing an outward shift in the center of gravity. As a result, the watch will show a time loss of exactly two seconds daily.

However, a correction as small as ½ second a day can be made by moving the regulator only one-quarter of a division. There are seven divisions on each of the regulators (4 lands, 3 grooves). Thus, because each division is equal to 2 seconds per day, it would be impossible to make a correction of more than 28 seconds per day, even if both regulators were originally set all the way in or out (which they are not). An Accutron which gains or loses more than about a minute a week requires *servicing*—not regulation.

Setting the Hands

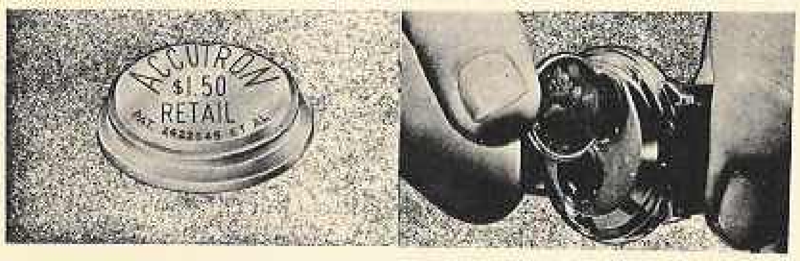
Unlike ordinary, mainspring-powered watches, this electronic watch does not have a stem or crown on the side of the case. The setting crown has been placed on the back of the Accutron so that no projection interrupts the smooth contour of the case. Its location is shown in Figure 17. By lifting the setting handle to an upright position, as in Figure 18, the setting mechanism is engaged. This is equivalent to pulling out the crown on an ordinary watch. The hands can then be set by rotating the setting handle either clockwise or counter-clockwise to bring the hands to the desired position. The handle (or latch as it may be called) is then folded down. This is the same as pressing in the crown of an ordinary watch after setting.

Lifting the Setting Handle *Figure 17*

Setting the Hands *Figure 18*

Changing the Power Cell

Figure 19 shows how the power cell (battery) is removed for replacement. The hatch opposite the setting crown is grooved to accommodate a coin, which may be used to unscrew the hatch.



The ACCUTRON Power Cell *Figure 19*

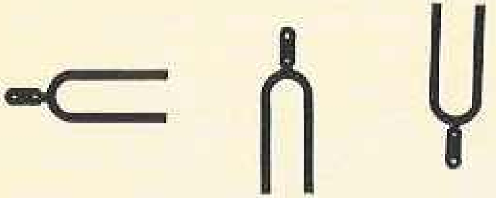
In Figure 19, a dime has been used to open the gasketed hatch. Turning the watch to dial-up position will now cause the old power cell to drop out. A new power cell can then be tucked into the empty compartment, after which the hatch is screwed down tightly to assure that the watch will be waterproof.

Position Errors

The position error of the Accutron is very small. All Accutrons have the same relative performance in the same position.

Wrist watches are generally tested in the dial up, dial down, 3 down, 12 down and 9 down position. The maximum difference in any of these positions in *all* Accutrons is *always* 5 seconds per day. Unlike balance-wheeled watches, this positional error is a function of design and cannot be altered or "adjusted" by the watchmaker. It is a small but predictable error.

The effect of various positions on the rate of this electronic watch can best be explained by referring again to the classical tuning fork. When the long dimensions of the tuning fork is horizontal as shown in Figure 20, the frequency of vibration does not vary whether the tines of the fork are along side of each other or one over the other. This is because gravity has no effect on a horizontal tuning fork. In most models of this watch, the tuning fork is mounted along the 12-6 axis of the movement. The rates in dial-up, dial-down, 3-down and 9-down positions will therefore be precisely the same.



Figures 20, 21, 22. Tuning fork at left (horizontal) has no position error; down position (center) causes five seconds per day increase; and fork in up position at right slows watch five seconds per day.

When the long dimension of the tuning fork is vertical with the tines down (Figure 21), which is the 12-down position in most models of this watch, the effect of gravity causes a slightly higher tuning fork frequency. In this position, the watch's rate is 5 seconds per day faster than when the fork is in the horizontal position.

Conversely, as shown in Figure 22, when the fork is vertical with the tines up (the 6-down position in most models of the Accutron), the frequency of the fork will decrease, causing a rate 5 seconds per day slower than when the fork is in the horizontal position. The 6-down position is rarely experienced when this watch is worn on the outside of the wrist.

This small position error is taken into consideration in the regulation of the watch at the factory. It is regulated for perfect timekeeping when worn on the outer side of the wrist. It is recommended that if the owner prefers to wear this watch on the inner side of his wrist (making the 6-down position occur more frequently) the watch should be regulated 3 seconds per day faster than the original factor adjustment.

Temperature Effects

The effect of various temperatures on the rate of the Accutron is far less than on conventional wrist watches. Accutron is designed for accurate performance under temperature extremes from 20° to 120° F. Outside this range, it may not keep time accurately, but this is of small concern since wrist watches are usually only a few degrees apart from body temperature, even in extreme cold or hot weather.

Power Cell

The power cell used in this electronic watch is a special mercury unit which operates at about 1.3 volts. It is designed to supply power at its rated voltage for at least a year. Although it seems to be the same sort of cell which is used in hearing aids, the necessity of maintaining level output for a long period at an extremely low current drain (less than 1 per cent of that used in a hearing aid) required a special design.

According to information from Bulova, if a hearing-aid battery were used in this watch, it would fail after a few months' operation and serious damage to the movement may result from cell leakage. Only the genuine Bulova Accutron power cell is recommended by them for use in this watch. It is suggested that the customer change the power cell every 12 months, perhaps on his birthday or some other significant anniversary, or on the date he received the watch.

Resistance to Shock

The most delicate parts of most watches are the balance pivots and jewels. Some of these have shock resistant devices. In Bulova's electronic tuning fork watch, shock protection has been provided by the use of a shock *bridge* and *stops* to limit the movement of the tuning fork tines so that they cannot be deformed by severe jolting. A guard surrounding the index and jewel fingers has also been provided.

Anti-Magnetic Properties

The criterion for an "anti-magnetic" watch is as follows: When subjected to a magnetic field with a strength of 60 Gauss and then removed from this influence, the watch shall operate without being affected more than 15 seconds per day. Since it has neither balance wheel nor hairspring, the Accutron avoids much of this fault, changing rate only a few seconds per day.

The watch should not be deliberately exposed to a powerful magnetic field such as a demagnetizer or a strong permanent magnet, since this could demagnetize the permanent magnets on each of the tuning fork tines. However, in normal use, this watch can be considered "anti-magnetic." Should the Accutron be accidentally demagnetized, the tuning fork must be returned to Bulova for re-magnetizing.

Servicing

Figure 23 shows the units of a disassembled Accutron movement. Compared to the mainspring-driven watch, there are relatively few parts. Because of the absence of high torque as in mainspring watches, deterioration of oil and parts will not occur as rapidly. Therefore, Bulova claims that the Accutron does not require frequent periodic cleaning for reasons of preventive maintenance.

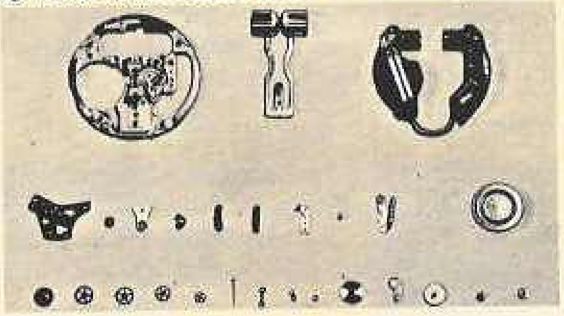


Figure 23. When compared with mainspring-driven watches, "Accutron" movement has relatively few parts.

Replacement of parts is done on the module system such as is employed by the Armed Forces. A module is a unit which can be replaced easily and simply without need for repair or adjustment. The Accutron contains two sub-assemblies or module, which can be removed and replaced as separate units, and which do not lend themselves to "field repair." These are the complete coil assembly, consisting of the entire electronic circuit and all electrical connections; and the complete fork assembly consisting of the tuning fork, magnets and magnetic cups, the index finger and jewel. The other parts of the Accutron will be familiar to all watchmakers.

The amplitude of the tuning fork is not affected by sound waves originating outside the watch.

Shocks do not cause the index and pawl jewels to "overbank" or jump on the side of the wheel. This is because the jewels, which straddle the thin index wheels are rather wide; these jewels also serve as banking guards for the index finger jewel.

WHEN THE ACCUTRON malfunctions, the trouble will probably lie in two main divisions—the indexing mechanism and train of gears, or in the electronic circuit with its electro-magnetic unit and tuning fork.

Since proper diagnosis is so important before the watchmaker begins his work, Bulova recommends the following kit. It consists of a microscope which has proper features for examining the indexing mechanism; a special test set for checking power cell voltage and electronic circuit operation, and to provide a special voltage for checking and adjusting the indexing mechanism; a special holder-jig which gives maximum protection to the movement during servicing and adjustment; an index finger post wrench; and a waterproof case wrench.

Microscope Needed

The most critical test in the diagnosis of Accutron malfunctions is the check on the indexing mechanism, mentioned so often before. The index wheel is not only small (just under 1/10th of an inch), but it contains 300 teeth which are only 1/1000th inch apart. The jewels of the index and pawl fingers are only 7/1000th of an inch square and only 1/500th of an inch thick. These dimensions are too fine to be seen objectively with the naked eye, or even with the most powerful bench loupe. Therefore, it will be necessary to use a microscope to magnify the unit sufficiently to check its function. (After checking the indexing mechanism, the actual adjustment can be made with a loupe if preferred.) Any microscope can be used if it has these qualifications: 20 to 30 diameters magnification, a wide field upright image, and approximately two-inch working distance. Generally, biological and metallurgical microscopes are unsuited for watch repair because they have a small field, short focal length and working distance, and give an inverted image. A recommended type of microscope is shown in Figure 24.

Figure 24

A second piece of equipment needed is shown in Figure 25. It has three important functions. First, it is used as a voltmeter to check power cell voltage. Second, it can be used to check the current that is drawn by the electronic circuit and indicate its operating condition. Third, it is used to supply smaller amounts of power for the adjustment of the indexing mechanism.

Figure 25

Figure 26

Figure 27

A movement holder with special molded surfaces on the bottom and top is an essential specialized piece of equipment for use with the Accutron. For example, it prevents damage to the indexing mechanism and permits removal of the tuning fork and coil circuit assembly. This holder *must* be used in removing the coil and fork to prevent damage to the delicate mechanism. One side of the holder contains a "nest" which receives the coil and fork assembly. The holder has a locating key (Figure 26) so the movement is accurately positioned. This holder is also a "*must*" when checking and adjusting the important indexing mechanism. The notch in the side of the holder is designed to permit the spring clip (Figure 27) of the test set to be attached to the movement.

TROUBLE SHOOTING CHART

PROBLEM	POSSIBLE CAUSES (in order of probability)	DIAGNOSIS PROCEDURE	REMEDIAL ACTION
GAINING OR LOSING A FEW SECONDS A DAY	Abnormal wearing habits or Improper regulation		Regulate
STOPPED (No hum)	1. Exhausted Power Cell	Check Power Cell voltage. If low or no voltage, Power Cell is exhausted.	Replace Power Cell
	2. Faulty electronic circuit	If voltage is normal, check current. If no current, electronic circuit is faulty	Replace complete coil assembly (Part No. 711)
	3. Mechanical blockage of tuning fork	If current is high, check if tuning fork is blocked	Find blockage and remove it
	4. Faulty electronic circuit	If no blockage of tuning fork, electronic circuit is faulty	Replace complete coil assembly (Part No. 711)
STOPPED (Sweep second hand does not turn but fork hums)	1. Exhausted Power Cell	Check Power Cell voltage. If voltage is low, Power Cell is exhausted	Replace Power Cell
	2. Indexing mechanism maladjustment	If voltage normal, open case, remove movement, expose indexing mechanism, and examine under microscope. Check index jewel engagement	Readjust indexing mechanism if necessary
	3. Mechanical blockage of train	If jewels appear normal, check train freedom. Train may be blocked	Find mechanical blockage and remove it
	4. Dirt on index wheel	If train is free, and index jewel engagement is correct, tap movement lightly with pencil to increase fork amplitude, while observing closely with loupe. If index wheel rotates once and then stops again, this is evidence of dirt on index wheel tooth	Clean entire movement in ultrasonic cleaner
	5. Damaged teeth on index wheel	If symptoms persist after cleaning, index wheel has been damaged	Change index wheel
GAINING OR LOSING EXCESSIVELY	1. Tuning fork not free	Open case, remove movement and check current. If current too high, examine for obvious foreign material interfering with free vibrations of tuning fork	If foreign matter is observed, remove same and recheck to see that current is normal
	2. Defective coil	If current too high and no evidence tuning fork is not free, expose indexing mechanism, disengage pawl jewel and check current again. If current remains high, coil assembly is defective	Replace complete coil assembly (Part No. 711)
	3. Mechanical interference in train	If current drops within "OK" range or below in 2, above, cause is excessive train friction	Find interference and remove it
	4. Foreign material clinging to magnetic elements	If current is "OK" in 1, above, and rate is many seconds per day slow, check for loose screw or other matter clinging to a tuning fork magnet	Find foreign matter and remove same
	5. Indexing mechanism maladjustment	If current is "OK" in 1, above, indexing mechanism may be out of adjustment	Check and readjust indexing mechanism as necessary
	6. Dirt in index wheel teeth	If current and indexing mechanism adjustment have been found correct, there may be dirt in index wheel teeth	Clean entire movement

A regular waterproof wrench to fit the case back is also part of the kit. The kit is completed with the addition of a special wrench (shown in Figure 28), an aligning tool. Its tip is hollow and is designed to align the index jewel finger. In use, it is placed over the end of the finger post on the tuning fork tine and gently stressed in the direction which will align the index jewel properly.

Figure 28

Diagnosis

With the exception of a broken crystal or loose hands, the possible causes for complaints on this watch will be:

(1) It loses or gains a few seconds a day;
(2) It gains or loses more than a minute a week;
(3) It has stopped.

Unlike ordinary balance wheel watches than can have large timing errors regulated out, the Accutron has no wearing conditions or environmental effects to affect timing more than a few seconds a day. If the Accutron has stopped, be sure to listen carefully for the characteristic hum. If you can hear it, the fork is vibrating. Perhaps, then, the trouble is in the mechanical system—possibly in the indexing unit or the gear train.

On the other hand, if the watch is silent there may be some malfunction in the power cell, electronic circuit or tuning fork. Like all diagnoses (or in murder mystery stories), the process of finding the "guilty party" is to eliminate suspects and narrow the field down to one "culprit." So it is with this watch. The trouble-shooting chart on the opposite page is submitted here to acquaint the watchmaker with all possible malfunctions.

The post on the tuning fork, its projecting spring-finger and jewel assembly, as well as the spring-finger and pawl jewel, are very delicate. Therefore, when removing the hands, be careful neither to let the train spin forward nor force it backward—this will damage the indexing mechanism. Avoid unnecessary handling, but when it is absolutely necessary to handle them, be cautious. If it is necessary to handle the indexing wheel be especially careful in removing it. To avoid damaging the very fine teeth, never grasp the wheel with tweezers. Instead, handle the wheel by grasping the pinion.

In removing the coil assembly do not scratch or pierce the insulation on the wires or coils.

Do not demagnetize an Accutron or subject it to any high strength magnetic fields. Since this watch is based on electromagnetism, anything affecting the permanent magnets on the tuning fork will also seriously affect the operation of the timepiece.

Keep anything made of steel away from the tines of the tuning fork. The tine magnets are very powerful and will attract themselves to larger steel articles. Even the smallest magnetic particls may damage the fork or affect the timing.

Do not oil the teeth of the index when or the pawl or index jewels.

Do not bend the tines of the tuning fork. It will so seriously affect its timekeeping ability that it will have to be replaced.

Testing

Here's how to test the Accutron:

Before any other work is done, check the Power Cell to make sure that it is functioning properly.

1. Wipe the back of the case to remove any loose material near the Cell cover (to prevent the entrance of dirt when the cover is removed).

2. Unscrew the Cell compartment cover using a U.S. dime.

3. Turn the timepiece over and the Cell will fall out.

4. Place the Power Cell in the nest of the Test Set with the smaller diameter *down*.

5. Turn the rotary switch to "CHECK POWER CELL" position.

6. Read the Power Cell Voltage on the right-hand scale. The voltage reading should be in the "OK" area of the scale (1.25 to 1.45 volts). If it is,the Power Cell is in satisfactory operating condition.

Note: Poor electrical contact between Power Cell and Test Set will cause either a low reading or a wavering indication of cell voltage. It can be readily avoided by making certain that Cell surfaces and contacting points of the Test Set nest and clip are clean. Rubbing or twisting a suspected cell between the contacts while checking voltage is good practice. A wavering reading of voltage is *always* an indication of poor contact, not an indication of a bad cell. Testing should always be done with the authorized ACCUTRON Test Set or with any other equivalent high-resistance voltmeter with not less than 10,000 ohms per volt sensitivity. (A low-resistance voltmeter is not suitable.)

To check the electronic circuit, remove the movement from its case. Place the movement in its movement holder dial side down with the power cell recess adjacent to the notch in the side of the holder. With the power cell still in the test set clip, connect the spring clip at the end of the lead to the movement so the center finger touches the contact in the center of the power cell recess. This connects the power cell to the movement through the meter. The meter will give a reading of current on the left-hand scale.

Sometimes it may be necessary to tap the movement slightly to start the tuning fork vibrating after connecting the clip. The current reading should be in the "O.K." area of the scale (4.5 to 7.0 microamperes). If the movement be warmer than average room temperature (from nearness to a lamp bulb or being held in the hand) it may cause a reading higher than the "O.K." area. Let the movement cool to room temperature for a half hour and recheck it.

Figure 29

The purpose of checking and adjusting the indexing mechanism is to control the alignment, depth of engagement, and distance between the index and pawl jewels. Figure 29 shows how to expose the index mechanism. First, remove the safety bridge screw. Loosen the index guard screw as shown in Figure 30 and turn the index guard away from the wheel (guard should only be turned out of the way—not removed). Be careful not to hurt the index or pawl fingers which run through the guard (see Figure 35). Loosen the pawl bridge locking screw slightly, but leave the pawl adjusting bridge screw tight as shown in Figure 30. Observe the movement under the microscope to make certain that the pawl is engaged with the index wheel. The pawl must be engaged with the index wheel so the latter will remain stationary during the check for engagement. If it is engaged, rotate the pawl bridge cam until the pawl is brought into contact with the wheel.

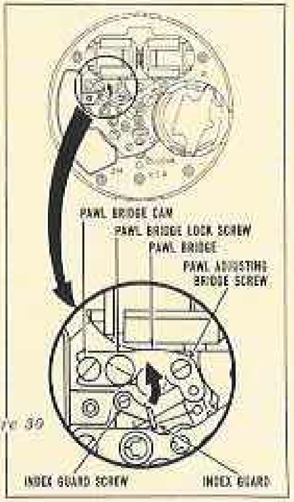


Figure 30

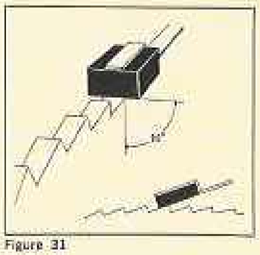


Figure 31

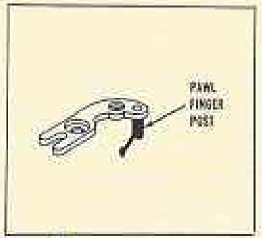


Figure 32

Under the microscope, check both jewels to be sure the fingers are straight. Also ascertain that the jewels are centered on the wheel and perpendicular to the wheel as shown in Figure 31. If they are off-center, straighten them with the index finger post wrench. Place the wrench over the post on the tuning fork tine. Stress it gently to center the jewel on the wheel. The pawl jewel can be centered by bending its finger post (see Figure 32) with tweezers. If either jewel is not perpendicular to the plane of the wheel, correct it by lightly twisting the jewel finger close to the point when it is pinned (don't touch the jewel itself).

Here's how to check the engagement of the index jewel: Grasp the tine at the cup, preferably with tweezers made of non-magnetic alloy. Count the number of teeth before the index jewel pulls away from the wheel. The jewel should remain engaged with the wheel for five to seven teeth. If the number is less than five or greater than seven, modify it near the end where it is pinned by *gently* pressing the index finger toward or away from the wheel. Use the end of the tweezers or a needle as you would bend a hairspring near its stud. Check the engagement after each adjustment for the proper engagement. (See Figure 33).

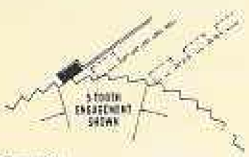


Figure 33

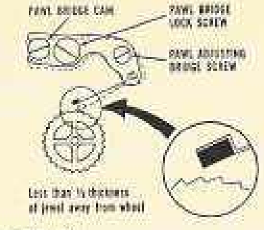


Figure 34

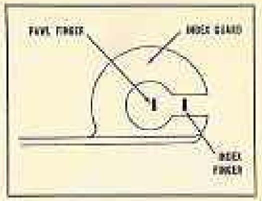


Figure 35

Next, using a loupe, completely disengage the pawl jewel by rotating the pawl bridge adjusting cam until the bridge is at its maximum distance from the index wheel (Figure 34). Then examine the pawl jewel under the microscope. It should not touch the index wheel; it should be separated from the latter by a distance less than half the thickness of the jewel. You can adjust this distance by pressing gently in or out on the pawl finger, as described earlier.

With the power cell still in the test set clip, turn the right hand switch to the "Low Amplitude" position and turn the meter control switch to "Read Microamperes." Using the spring clip, attach the test set to the movement. The notch provided in the movement holder will cause contact between the spring clip, power cell and movement. The tuning fork should then begin to vibrate; but if it doesn't, an excess current reading will show on the meter. Tap the movement lightly and the tuning fork will begin to vibrate, decreasing the current reading to the lower end of the "O.K." area or slightly below it.

To bring the pawl toward the wheel, rotate the cam slowly in either direction until the watch begins to run. You can observe this without the microscope by watching the visible wheels. Next, turn the cam further in the same direction until the watch stops; then continue still further until the watch starts again and continues to run. At this point the adjustment is complete.

Tighten the pawl bridge lock screw and pawl adjusting bridge screw to prevent the bridge from moving out of its position. The watch should continue to run. If it doesn't the adjustment just explained must be repeated. Then disconnect the test set spring clip from the movement. Loosen the index guard screw and turn the index guard back into position, the index finger should pass through a point slightly inside the center of the slot in the guard (Figure 35). The index finger should not touch either side of the slot. If it does, lightly bend the guard to center the index finger, making certain that the pawl finger does not touch the guard. Finally, replace the safety bridge and safety bridge screw.

As a last check on the adjustment, time the watch accurately for at least an hour. If it is off more than a second, the trouble may be dirt on the index wheel or an incorrect adjustment of the indexing procedure. Check the index wheel under the microscope for dirt or damage.

If the trouble-shooting chart indicates some fault in the gear train, check the train's freedom by moving one of the wheels with tweezers. (This is not altogether recommended because it might damage the index and pawl fingers and jewels unless the wheels are rotated in the correct direction.) The simplest, safest and most convenient method to test the freedom of the train is to pluck the tuning fork tine to which the index finger is attached. The tine will vibrate a few seconds and the motion should cause the index wheel and the rest of the gear train to move. Even if the tine vibrated for only a second, it would be long enough to watch the index wheel make more than a full revolution. You can watch the process either with a loupe or the microscope. If you have checked the indexing mechanism and now pluck the tuning fork without producing motion in the train, you may conclude that the train is blocked.

METHODS OF ASSEMBLY AND DISASSEMBLY

Removing Hand, Dial and Dial Train

Disassembly

1. Remove the ground strap so movement can be placed in holder.
2. Remove the two dial holding nuts. Exact location is shown in Figure 36.
3. Use hand remover to remove hands.
4. Remove the dial. (Figure 37)
5. Remove the hour wheel.
6. Remove the cannon pinion.
7. Remove the setting wheel spring and minute wheel spring which are held by one setting wheel spring screw.
8. Remove the minute wheel.

Figure 36

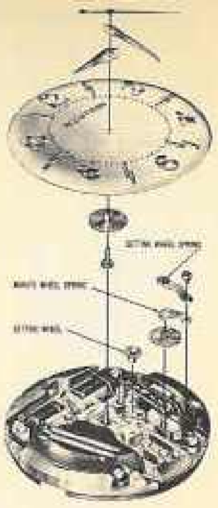


Figure 37

Figure 38

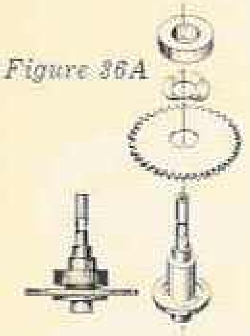


Figure 36A

9. Remove the setting wheel.

CAUTION: If train is spinned forward or forced backwards in removing or replacing the hands, the indexing mechanism will be damaged.

Assembly

1. Moisten center pinion staff with oil and replace cannot pinion. Cannon pinion should be rather tight on the center post; hand clutch traction is taken up by a spring washer on the center post between a friction bushing and the otherwise loose-riding center wheel. (Figure 36a.)
2. Replace the setting wheel.
3. Replace the minute wheel.
4. Replace the setting wheel spring, minute wheel spring and setting wheel screw.
5. Replace the hour wheel.
6. Replace the dial.
7. Replace the hands.
8. Replace the two dial holding screws.
9. Replace the ground strap.

1. Place movement in dial up position on holder.
2. Remove shock bridge, which is held by one shock bridge

screw (Figure 38).

3. Remove the two tuning fork screws.

Figure 39

Figure 40

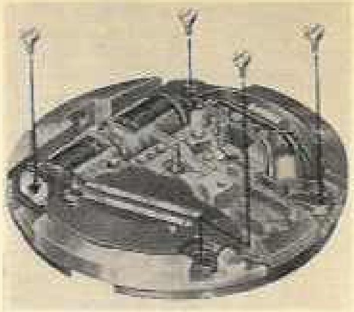


Figure 41

Removing and Reparing Coil and Fork Assembly

Removing

1. Place movement in dial up position on holder.

2. Remove shock bridge, which is held by one shock bridge screw (Figure 38).

3. Remove the two tuning fork screws.

4. Place movement in dial down position on movement holder (Figure 39).

4a. Remove safety bridge (see Figure 29).

5. Loosen index guard screw and turn index guard away from index wheel. Do not remove guard when turning it out, and be careful not to damage index and pawl fingers. Now tighten the screw.

6. Using a metal punch, disengage tuning fork by tapping on its base through hole provided in pillar plate.

7. Pick up movement and holder; invert them so movement is on bottom; remove holder and place it under movement.

8. Lift fork at base and carefully rotate it upwards until it is self-supporting in a vertical position (Figure 40).

9. Remove coil lead retainer plate, which is held by two screws.

10. As shown in Figure 41, lower the fork carefully, but do not force it down.

11. Remove the four coil form screws.

12. Without turning over movement, remove holder from bottom. Nested side of holder (Figure 27) is placed over movement and rotated until locating key of movement holder engages notch at edge of pillar plate. Invert complete assembly. Pillar plate must be firmly seated in movement holder.

13. Use pegwood stick to push down on coil assembly at various points to disengage coil and fork assembly from pillar plate (Figure 42). Nested holder is designed to receive tuning fork and coil assembly without permitting index finger to touch opening in pillar plate during removal.

14. Movement can then be removed from movement holder. Coil and fork assembly should be left in place in movement holder. If it is necessary to remove them for cleaning or replacement, the coils can be disassembled from the fork by gently spreading the coils.

Figure 42

Figure 43

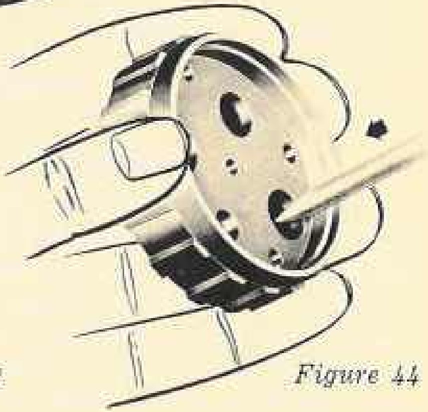


Figure 44

(Some models of Accutron do not have a coil lead retainer plate. Disassembly is easier, and only three steps must be followed: 1, 2, 11, 3, 4, 5, 6, 13 and 14.)

Replacing

1. Place coil and fork assembly into prepared slots in movement holder (Figure 43).

2. Position pillar plate over assembly. Be sure that notch in pillar plate engages key in movement holder.

3. Hold movement holder as shown in Figure 44, so pillar plate will not drop out; turn over and press through holes in back partially to seat assembly in pillar plate.

4. Transfer pillar plate and coil and fork assembly from one side of movement holder to the other, placing it in dial-up posi-

tion.

5. Press down firmly on coil form only, to make sure it is completely and evenly seated in pillar plate (Figure 41).

6. Replace the four coil form screws.

7. Lift base of fork to vertical position and replace coil lead retainer plate and screws (Figure 40).

8. Lower fork carefully and press firmly into place. Apply pressure only at tongue of fork—avoid conflict with tines.

9. Replace the two tuning fork screws as shown in Figure 38.

10. Replace shock bridge screws. Check to see that fork is free to vibrate and coils fit into cups on the end of tuning fork tines without touching them. Nothing should be in contact with the tine at any point.

11. Replace dial and hands, replace ground strap and screw.

(For models of Accutron with no coil lead retainer plate, follow these steps in assembling; 1, 2, 3, 4, 5, 6, 9, and 10.)

Cleaning the Accutron

(The following additional disassembly and assembly steps should be taken only when cleaning is necessary.)

Disassembly for Cleaning

1. Remove pawl adjusting bridge and finger assembly by removing two screws shown in Figure 45. Pawl bridge cam is not threaded and will come out with the bridge. Care should be taken not to bend the pawl finger.

2. Remove the two Duofix cap jewels by applying horizontal pressure to the closed side of the U-shaped spring, allowing lip of spring to emerge from under bezel. Spring can then be tipped up, and jewels removed.

3. Remove center second chaton which is held by two chaton screws.

4. Remove center second pinion and washer by grasping with tweezers and lifting out through hold in train bridge.

5. Remove lower jewel plate, which is held by one screw as shown in Figure 46.

Cleaning

Ultrasonic equipment is preferred in cleaning the Accutron. Treat it as you would any very fine watch. However, the electronic circuit, tuning fork and pawl-adjusting bridge should not be cleaned in a machine because of the possible danger to such delicate parts. The fork, coil and bridge may be satisfactorily cleaned by dipping them in a "benzine cup" and then drying with clean tissue paper. Do not allow metal chips or filings which may be in the cleaning basket or cup to become attached

magnetically to the magnets on the tuning fork. Inspect the watch for such chips carefully; and if they are present, remove them by dabbing the magnets with masking tape.

Assembly after Cleaning

1. Oil all train wheel pivots and cap jewels. *Caution*: Do not oil the index wheel teeth or index or pawl jewels.

2. Replace lower jewel plate as shown in Figure 46.

3. Replace center second pinion and washer.

4. Replace center second chaton and its two screws.

5. Replace the two Duofix cap jewels.

6. Replace pawl bridge cam. Do not push it all the way in.

7. Slide forked end of the pawl adjusting bridge under the head of the bridge, being careful not to damage the cam and position the pawl adjusting pawl finger. Replace the two screws.

8. Turn index guard back into position. Do not move it so far that it bends or touches the pawl finger. When it is positioned (Figure 35) secure index guard screw.

9. Replace safety bridge and screw.

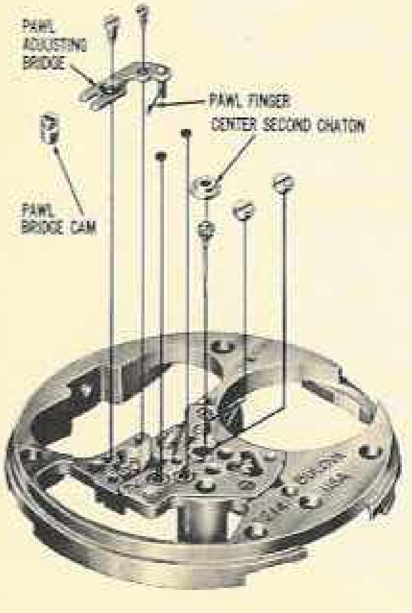


Figure 45

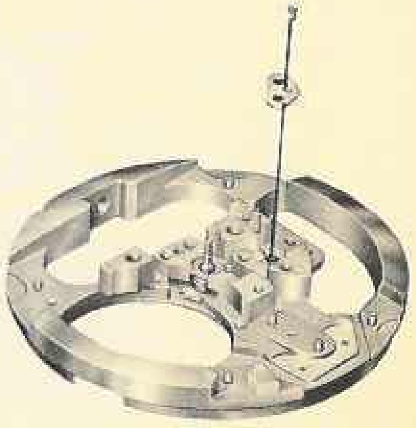


Figure 46

THE BENRUS ELECTRIC WATCH

(Models FU 3 and FU 13)

This model is made by Lip of France. Its basic principles are similar to the older, bulkier Lip R 27 which uses two batteries as compared to the Benrus version which employs but one energy cell.

Like some other electric watches, its balance is a form of controlled electric motor adjusted to run at precise speeds.

The balance beats 18,000 times an hour but makes only 9,000 electrical contacts during this period. Therefore, the balance receives an electromagnetic impulse every other beat, while traveling in only one direction.

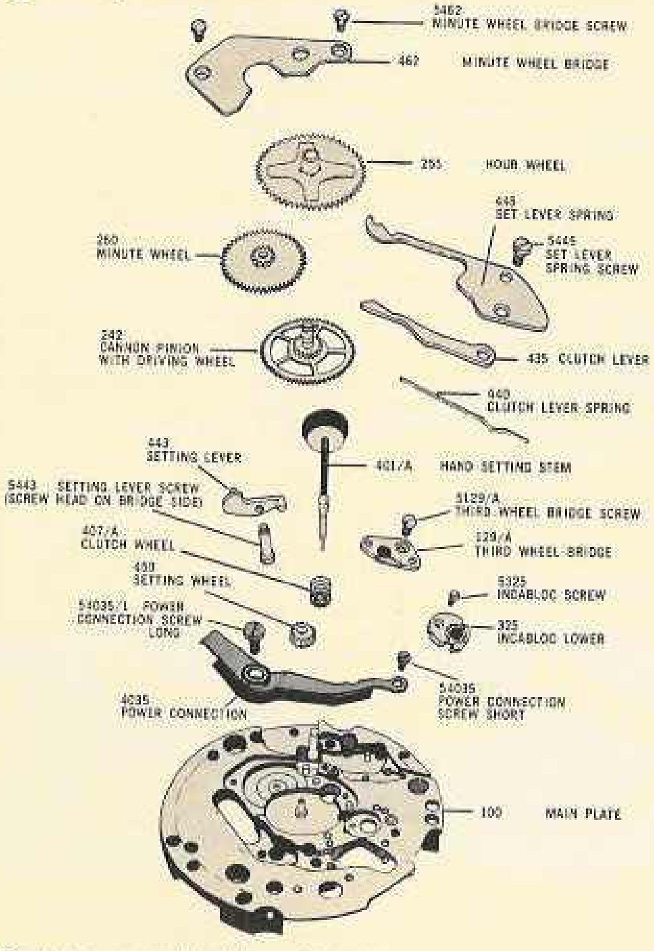
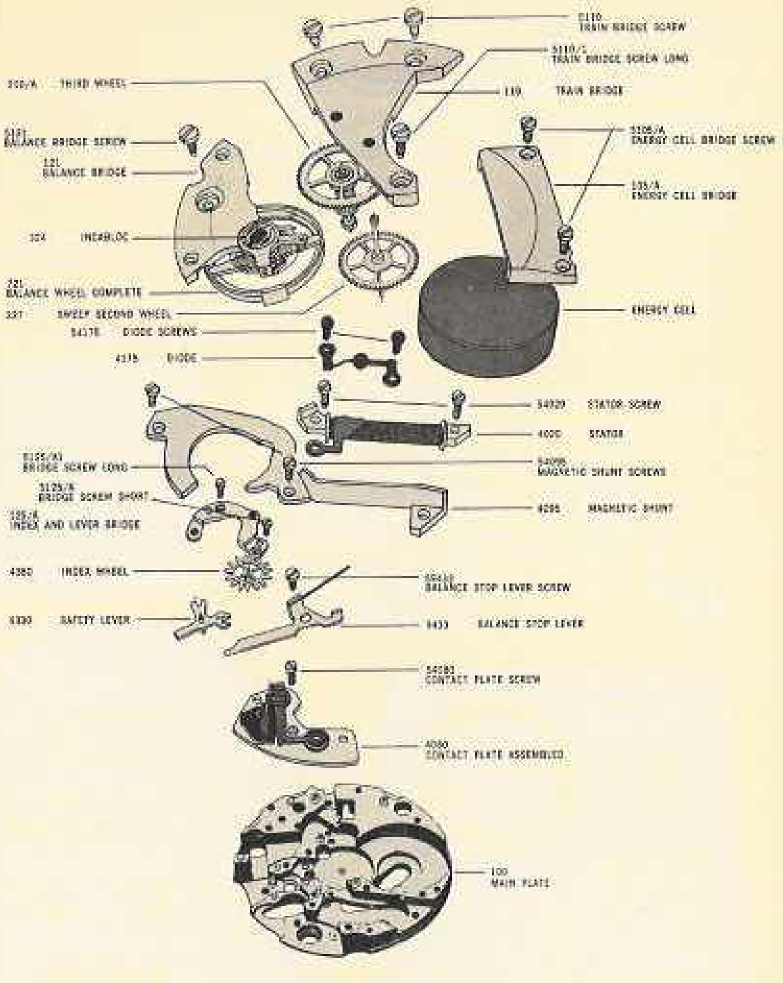


FIGURE 1: Above, an exploded view of individual parts on the DIAL SIDE of the movement provides a diagram for the watchmaker. When the hand setting stem is pulled out, the watch stops and the time can be adjusted. Pushing the stem in again starts the watch.



BRIDGE SIDE

FIGURE 2: All the electrical parts of the circuit are fitted to the BRIDGE SIDE of the movement at right. The energy cell fits into the main plate, secured by the energy cell bridge.

Benrus designates this model by numbers FU 3 and FU 13. It contains 14 jewels as well as shock absorbent jewel settings for its motor-balance. The size of the movement is 11½ lignes (25.92 mm.; 1.02 in.).

Exploded views of the movement can be seen in *Figures 1* and *2*. All the electrical parts and the electronic spark suppressor (diode) are fitted to this movement like other mechanical parts. Since they are factory adjusted, we need not concern ourselves with attempting to re-align their electrical values.

Starting the Watch

To set the regular hands as well as the seconds hand, pull out the crown when the seconds hand is directly over the 60 mark. This stops the watch in a non-contact position. To start the watch again, push in the crown. It might be necessary to twist the timepiece slightly.

To replace the energy cell, follow *Figure 3*. Remove the energy cell bridge No. 105/A. Turn the movement upside down and the cell will fall out. Replacement cells must match the movement identification such as FU 3 or FU 13—never attempt to substitute any other than the specified cell for this movement.

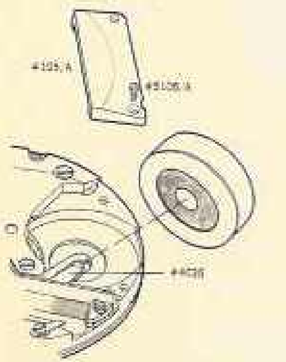


FIGURE 3: When replacing the energy cell, insert it in the main plate with its flat side facing the bridge 105/A. The negative pole contacts the power connection No. 4035.

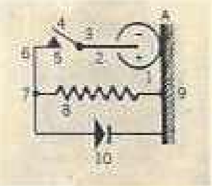


FIGURE 4: A diagram of the circuit traces power connections from the cell (1), to the contact springs (4), to the contact regulator (5), through both a coil (8) and a diode (10), to the framework (9), back to the cell.

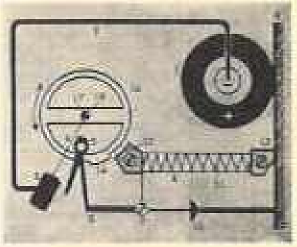


FIGURE 5: Compare this layout of the circuit parts to the diagram of the circuit in Figure 4. The diode is connected in parallel to the coil to suppress sparking during contact.

If you will handle the cell with tweezers, be especially careful to grasp this piece at its round sides rather than on the flat surfaces. This way you will not short the battery and drain its energy.

Now, position the cell with its smooth flat surface facing the bridge 105/A. This causes the negative pole on the opposite side of the cell to contact the power connection. No. 4035. Finally, press down on bridge 105/A against the spring action of the power connection 4035. Align the screw holes and secure.

Examine the Circuit

A diagram of the circuit appears in *Figure 4*, with the layout of the circuit parts in *Figure 5*. The energy (1) contacts the framework of the movement (A) with its positive terminal. Its negative terminal is connected through a wire (2) to the contact springs (4). An impulse occurs when the contact spring touches the beak of the contact regulator (5), which connects to the input end of the circuit (12) and coil (8). The layout end of the coil (13) is connected and grounded to the frame at (9).

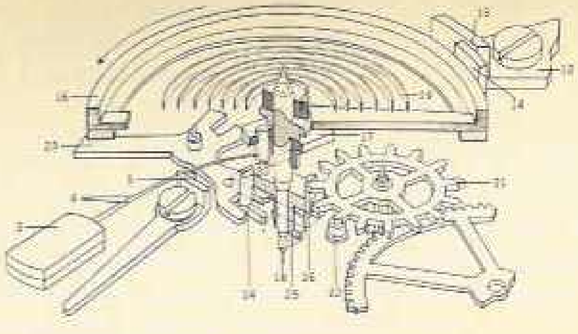
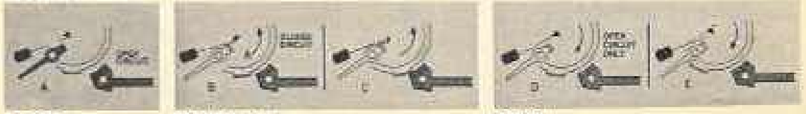


FIGURE 6: A greatly enlarged view shows the circuit closed. As the impulse is relayed, the drive jewel (26) advances the index wheel (21) one tooth further.

A diode (10) is connected in parallel with the coil. This suppresses sparking, which would otherwise erode the contact points.

An enlarged view of the heart of the watch appears in *Figure 6*. The balance (16) is shown at the end of its contact phase. The balance horn (14) is a magnetically permeable tab on the edge of the balance. It is influenced by the magnetic surges of the electrical coil. In this view, the contact jewel (20) is pushing the flexible contact springs (4) against the contact regulator (5), closing the circuit. The horn has received an impulse from the stator horn (12). In the next instant, the drive jewel (26) will advance the index wheel (21) one tooth further.

FIGURE 7



AT REST FORWARD DRIVE RETURN

Impulsing Sequence

When the watch is at rest without an energy cell, the circuit is open, and the two contact springs lie, one directly over the other, along the line of centers to the balance wheel. They do not touch the beak of the contact regulating lever.

Now compare the views in *Figure 7* with the diagrams already shown. The driving action of the movement starts forward.

When the balance wheel turns in the direction of the arrow (A), the contact jewel on the balance nudges the contact springs against the beak of the contact regulating lever. This closes the circuit. The current then flows through the coil, causing the stator to become an electromagnet. The stator horn in turn attracts the horn on the balance rim and gives it an impulse. Contact is made when the balance horn has almost reached the stator horn.

In *Figure 7E* as long as the circuit is closed, the magnetically created impulse continues to attract the balance. In *Figure 7C*, however, as the balance continues on its way, the contact jewel falls off the contact springs. These springs then tense away from the beak of the contact regulating lever. This action opens the circuit and the electromagnetic attraction ceases.

To see the details of the return balance swing, examine *Figure 7D*. When the balance wheel swings back in the opposite direction, the contact jewel will again strike the contact springs. But since the wheel is going in the opposite direction this time, the contact jewel will push these springs away from making contact with the beak of the contact regulating lever.

Thus the circuit remains open when the balance swings in the clockwise direction. As the jewel moves past the contact springs, the springs return to their original position of rest without touching the contact regulating lever, as in *Figure 7E*.

When the balance swings counterclockwise again, its jewel pin meets the contact springs once more, pressing them against the contact regulating lever, and closing the circuit. This action, like that of a mechanical electric switch, is seen in *Figure 7*, views A and B.

We see that there is only one impulse for each complete oscillation—a round trip of the balance.

The illustrations in *Figure 7* show that the contact regulating lever is just what its name implies. By moving the tail of this lever, its beak is moved nearer or farther away from the contact springs. In this way, the period of contact can be lengthened or shortened to timekeeping precision. This arrangement also enables the watchmaker to efficiently adjust the balance wheel amplitude without disturbing the shape or position of the delicate springs.

LIKE ALL ELECTRIC TIMEPIECES, the oscillating unit drives the train of gears which move the hands. In the Benrus electric watch this unit is the balance. The balance wheel's jewel pin, also called the drive jewel, pushes the teeth of the index wheel. Both the drive jewel and the index wheel teeth are shaped so that only one tooth is advanced during each complete oscillation, or to-and-fro swing, of the balance.

The index wheel pinion meshes with the train of gears which lead to the cannon pinion and finally to the dial train.

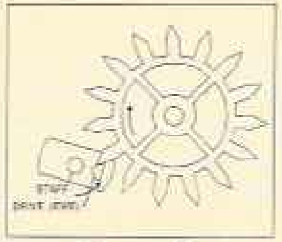
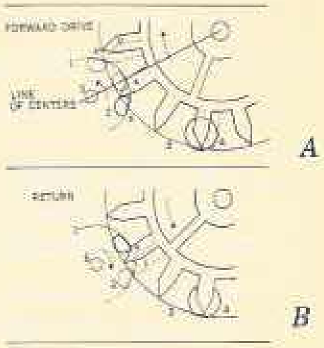


Figure 8

Figure 9



The Indexing Mechanism

In *Figure 8* we can see how the drive jewel is positioned to push the index wheel in a clockwise direction. Study *Figure 9A* closely to see how this forward drive action works.

The overlapping paths of the wheel and the jewel intersect at *X-X'*. A small permanent magnet (4) is attached to the lower plate directly below the index wheel. The magnet pulls a tooth of the index wheel into position directly above itself. This puts tooth *A* in the path of the drive jewel at *X*, before the line centers. The next tooth, *D*, lies beyond the path of the drive jewel.

When the balance turns in the direction of the arrow, the drive jewel (2) meets tooth *A* and pushes it to position *X'*. At this point, the tooth moving toward the magnet (4) has reached the position indicated by the dotted line. The magnet then pulls the tooth into rest position directly overhead, bringing tooth *A* to replace *D*.

The wheel advances one tooth at a time with each oscillation and positive contact by the drive jewel. The gear train and hands are advanced two-fifths of a second with each indexing action.

Now examine Figure *9B* to see how the drive jewel returns to the drive position. The balance turns in the opposite direction. As the jewel swings around it meets the rear, slanted face of the index tooth *A* and drives it as far as *E*. The jewel then parts contact with this tooth, as its slanted face slides away, and continues on its way by momentum.

The index wheel has lapsed backward slightly but not enough to be indexed. Thus, the same tooth is still under the influence of the magnet and is drawn back to its original position of rest. The wheel is indexed only when the balance turns in the counterclockwise direction shown in *Figure 8*.

The Gear Train to the Hands

Begin with the index wheel to trace the transmission of power through the gear train to the hands. The sequence passes from the index wheel (4360) to the fourth wheel (227), the third wheel (210/A), to the drive wheel of the cannon pinion (242). This last wheel is actually the center wheel.

It is important to note that there is no slippage between the drive wheel and the cannon pinion. They are riveted together; no attempt should be made to separate them.

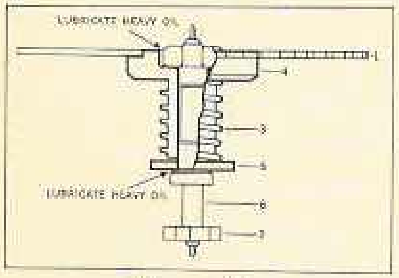


Figure 10

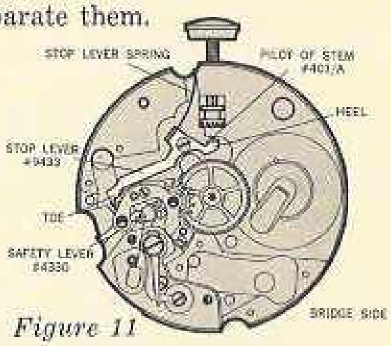


Figure 11

Instead, the third wheel provides the clutch, or slippage action. *Figure 10* shows the construction of this wheel in detail. The arbor (6), bearing the pinion (2), is free to turn independently of the wheel (1). The wheel is riveted to the wide head of a long tube (4) which fits loosely over the arbor. A spring (3), held in place by a washer (5), provides tension. This spring is calibrated, factory adjusted, and lubricated to supply the exact amount of clutch action for manual turning of the hands. Yet the spring provides enough traction to allow the train to advance the hands during normal running of the watch.

Limiting Balance Wheel Amplitude

The construction of the safety lever (4330) is similar to that of the traditional pallet in mainspring watches. It also provides the same safety action as the pallet.

Since there is no "draw" action of an escape wheel against pallet jewels, the lever is made to be drawn to its banking stop and to be held there by the permanent magnetism in the banking pin. However, unlike a pallet when the roller jewel pushes it from side to side, the lever is merely idling. Its action is significant only if the balance wheel amplitude becomes excessive. The roller jewel then strikes the back of the fork and harmlessly rebounds.

This blocking action of the fork eliminates any possibility of a secondary contact and a secondary index wheel drive due to excess balance amplitude. The notch on this lever functions also in the hack or stop position.

In Stop Position

The purpose of the hack mechanism is to enable the wearer to mechanically stop the watch when it is being set. The watch can be coordinated with the time standard to the second.

The mechanism can also be used to prevent drainage on the battery when the watch is not in use. Electrical contacts are disengaged in the hack position.

In *Figure 11*, the stem is pulled to the "out" position. The heel of the stop lever (9433) rests close to the pilot pin of the stem. The toe of this lever is under tension from its spring and is pressing against the notch of the safety lever (4330). This locks the roller jewel of the balance, stopping the balance in its out-of-contact position.

When the crown is pushed in, the pilot pin of the stem depresses the heel of the stop lever. As this lever swivels around the screw, its toe swings out of the notch of the safety lever (4330) and frees the balance wheel.

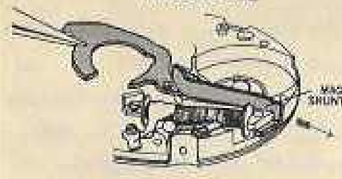
Overhauling and Service Hints

Third wheel 210/A should be cleaned in solutions only when absolutely necessary because a special life-time lubricant has been applied at the factory. Therefore, when possible, merely brush and check for smoothness of slippage between the arbor and the wheel. If the wheel is cleaned in a solution, lubricate this afterwards as indicated in *Figure 10*.

If the watch doesn't require cleaning, do not remove the stator 4020. Removal of this part may change the air-gap distance between stator horn and balance wheel tab-horn. This would then require a readjustment. Methods of adjusting the air-gap distance are explained in the section, "Assembly, Balance wheel No. 721-Air Gap".

However, to gain access to many parts, it may be necessary to remove the magnetic shunt 4095. This can be accomplished without removing the stator 4020 in the following manner: Remove three screws; both magnetic shunt screws 54095 and the stator screw 54020 located near the edge of the plate. Then lift the magnetic shunt 4095 clear of the horn of the stator 4020 and the pivot of the sweep second wheel 227 as shown in *Figure 12*. Then slide it out in the direction of the arrow.

FIGURE 12



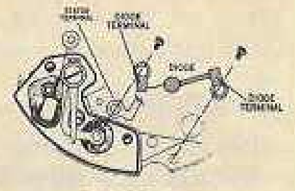


FIGURE 13

WHEN THE DIODE SCREWS ARE TIGHTENED OR LOOSENED THE DIODE TERMINALS SHOULD BE HELD IN POSITION TO PREVENT THEM FROM TURNING WITH THE SCREW AND BREAKING OFF.

Note: The shunt 4095 is made of soft metal. Do not distort its shape.

Disassembly

Bridge Side . . . Remove in this sequence.

1. Energy cell bridge 105/A and the energy cell.
2. Balance wheel bridge 121/A and balance wheel 721
3. Diode 4175

Note: To avoid breaking off the attached diode wire and lead, support the terminals. See *Figure 13*.

4. Stator 4020
5. Contact plate, assembly 4080
6. The contact plate is now held by two screws; the small head power connection screw 54035/1 on the dial side and the contact plate screw 54080 on the bridge side.

Do not disturb the wires and contacts

6. Train bridge 110 and third wheel 210/A
7. Magnetic shunt 4095
8. Balance stop lever 9433

9. Index wheel and lever bridge 125/A and the wheel 4360 and lever 4330 which is beneath it.

Do not use tweezers on coil of stator 4020. Damage to its protective coating will cause the wires to touch and produce a short-circuit.

Remove the energy cell when working on the movement. Replace this cell only for final checking and finishing procedures. This avoids accidental short circuiting which would otherwise reduce the life of the energy cell.

Never demagnetize the main plate No. 100. This would destroy the permanent magnets which attract the index wheel teeth 4360 and the safety lever 4330. All other parts may be demagnetized in the usual manner.

10. Sweep second wheel 227.

DIAL SIDE

11. Power connection 4035
12. Continue as in an conventional watch.

Cleaning

Caution: *Do not immerse the following parts in solutions:*

Energy cell
Diode 4175
Stator 4020

Clean in Pure Isopropylic Alcohol Only The Following Parts:

Power connection 4035

Contact plate, assembly 4080

(Do not disturb contact wires, dry in warm, dust free air).

Clean All Other Parts in The Usual Manner

To avoid scratching the soft metal on the poles of the stator 4020 and the horn-tab of the balance 721, remove dirt, dust or metal burrs with sensitized paper or soft peg-wood.

Assembly and Checking

To assemble proceed in the reverse order of disassembling and check for endshakes, side shakes and clearances in the usual manner. After positioning the part listed below, make these additional checks:

Index Wheel and Lever Bridge 125/A

Check both permanent magnets in the plate. One of these is the index wheel magnet. This is located on a raised step in the main plate No. 100 directly under bridge 125/A. The magnet should be able to attract the tooth of the index wheel 4360 above it. The other magnet is:

Lever Magnet

Under the opposite end of the bridge 125/A also located in the main plate 100 and situated between the fork and notch of lever 4330 is a single banking pin. This banking pin confines the swing of the lever 4330. It is magnetized to provide the equivalent of "draw". Push the lever 4330 from side to side to test this attracting action of the magnet.

Balance Stop Lever 9433

Check the freedom of this lever and its spring action.

Contact Plate 4080

Check the two contact springs. One should be directly over the other. Also, they should be aligned with the center of the hole jewel of the balance as shown in *Figure 13*. The contact plate should be clean. There should be no dust or burrs on the springs nor on the beak of the contact regulating lever.

Stator 4020

The tolerance of the screw holes permits the stator to be shifted so that the air-gap between stator horn and the balance horn-tab can be adjusted. Check that the stator horn doesn't block the balance horn-tab. Instructions on adjusting the air-gap appears in the section following Balance Wheel No. 721—Air Gap.

Diode 4175

Refer to *Figure 13*. Note the correct position of the diode terminals before reassembling.

Balance Wheel No. 721 and Balance Wheel Bridge 121/A

To facilitate repositioning the balance wheel, put stop lever 9433 in the lock position. The roller jewel should enter the fork of the safety lever 4330. Release stop-lever 9433 to check balance for freedom. If insufficient end-shake is experienced, use a balance bridge wedge. Check for freedom between the balance horn-tab and the stator horn and then check the air-gap.

Air-Gap

Check the air-gap by bringing the balance wheel horn opposite the stator horn. They should be parallel with an .03 to .06 mm space between them. If the gap requires adjustment, the stator 4020 can be shifted. Slightly loosen one or both screws as required. Hold this in the desired position with the tweezers pressed against the flat side of the stator horn near the screw and tighten one or both screws. To facilitate this operation, consider the screw at the opposite end of the stator a pivotal point around which the stator can be shifted.

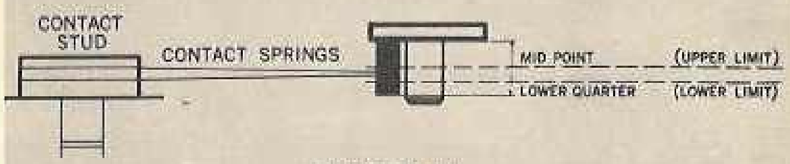


FIGURE 14

Recheck the Contact Springs

Now recheck the contact springs. Their correct height in relation to the contact jewel is shown in *Figure 14*. Note that they meet the jewel in the section between th jewel's midpoint and its lower quarter. This is an important checking point. For example, if the springs were raised, they could contact the drive jewel table and cause a short-circuit.

Energy Cell

Refer to steps 4-5 and 6 in section "Replacement of Energy Cell".

Finishing Checking Points.

Balance Amplitude

The amplitude of the balance wheel in the horizontal position should be 270° in one direction. If necessary, correct this with the contact regulating lever.

Timing and Regulation

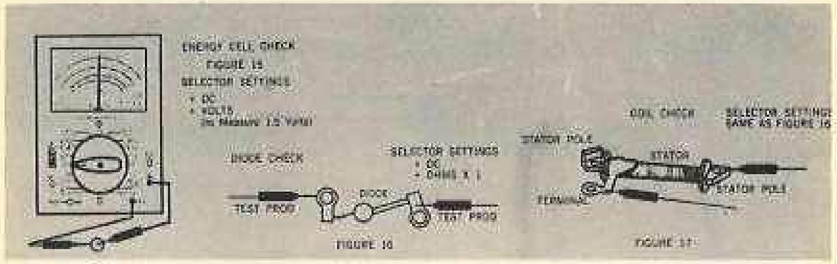
The balance makes 18,000 oscillations per hour and can be timed on any timing machine. Regulate as any conventional watch by moving the (hairspring) regulator 307/1. Excessive variations in rate indicate mechanical or electrical misadjustment.

Electrical Checking Points

Electrical Instruments Needed

A volt-ohmmeter milliameter is needed for checking the energy cell, coil and diode resistances as well as for current consumption.

This instrument should have a 20,000 ohms per volt resistance for DC voltage measurement and a 50 microampere current range. There are some instruments marketed by jeweler's suppliers that meet these to those required for most of the electric watches on the market.



Checking the Individual Parts Before Assembly of Movement. Energy Cell, Figure 15.

1. Set the selector switch of the multimeter to measure 1.5 volts D. C.

2. Place the (—) minus test rod on the negative terminal at the center of the cell and the (+) plus test rod against the wall of the cell or the positive terminal.

A new cell supplies 1.5 volts. If the reading is less than 1.3 volts, the cell should be replaced.

Note: To avoid unnecessary drainage of the cell during this check, stop the test as soon as the correct voltage reading is determined.

Diode: Figure 16.

1. Set the selector switch to measure ohms, using the A1 resistance scale. For details, see your meter manual for the correct settings.

2. Zero the meter according to the instructions in the meter manual.

3. Place one test prod on one terminal of the diode and the other test prod on the other terminal of the diode. Take a reading.

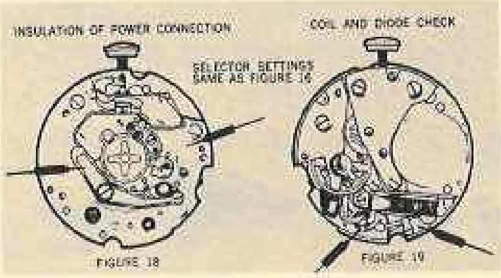
4. Reverse the positions of the prods in relation to the diode terminals. Take a second reading. In one direction, the diode's resistance should range from 10,000 ohms to infinity. In the other direction, its resistance should range from 30 to zero ohms.

Coil: Figure 17.

1. Follow the same procedure as above for proper meter settings, steps 1 and 8.

2. Place one test prod on the stator terminal and the other test prod on the stator pole. The coil resistance should be approximately 900 ohms.

Check after Assembly without Energy Cell or Stem in "Out" Position



Insulation of Power Connection : Figure 18.

1. Use the same meter settings as for diode etc.

2. Place one test prod on the power connection and the other test prod on the main plate. The resistance should be infinite.

3—Coil and Diode Assembly: Figure 19.

1. Use same meter settings as above.

2. Place one test prod on the terminal of the diode which is attached to the contact plate and the other test prod on the main plate. Observe the reading of the meter scale.

3. Reverse the position of the test prods. Compare the reading in this position with the previous reading. In one direction, the resistance should be approximately 900 ohms. In the opposite direction the resistance ranges from 30 to zero ohms.

IMPORTANT: The terminals of the diode must be correctly positioned (See *Fig. 13*).

Current Consumption Test

The method indicated below utilizes a current consumption test block which can be purchased from the Benrus Watch Co.

1. Place the movement without the energy call into the test block in accordance with the directions provided with the block.

2. Set the selection switch or switches to the 50 microampere

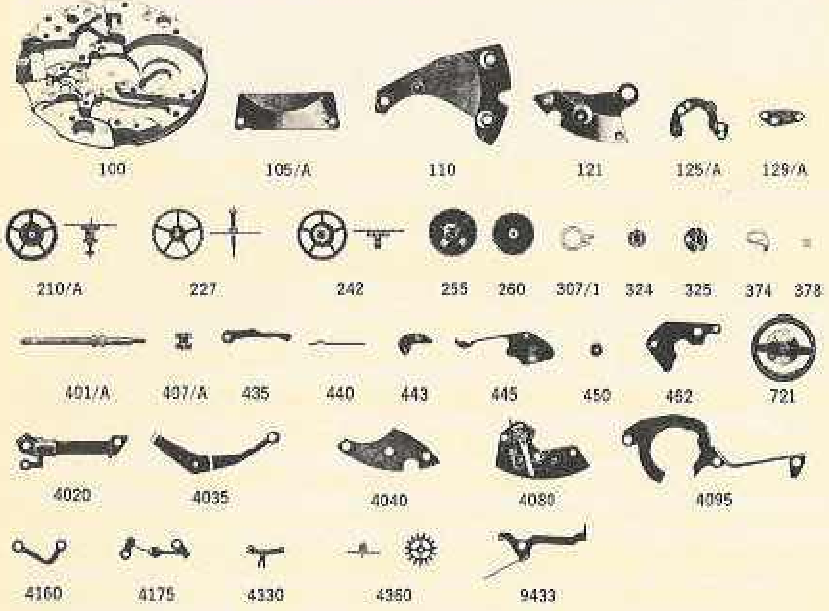
current range D. C.

3. Insert the positive and negative meter leads into the corresponding terminals in the test block.

4. Depress the crown and start the balance wheel.

5. When the motion of the balance wheel is stabilized, take a reading on the meter.

Current consumption should be no more than 7 microamperes. Higher current consumption indicates a mechanical or circuit fault. The most common causes are excessive air-gap between balance horn-tab and stator horn, lack of train or hand freedom, or improper contact adjustments.



PART NUMBER	PART NAME
100	Main Plate
105/A	Energy Cell Bridge
110	Train Bridge
121	Balance Bridge
125/A	Index Wheel and Lever Bridge
129/A	Third Wheel Bridge
210/A	Third Wheel and Pinion with Tension Spring
227	Sweep Second Wheel
242	Cannon Pinion with Driving Wheel
255	Hour Wheel for Sweep Second
260	Minute Wheel and Pinion
307/1	Regulator for Adjustable Holder
324	Incabloc Complete Upper
325	Incabloc Complete Lower
374	Hairspring Holder
378	Hairspring Fastener
401/A	Hand Setting Stem
407/A	Clutch Wheel for Setting
435	Clutch Lever

PART NUMBER	PART NAME
440	Clutch Lever Spring
443	Setting Lever
445	Setting Lever Spring
450	Setting Wheel
462	Minute Wheel Bridge
721	Balance Complete, Incabloc
4020	Stator
4035	Power Connection
4040	Balance Bridge Holder
4080	Contact Plate Assembled
4095	Magnetic Shunt
4160	Lead
4175	Blade
4330	Safety Lever
4360	Index Wheel
9433	Balance Stop Lever
	SCREWS
5105/A	Screw, Energy Cell Bridge
5110	Screw, Train Bridge

PART NUMBER	PART NAME
5110/1	Screw, Train Bridge Long (Same as 5121)
5121	Screw, Balance Bridge
5125/A	Screw, Index Wheel and Lever Bridge, Short
5125/A1	Screw, Index Wheel and Lever Bridge, Long
5129/A	Screw, Third Wheel Bridge
5325	Screw, Incabloc Lower
5374	Screw, Hairspring Holder
5443	Screw, Setting Lever
5445	Screw, Setting Lever Spring
5462	Screw, Minute Wheel Bridge
54020	Screw, Stator
54035/1	Screw, Power Connection Long
54035	Screw, Power Connection Short } Same as 5125/A
54080	Screw, Contact Plate } Same as 5125/A
54095	Screw, Magnetic Shunt } Same as 5125/A
54175	Screw, Blade
59433	Screw, Balance Stop Lever

ELGIN'S ELECTRIC WATCH

THE ELGIN NATIONAL WATCH CO. has announced a new entry in the electric watch field—the Lord Elgin. Grade 725. It is the smallest electric watch powered by an electric cell on the market.

The movement is an 8/0 size; 10½ lignes or .9325 inches. It contains 15 jewels, all it needs to be fully jeweled. The Lord Elgin has an 18,000 beat train, or five beats per second, and makes 9000 electrical contacts per hour.

A Parechoc system is used to cushion shocks to the balance, and the watch contains a hacking mechanism which allows it to be stopped for exact second hand setting. During the hand-setting sequence, which is controlled by the button on the back of the watch case, the electrical system is interrupted to prevent drain on the battery.

The electrical system closely resembles the Lip electric watch used by Benrus here.

The timepiece is designed so that servicing and cleaning can be accomplished without touching the electrical components. The horological section of the watch follows conventional train and dial train design. The manufacturer says any competent watchmaker should be able to service the watch without difficulty.

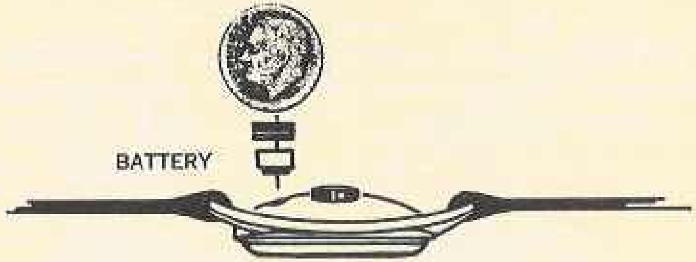


FIGURE 1

Replacing The Battery

Figure 1 shows how to remove the battery without removing the movement. Insert a dime or other thin coin into the back case nut, and use it like a screwdriver. Remove the case nut and drop out the battery.

The battery should have a voltage reading of 1.32 to 1.36 volts. It is important that only Elgin batteries stamped "W1" be used. They are not interchangeable with other batteries.

Figure 2 is a picture of the Elgin 725 electric watch and its single cell.

Setting The Hands

The crown on the back of the case is pulled out to set the hands, and turned to the desired time. This automatically stops the watch, disconnecting the electrical system and allowing co-

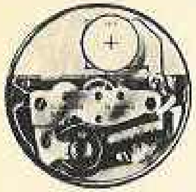


FIGURE 2

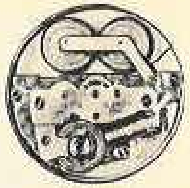


FIGURE 2A

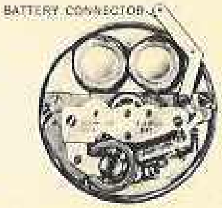


FIGURE 2B

CHANGING THE BATTERIES OF OLDER MODELS

Earlier Elgin models employed two small dry cells in parallel. If batteries be changed on the older model and the movement is in a one-piece case, Remove the crystal with a crystal remover. Drop the movement out of the case. Then, with the movement in a movment block, hold down the battery connector shown in Figure 2A with your finger. Loosen the battery connector screw and swing the battery connector to one side, as shown in Figure 2B. The side of the battery stamped "W1" should be placed against the dial. Reposition the connector and tighten the connector screw firmly. Remember that the battery connector goes to the insulated side of the case. When recasting the movement, center the dial's number "12" so that it is between the case lugs, then seat the movement firmly into position. Reassemble the crystal, crown and screw.

ordination of the second hands to exact time. To start the watch again, merely snap the crown straight in, without twisting it to avoid spinning the hands.

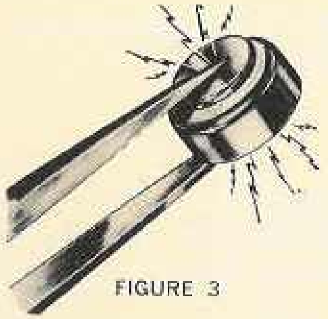


FIGURE 3


FIGURE 4

Precautions

Figure 3 shows the incorrect method of handling the battery. This will cause a "short" and prematurely drain the cell. It is best to avoid metallic tweezers when handling the battery. But if you must use them, hold the battery as shown in Figure 4.


FIGURE 5

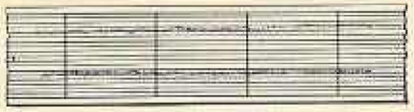


FIGURE 5A

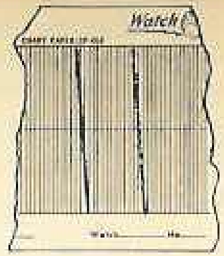
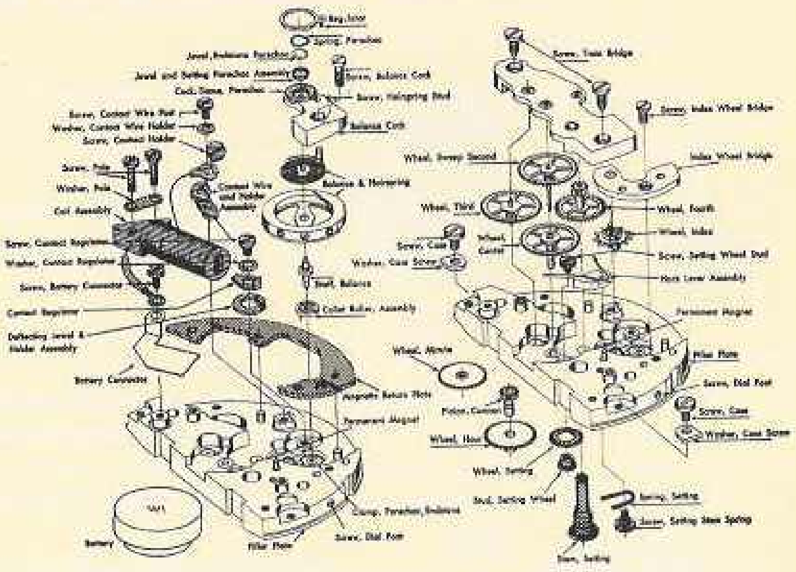


FIGURE 5B

Regulating The Watch

As mentioned earlier, the Lord Elgin is a standard 18,000 beat train. Therefore it can be timed on any standard timing machine. The lines shown in Figures 5 and 5A are typical of those recorded on tape machines. Figure 5B shows how this watch, running 20 seconds fast, would record on a drum type of watch timer. The lines in either case may be separated and scalloped, but it does not mean the performance of the watch is unacceptable. The direction of the lines is the only criterion for determining the rate of regulation.



This is an **exploded view** of the Lord Elgin electric watch movement. **Shaded parts**—the contact assembly, contact regulator, deflecting jewel, coil assembly, setting spring, setting spring screw, setting wheel, setting wheel stud and screw and the setting stem—**should not be removed.**

Regulating is the same as in conventional movements—by moving the regulator. In this model the regulator has no tail, and is moved by adjusting the part that holds the hairspring.

To overhaul the movement of Elgin's Grade 725 electric watch the usual dismantling, parts-cleaning, assembling and checking are carried out. Observe the following steps to dismantle the movement.

Remove the screw from the setting crown and lift off the crown. Remove the crystal (if it is a one-piece case). Drop the movement out of the case. If it sticks, push on the setting stem through the back of the case.

Remove the battery connector and battery. Remove the balance and balance bridge. Remove the case ring, dial and hands. Remove the train bridge and train wheels. Remove the hack level assembly and index wheel.

Shaded parts shown in the exploded view should not be removed. These include the contact assembly, contact regulator, deflecting jewel, coil assembly, setting spring, setting spring screw, setting wheel, setting wheel stud and screw and the setting stem. *If it is necessary to remove the stem, use the back of the tweezers and push the stem from the top until it is past the setting spring, as shown in Figure 6*).

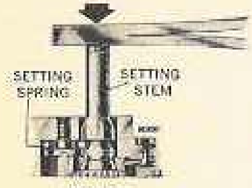


FIGURE 6

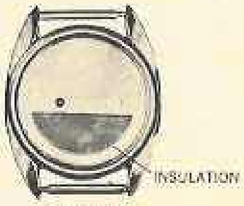


FIGURE 7

FIGURE 7A

Cleaning

Do not use cleaning fluids containing alcohol. Clean all parts as in conventional mainspring watches. Be careful to clean the lower plate with the contact assembly and coil intact and separate from other parts, in order to avoid damage to the delicate contact system.

Do not use excessive heat in any stage of the cleaning or overhauling process. Elgin recommends that drying and dehydrating be done in warm air. *Do not use sawdust.*

After cleaning and drying, remove foreign particles that may adhere to the permanent magnet. You can do this by dabbing the magnets with cellophane tape. (See the exploded view for the location of the magnet.) Check the index wheel and remove foreign particles. Before dipping the case into cleaning solution, remove the one-piece, self-adhering insulation in back of the case (*Figure 7*). With other cases, make certain you do not disturb or wet the insulation on the underside of the dial, as shown in Figure 7A.

Lubrication

Apply a light film of oil on the dimple groove of the center staff, as indicated in Figure 8, so that the cannon pinion can be turned on the staff during hand-setting. Clean and oil the upper and lower balance jewels as in conventional watches. Lightly oil the sweep-second bearings, as shown in Figure 9.

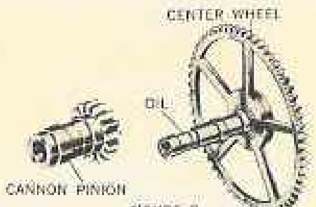


FIGURE 8

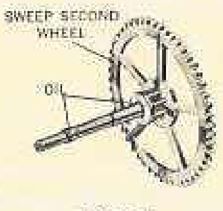


FIGURE 9

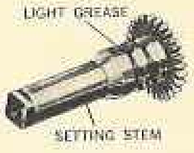


FIGURE 10

Put a trace of light grease where the setting stem fits the setting spring, as illustrated in Figure 10. *No other parts or jewels should be lubricated during servicing.*

Assembling

Replace the fourth wheel, center wheel, hack lever assembly and third wheel.

When assembling the sweep second wheel (*Figure 9*), note the thrust bearing on the underside of the sweep pinion leaves. Tip the third wheel to one side as you place the sweep wheel and pinion into postiion (*Figure 11*).

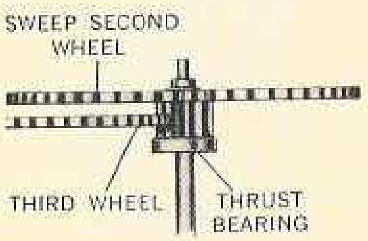


FIGURE 11

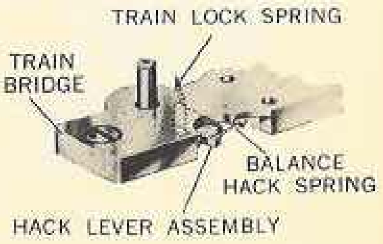


FIGURE 12

When replacing the train bridge, be sure to position the hack assembly to allow the train bridge to clear the train lock spring (*Figure 12*). Replace the index wheel and index wheel bridge. Replace the dial train; fit the dial and install the battery. Replace the balance bridge and balance in the conventional manner.

Exercise care when replacing the balance to avoid damage to the contact wire and deflecting jewel.

Check the motion of the balance. It should be between 1⅜ and 1⅝ turns (495°-585°) in all positions.

It is possible to check the electrical components separated from the train by omitting the index wheel. Be certain to replace the index wheel bridge, since it is part of the magnetic return.

Should the watch accelerate to the high motion without the train, there is some binding in the train, or perhaps foreign particles adhering to the permanent magnet or index wheel.

Should the motion still be too low, change to another battery or, in the older models, to another pair of batteries.

Check for bent or damaged balance pivots. Check the hairspring. If the watch still has an unsatisfactory motion the trouble is in the electrical components. (In this case return the watch to the factory.)

Fit the case ring and crown to check the hack lever assembly function.

The functions of the hack lever assembly (pulling the setting stem into the "out" position for setting the hands) are:

To brake the train to avoid movement of the train wheels while the hands are being set; to stop the balance in the "out-of-contact" position to assure self-starting after the hands are re-set; and to conserve the battery's life if the watch is being stored.

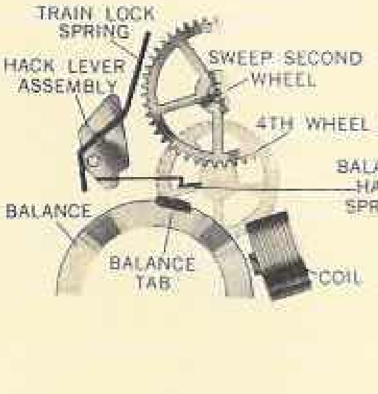


FIGURE 13

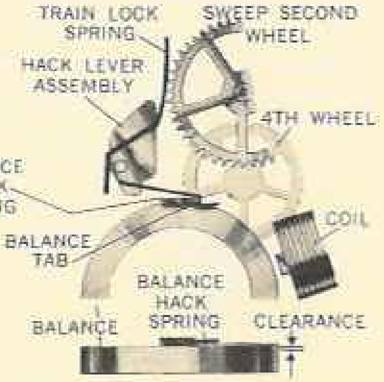


FIGURE 14

Figure 13 shows the proper relationship of the parts. Remember that the balance hack spring must clear the balance while the watch is running. When the watch is hacked, check to see whether the hack spring clears the balance rim but catches the balance tab. Note the clearance required between the hack spring and rim, as shown in Figure 14.

Hands must be fitted with the greatest care, so that hour and minute hand are coordinated to the dial divisions.

Staff replacement is accomplished as in ordinary watches, but some extra precautions will help. Do not disturb the motion control wire, shown in Figure 15. When the balance amplitude reached about 1¾ turns because of a servere jar or action, the motion control wire touches the bend in the hairspring overcoil, forcing it against the rim of the balance. Motion is thus reduced to normal.

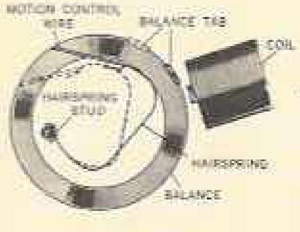


FIGURE 15

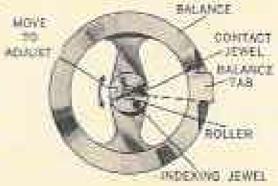


FIGURE 16

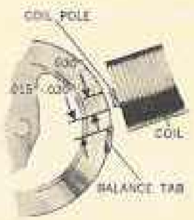


FIGURE 17

Before removing the hairspring, mark the location of the stud with respect to its position on the balance rim. Before removing the roller, very carefully mark the balance and roller with respect to their positions to each other, so that the roller can be replaced exactly.

The contact jewel, which is on the roller, controls the time period of the contact action. The correct location for the contact jewel in relation to the balance tab is shown in Figure 16. Actually, the correct position varies slightly from watch to watch, but again motion will show whether it has been relocated properly. The roller can be turned clockwise or counterclockwise until the proper motion level is obtained. A very slight movement will place the roller in the correct position.

The "in-beat" position is not critical, but the correct location of the balance in relation to the coil-pole is shown in Figure 17. With the balance at rest, the distance between the leading edge of the balance tab and the leading edge of the coil-pole should be .015 inches to .030 inches (.38 to .76 mm). The width of the coil-pole is .030 inches (.76 mm) and can be used as a gauge.

The beat of the watch can be adjusted as in ordinary watches by twisting the hairspring collet on he staff.

ALTHOUGH THE CONTACT SYSTEM of the Grade 725 is of simple design and rugged construction, exercise care when handling it, especially during servicing. The procedures that follow are recommended by Elgin National Watch Co. Learn them thoroughly and you will save time and increase your efficiency.

The contact system is carefully set and tested at the factory. It normally should require no servicing or adjusting unless a part becomes damaged.

The basic parts of the contact system are the *coil*, *contact wire*, *make and break* and *contact regulator*, and the *deflecting jewel*.

The Coil

The coil is the electromagnet. When the contact is closed by the balance, a strong magnetic field is created at the coil-pole. This magnetic field imparts an impulse to the balance, causing it to oscillate at 18,000 beats per hour. As the balance oscillates, it closes and opens the contact, indexing the train and thus driving the hands.

The balance tab and coil-pole should be parallel vertically, as shown in Figure 18.

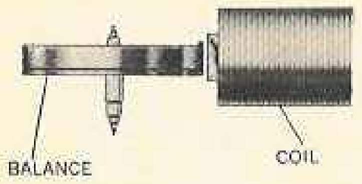


FIGURE 18

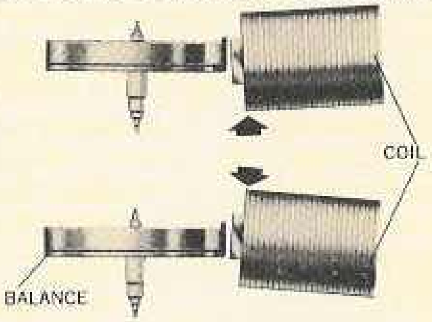


FIGURE 19

In order to correct errors in the alignment of the coil-pole and the balance, as illustrated in Figure 19, pry up or push down on the coil with a piece of pegwood until the coil-pole and balance tab are properly aligned on the same horizontal axis.

Do not use tweezers or other metal tools which may damage or cause a short in the coil. When adjusting, make certain that the coil--pole screws are tight. Do not use shims or washers of any type when attempting to level the coil-pole. For an efficient magnetic return, the coil and return path must be flat and as tight as possible (*Figure 20*).

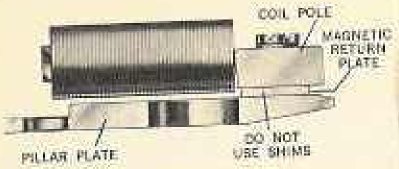


FIGURE 20

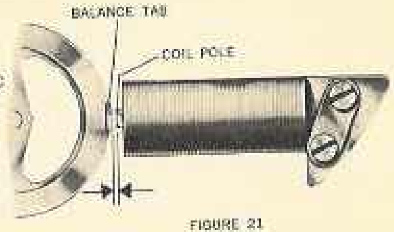


FIGURE 21

The curve of the balance tab should be lined up with the curve of the coil-pole, as indicated in Figure 21. To check the alignment, rotate the balance until the balance tab is opposite the coil-pole. The space between the coil-pole and the balance tab should be no less than .001 inches (.025 mm). The contact wire is .001 inches in diameter and can be used as a guide.

Under normal conditions, no adjustment will be necessary unless a new coil is installed.

To make spacing adjustments:

Loosen the two pole screws. While holding the balance tab towards the coil with a pair of tweezers, move the coil until the balance tab and coil-pole curvature are equal. Adjust until the space between the balance tab and the coil-pole is .001 inches. Tighten the pole screws when the adjustment is satisfactorily completed.

The Contact Wire

The contact wire should line up with the edge of the hole in the balance jewel setting (*Figure 22*). Use tweezers to make a definite bend in the contact wire when adjusting. Bend it as close to the contact holder as you can without touching it.

Avoid kinking the wire—it is made of a soft platinum-gold alloy and nicks will cause breakage.

The correct vertical adjustment for the contact wire is shown in Figure 23; it should be .003 to .004 inches (.08 to .10mm) up

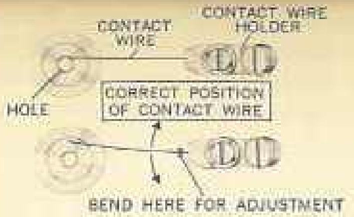
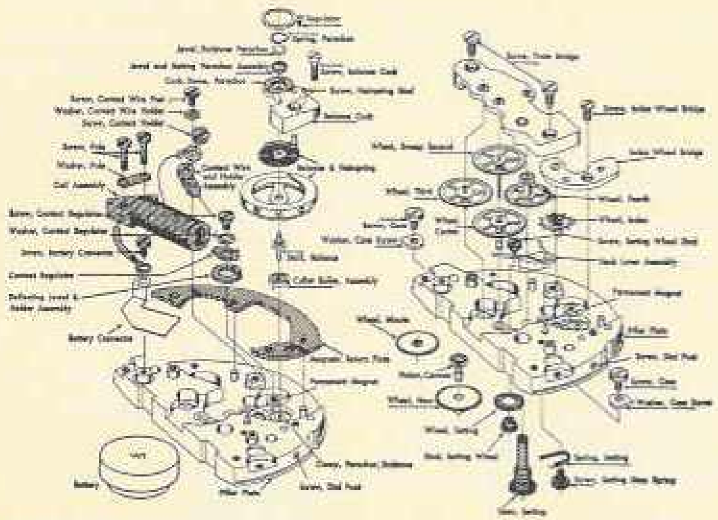


FIGURE 22

FIGURE 23

from the underside of the contact jewel. Again, bend it to arrive at the correct adjustment. See Figure 23 for the correct depthing adjustment. To check the adjustment, turn the balance counterclockwise until the contact jewel is on the backside of the contact wire. Correct depth of the adjustment is .003 to .004 inches, or .08 to .10mm. The adjustment can be made by loosening the contact holder screw and moving the wire in or out as is necessary.

SHADED PARTS ARE NOT TO BE REMOVED IN CLEANING



Make and Break

The term *make and break* refers to the length of time the electrical switch or contact is on. *Make* is the point when the switch or contact is first made. *Break* occurs when the switch or contact is broken. Since make and break limits the length of time on for the electrical current, it controls the motion of the balance and amount of battery power consumed.

The Contact Regulator

The contact regulator is the positive side of the switching or contact mechanism.

The contact blade should be .002 to .003 inches (.05 to .075mm) from the contact wire (*Figure 24*). It is adjusted by turning clockwise or counterclockwise as is necessary. As previously mentioned, the contact wire is .001 inches or .025mm in diameter and can be used as a visual gauge for adjustments. The contact regulator is held in position by a friction washer and can be adjusted without loosening the screw.

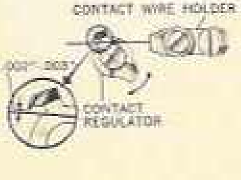


FIGURE 24

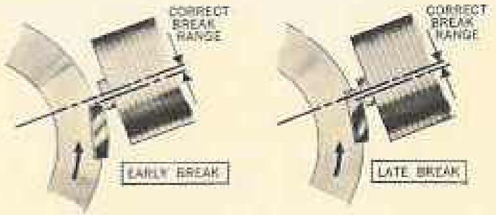


FIGURE 25

Make and Break Adjustment

Break should be adjusted first, and should occur just before the leading edge of the balance tab reaches the center of the pole face (*Figure 25*). Check it by turning the balance counterclockwise and observing when the contact wire breaks away from the contact regulator. To adjust, remove the balance and bridge and turn them upside down. Twist the roller counterclockwise to correct an early break and clockwise to correct a late break (*Figure 26*). Only a slight twist of the roller on its staff is necessary to make a minor adjustment.

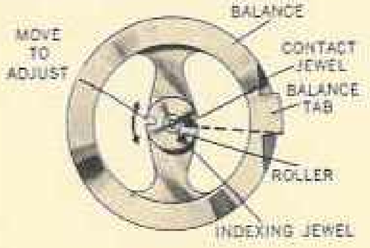


FIGURE 26

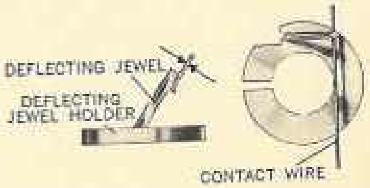


FIGURE 27

Make is adjusted by the contact regulator. Make should occur when the leading edge of the balance tab is about .001 inches (.025mm) from the leading edge of the pole face. At this point the balance motion is the best check for adjustment. Once again, balance motion should be between 1⅜ and 1⅝ turns in all positions (495° to 585°).

The Deflecting Jewel

Figure 27 shows the deflecting jewel. It is set at a slant and angles across the contact wire. As the balance oscillates counterclockwise it picks up the contact wire and touches the contact regulator. But there is no electrical contact when the balance is moving clockwise. The deflecting jewel causes the contact wire to slide under the contact jewel during clockwise movement, cutting down the amount of interference with the balance. The deflecting jewel also dampens the vibration of the contact wire after contact has been made, and diminishes the possibility of casual electrical contact due to excess vibration of the contact wire.

The deflecting jewel should be .0005 inches (.012mm) from the contact wire, or about as close as you can get it without touching. With a beat tool or feeler in the slot of the deflecting jewel holder, rotate the assembly until the jewel is just about touching the contact wire (*Figure 27*).

The deflecting jewel is held in place with ordinary watchmakers' fresh shellac if it becomes loose.

THE HAMILTON ELECTRIC WATCH

HAMITON WATCH CO. has simplified its electric watch movement by eliminating the delicate gold contact springs. Contact is now made directly to the balance's coil through a star wheel which is mounted directly over the steel indexing wheel. The need for special instruction on adjusting the fine gold contact springs with its box-detent structure is thus eliminated, and with it one of the trouble sources in adjusting electric watches.

Figure 1

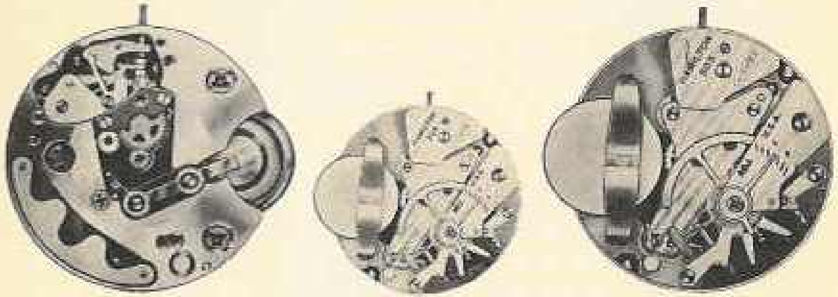


Figure 1 shows three views of the Hamilton calibre 505. To the left is the dial (side view) enlarged size. The center view shows the actual size of the movement. To the right is the train side of the new movement, also enlarged. In this figure, you can see that the balance is made simpler without screws, poising being effected by countersinking small drill cuts beneath the rims of the balance-motor.

Figure 2 shows an exploded view of the working principles of the calibre 505. The balance assembly is composed of the stamped rim-sector at the top, augmented by two kidney-shaped counterweights at the sides. The coil is held to the balance by supporting arms, which are fastened to the cross bar of the balance as well as to supporting yokes on the coil. One end of the coil terminates at the balance, connected by the "pig-tail" coming out of the center of the coil close to the fastening screw. The other terminal of the coil is connected to an insulated part of the balance and receives contact when the balance is in a planned position. The contact arrangement is shown in the enlarged view in the upper-left of this figure.

The indexing wheel, made of steel as in previous models, is now improved with a rachet-toothed auxiliary wheel. This wheel

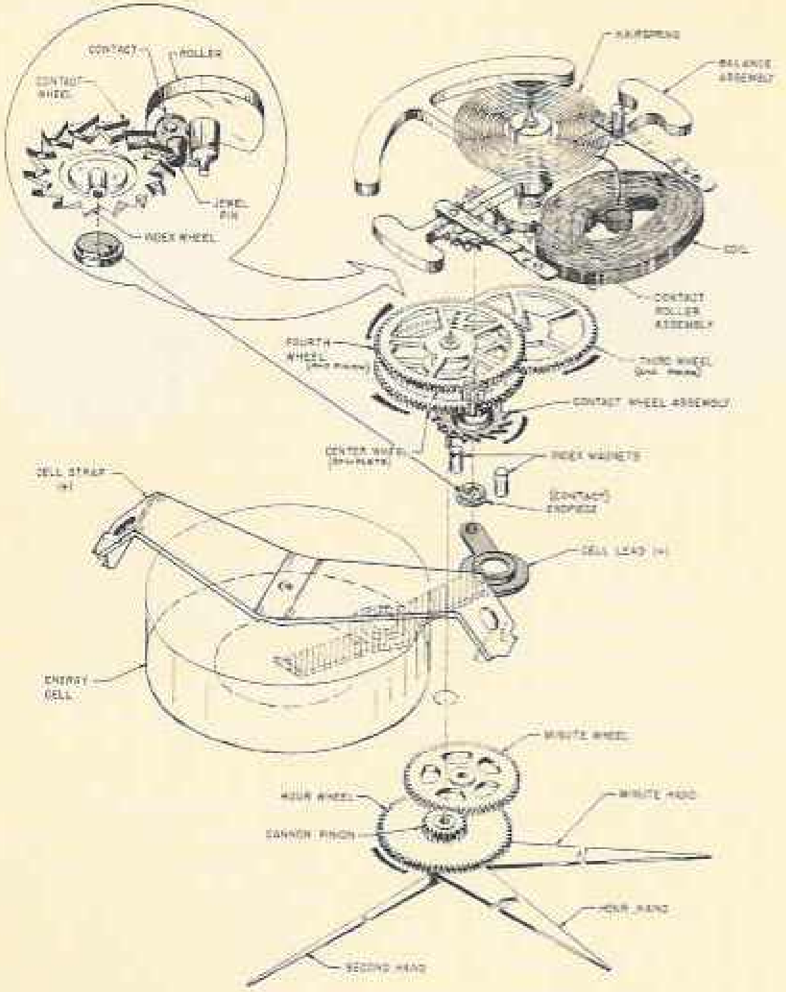


Figure 2. An exploded view of the working principles of the calibre 505. The stamped rim-sector at the top and two kidney-shaped counterweights at the sides make up the balance assembly. Note the enlarged view of the contact arrangement.

is made of an excellent electrical conducting platinum alloy. When the balance is in position so that the contact of the balance touches the contact wheel, electrical energy will flow from the "button" energy cell to the coil.

The balance contact unit is also new and novel. The contact is made up of two D-shaped pins, one smaller than the other. The larger is of non-conducting jewel while the smaller is of gold, a good conductor. The operation of this system will be explained in detail later. Briefly this combination of contact wheel and index wheel and half-gold, half-jewel pin, performs the double duty of making the electrical contact and advancing the train of wheels. This is a four-piece assembly; an index pin and index hub, a contact wheel and index wheel. The index pinion is insulated from the hub. Current flows from the energy cell through the cell lead, end-piece, and lower pivot of the index wheel to the contact wheel.

As the balance assembly turns counterclockwise, the gold side of the gold-jewel double pin meets the contact wheel, closing the circuit. Current flows through the gold half of the pin and wire "pigtail" to the coil, passes through and energizes it, then returns through the coil attachment, balance, hairspring, balance bridge and pillar plate to the positive side of the energy cell.

In addition to closing the circuit while the balance is turning counterclockwise, the gold side of the gold-jewel pin advances the index wheel. The steel index wheel is fastened to the lower side of the platinum contact wheel. The indexing action is completed and the wheels are held in their proper place or rest position by two small permanent magnets beneath the index wheel. The index wheel is advanced one tooth to each counterclockwise swing of the balance. The train, and in turn the hands, are caused to rotate by this indexing action.

On the clockwise swing the balance is merely returning. The jewel side of the pin slips past a tooth of the contact wheel; no electrical contact is made since the jewel side of the pin is a non-conductor.

An examination of Figure 1 shows the energy cell held down by the positive contact strap. The negative plate of the cell meets the cell lead which touches the bottom of the cell. This joins the endpiece on which the pivot of the double index containing wheel rests. The platinum contact wheel is insulated from the steel indexing wheel and its pinion. The enlargement at the upper left shows the platinum wheel contacting the gold side of the double pin. This supplies energy to the coil. The electro-magnetic impulse given to the balance soon forces it away from the contact wheel. Now the balance continues to turn on its own momentum until arrested by the resiliency of the hairspring. On its return, the jewel side of the pin strikes the contact wheel and no electrical contact results. The balance continues to turn on its momentum, brushing the contact wheel from its magnetically stationed position over the permanent magnet pins.

The train turns in sequence. The index wheel (Figure 2) is turned clockwise by the balance. The index wheel's pinion turns the fourth wheel. The fourth wheel pinion, turning counterclockwise (viewed as in Figure 2, from the movement side). The fourth wheel is mounted directly over the hollow center arbor and its long pivot reaches through to support a sweep center second hand. The dial train works off a common pinion attached friction-wise to the hollow center arbor.

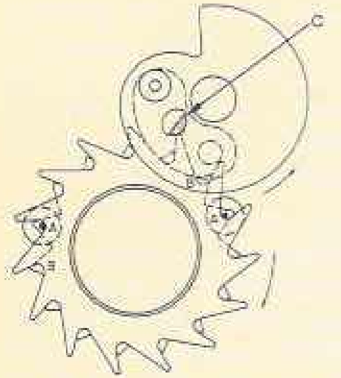


Figure 3. The teeth of the steel index wheel are situated directly over the permanent magnet pins at "A."

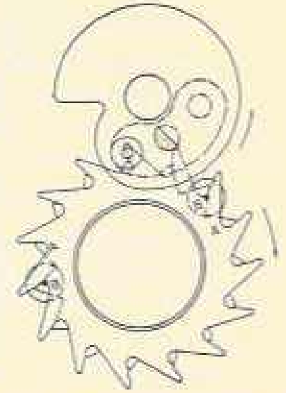


Figure 4. The contact wheel and index wheel are shifted by the jewel side of the gold-jewel pin on the balance.

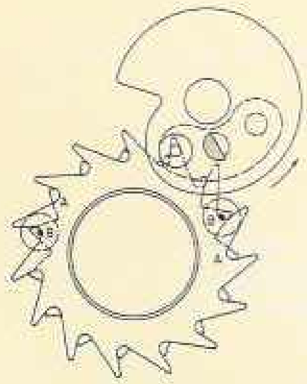


Figure 5. The jewel pushes the tip of the contact wheel, causing the magnet pins to attract the next index tooth.

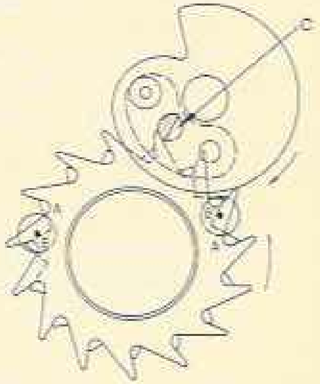


Figure 6. The balance is moving clockwise on its return trip. The jewel pin strikes the contact wheel tooth.

Figures 3, 4, 5, and 6 show the indexing-impulse sequence in detail. In Figure 3, the balance is moving counterclockwise. The gold side (C) of the gold-jewel pin has joined the platinum contact wheel's tooth. This causes the balance to be electro-magnetically impulsed in the same (continuing) direction. Notice also that in this position the star-pointed teeth of the steel index wheel are situated directly over the permanent magnet pins shown at position A. As the balance continues to move, the gold pin causes the contact wheel to move a bit in the clockwise direction.

In Figure 4 the jewel side of the pin on the balance takes over the shifting of the contact wheel and index wheel. When the index wheel's star-pointed tooth is moved out of the influence of the magnet pins, the additional push of the jewel on the tip of the contact wheel tooth causes the magnet pins to attract the nearest (and next) star-pointed index tooth. This is shown in Figure 5. Teeth A have advanced one position and now teeth B are positioned over the indexing magnetic pins while the tip of the contact wheel tooth is clear of the gold-jewel pins.

In Figure 6, the balance is on its return trip in the clockwise direction. The jewel side of the pin with its curved surface strikes the back slope of the contact wheel tooth. This motion, the incidence of the curve of the jewel and the sharp slope of the back of the contact tooth, cause a small back-lash. When the balance moves away, the permanent magnet pins draw teeth B back again to the positions indicated.

THE ELECTRICAL IMPULSE SYSTEM in the Hamilton 505 is like that of the previous models, calibre 500, 500A and 501. While knowledge of how the electrical impulse is imparted to the balance is not absolutely necessary to the servicing of the watch, it is given here for those who wish to understand the Hamilton electromagnetic system more thoroughly.

Frictioned into the pillar plate are two permanent magnets which work in conjunction with the coil on the balance, to impulse the balance. The magnets allow balance and coil to pass over them without touching. Every magnet has a north and south pole. These magnets are set in the pillar plate so that the north pole of one magnet and the south pole of the other are pointed up as shown in Figure 7.

Two shunt bridges are situated in this movement, an upper and lower. The lower shunt bridge is held across the lower end of the magnets. The upper shunt bridge is supported from the poles by an air gap. The permanent magnets, two shunt bridges and the pillars comprise two magnetic circuits whose lines of force move as illustrated in Figure 7. This sets up a uniform magnetic field in the air gaps between the magnets and the upper shunt bridge.

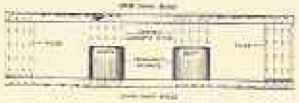


FIGURE 7

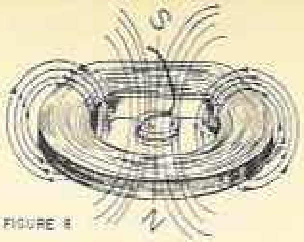


FIGURE 8

Figure 7 illustrates the lines of force of the two magnetic circuits.
Figure 8 shows the magnetic fields generated by the energized coil.

A coil, when energized, becomes similar to a magnet in that it produces a north and south pole magnetic field. In this watch, the south pole magnetic field is generated on the bottom of the flat coil. This is shown in Figure 8.

As illustrated, the magnetic lines of force flow from the north to the south pole of the coil. Notice that the lines of force on the right side of the coil move counterclockwise, while those on the left side move clockwise. Observe the reaction between the uniform magnetic field and the field set up by the energized coil.

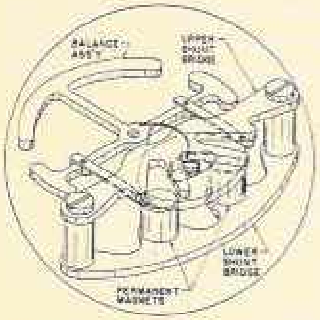


FIGURE 9

Note the position of the shunt bridges, permanent magnets and balance assembly.

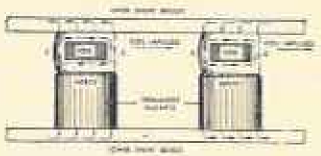


FIGURE 10

A cross section of the same view, showing the movement of the lines of force.

In Figure 9, we show the balance, the upper shunt bridge, the lower shunt bridge and the permanent magnets (not to be confused with the small, thin permanent magnets underneath the indexing wheel). In Figure 10, a cross section, we can observe the uniform magnetic field. At points *A* and *B*, the magnetic lines generated by the coil move in the opposite direction to that of the uniform magnetic field.

This causes the magnetic lines to cancel out or destroy one another in that area. However, at points *C* and *D*, the lines of force of the coil move in the same direction as that of the uniform field; this tends to strengthen the lines of force in that particular area.

As a result, there will be a crowding of these lines of force at points *C* and *D*. Lines of force react similarly to rubber bands bent and stretched under tension—they try to straighten out. The crowding of the lines at *C* and *D* will magnetically "flip" the balance by giving a magnetic impulse to the coil attached to it.

Changing the Energy Cell

The energy cell is held in place by a clamp having T-shaped ends, with a hole in each end. To release the clamp, insert the points of a tweezer in either hole of the clamp and press toward the cell; then remove the T-end from its slot in the pillar plate. Lift the clamp off, turn the watch over and the cell will fall out.

Replace the cell, flat side up, with your fingers. Replace the clamp by placing one end in the slot provided. Press the other end in place with your tweezers. Be careful not to short out the energy cell by touching both leads of the cell with your tweezers or other metal object. That is why it is best to use your fingers in handling the cell, rather than tweezers. A good suggestion: lightly scratch the insertion date on the new cell.

The energy cell of the calibre 505 is slightly larger than that provided for previous models. This newer, larger cell is colored white (stainless steel) rather than the gold color used previously. The energy cells used in earlier models are not interchangeable with the calibre 505.

Disassembling the 505

1. Remove the upper shunt bridge: Turn the movement so that the coil is nearest you with the balance at its dead rest position. The upper shunt bridge will then be directly over the coil. Make certain the two prongs extend outward, or toward you. Remove the screw on the right side and partially loosen the other screw. Lift off the free end and gently pull this outward until the shunt bridge is well away from the balance. Then remove the other screw and lift off the shunt bridge.

2. Remove the balance assembly: Disconnect the hairspring stud from the balance bridge, first making absolutely sure that the outer coil of the spring is free from the regulator pins. Lift the balance out carefully by placing the tweezers on its rim. *Never grasp the coil with the tweezers.*

3. Remove the cell lead and contact endpiece from the dial side. *Note*—the contact endpiece serves the same purpose as does an endstone cap for the lower index pivot. It has a small plastic washer fastened permanently to it which insulates it from the

pillar plate (which carries current and serves as part of the circuit). It is held in place by the springy cell lead. The cell lead screws have insulating washers under their heads; these may be left on even during the cleaning process. The cell lead insulator, located under the cell lead, need not be cleaned—but should be removed from the pillar plate. With the cell lead off, turn the movement upside down and the contact endpiece will drop onto the bench.

Cleaning Information

Cleaning can be accomplished with any commercially recognized watch cleaning and rinsing solution. They are all safe to use with the calibre 505. However, solutions used for everyday cleaning of watches become contaminated. It is suggested by Hamilton that the balance assembly and combination index-contact wheel be given a final rinse in a good grade of isopropyl or denatured alcohol after removal from the cleaning machine.

Minute iron filings may have gathered on the two large permanent magnets under the balance as well as on the two small magnets under the index-contact wheel during cleaning. They can be removed easily by applying the stick part of cellophane tape or similar adhesive to these surfaces. The tape will gather this dust without leaving its sticky adhesive on the magnets.

Assembly and Lubrication

1. Replace the stop lever; but do not oil it.

2. Replace the train wheels. First, oil the center wheel jewel and jewel bearing of the long fourth wheel staff with Hamilton PML 79 oil.

3. Replace the contact endpiece and cell-lead. *Never oil the contact endpiece.*

Place the endpiece, flat side down, in its recess over the contact-index wheel jewel. The exposed side should now reveal an indentation which matches a dimple in the cell lead. Replace the cell lead insulator, which insulates the cell lead from the pillar plate. Replace the cell lead. Make sure the cell lead screws have their insulating washers attached before replacing them. *Do not oil the index-contact wheel lower jewel.* This pivot must run dry. Lubricate all other jewels with PML 79.

Screws: Train bridge, cover plate and set cap spring screws are identical.

4. The balance assembly: Before replacing the balance assembly, check the freedom of the finger block in the middle of the balance staff. To do this the finger block should rest on the lower collar, as shown in Figure 11, with the balance assembly in a horizontal position. Invert the balance, with the hairspring on the bottom, and the finger block should drop from the lower collar to the upper collar as shown in Figure 12. If the finger does not drop between the collars and a light tap on the tweezers does not make it do so the complete assembly must be re-cleaned. When assembling the balance to the movement, line up the finger block under the coil before putting the balance in place, as shown in Fig. 13. Note that the finger block is pointing directly toward the center of the coil over the magnets. *Never oil the finger block. Never dry the balance in sawdust.* It is easier to replace the balance bridge, but the watchmaker can replace the balance and bridge in the conventional manner if he desires.

FIGURE 11

FIGURE 12

The finger block is resting on the lower collar in Figure 11. It should drop to the upper collar when the balance is inverted (Fig. 12).

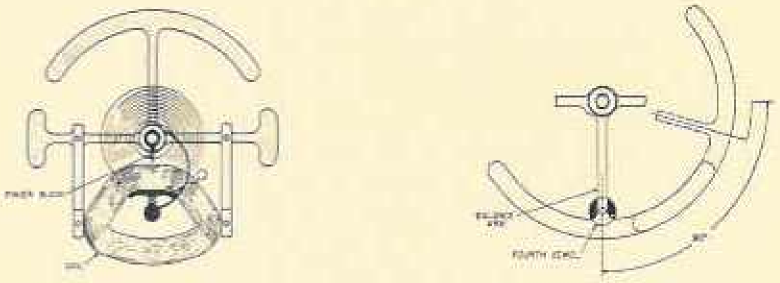


FIGURE 13

FIGURE 14

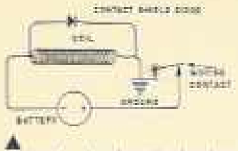
The finger block is aligned beneath the coil, and points at the coil's center in figure 13. Figure 14 illustrates the correct beat position.

Beat Position

Up to a point, the beat position has no effect on the performance of this electric movement. It can be obtained, however, in the following manner (refer to Fig. 14.).

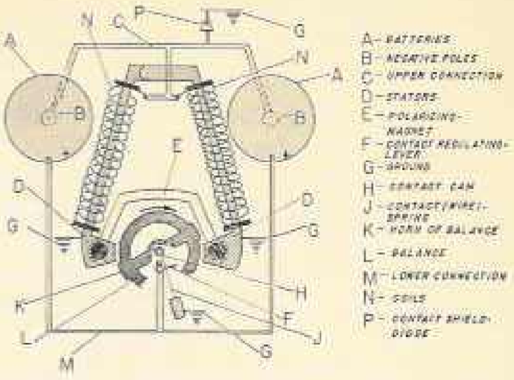
Place the movement with the coil away from you and the fourth jewel toward you. Lightly place a sharpened piece of pegwood to the left of the balance arm opposite the coil. Move the balance 90° counter-clockwise (to the right), and allow the balance to return slowly to its dead rest position in a clockwise direction. The arm will be approximately centered over the fourth jewel if the movement is in beat. If it is not, the hairspring collet can be turned until this position is obtained. The energy cell lead should not be in the watch while checking the beat position as contact may be prolonged and drain the cell.

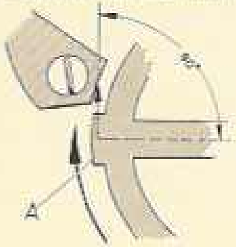
THE LIP ELECTRIC WATCH



▲ Figure 1. A schematic drawing illustrating the basic principle of the French-made Lip electric.

Figure 2. Two batteries (A) provide the power which produces the magnetic energy in the stators (D) which attract the balance horns (K) to begin the movement. ▶





◀ Figure 3. Before the stator can exert a permanent magnetic hold on the balance horn (A) the contact is broken and the balance continues in a clockwise direction until the hairspring overcomes its forward movement.

Figure 1 is a simple diagram to illustrate the basic principles of the Lip electric watch. The battery, about the size of a shirt button, energizes the coil and draws the moving contact. The contact shield diode (shown above the coil) serves two purposes. Like the bell-buzzer, as make-and-break occurs, a spark ordinarily jumps between the contacts. In a small watch a gap-spark would sap the battery and burn the contact points, or coat them with insulating carbon deposits. The diode is a small device that acts like a valve, suppressing the spark and prolonging the life of the battery.

The Basic Sequence

Figure 2 shows the scheme layout in simplified form. Two batteries (A) are used in parallel for longer life and a more even flow of electrical energy. The negative poles (B) are connected to the stationary coils (N).

These coils are wound around their base material to produce magnetic attraction at the stators (D) right and left. A strap (E) aids in polarizing the magnetic stators. In this figure, the circuit is open. The balance staff holds the contacting jewel cam (H).

The action is as follows: At rest, the balance unit is in the position shown. A slight twist will cause the jewel (H) to push the wire contact spring (J) against the point of the contact regulating lever (F). This closes the circuit and a magnetic pull is exerted on the horns of the balance (K) by the now magnetized stators (D). This occurs at the best possible point of tangency as shown in figure 3. The pull is from the stator on the horns (K). However, as the balance is pulled so that the horns approach being directly opposite the center of the stators (D), the cam will have passed the tip of the spring (J, Figure 2). This will cause it to jump back to the position shown in Figure 2, but contact is broken before the stators can exert an arresting magnetic pull on the fast moving balance horns. The balance continues, now free of magnetic influence until the hairspring's tensile strength is sufficiently wound to overcome the momentum of the balance. The balance then goes counterclockwise, still free from the temporary electromagnetic pull of the stators (D). The jewel cam (H), now returning, merely flips past the spring (J), pushing it away from the electric contact (F). The balance then continues in the anti-clockwise direction until the hairspring overcomes its motion, causing it to turn in the clockwise direction where it will again make contact and receive an impulse. Thus the cycle is repeated on alternate swings (clockwise only). As the spring (J) is made to contact the regulating lever (F), the diode (P) dampens or valves the surge of current to conserve it and suppress any tendency to spark at the contact points atop the nose-tip of the pivotal point of the contact regulating lever (F).

THE BALANCE performs three duties: It keeps time, it aids in making and breaking the electrical contacts and it moves the gear train for the time-indicating mechanism.

The Setting Mechanism

There is no escapement or escape wheel as such, but a jewel close to the balance center moves a count wheel one tooth with each alternate vibration, or only during the balance's clockwise motion. This can be best understood by examining Figures 4 and 5. Figure 4 shows the count wheel with its 12 teeth. The balance has a D-shaped jewel set into its disc in the position shown. As the balance turns clockwise, as indicated by the arrow, the jewel (*a*) contacts a tooth (*b*). As the balance continues to turn, it carries this tooth, and the wheel, in a counterclockwise direction. When this jewel is at *c*, it has moved the tooth to position *d*. When the jewel reaches point *e*, the wheel tooth is at *f* and can go no further on its own. But the jewel is now free to go on (position *g*). However, situated at right angles to the line between the balance and counterwheel centers is N, a strong magnetic pin. When a tooth is at *f*, another tooth will be as close to the center of N (the magnetic pin) as *f* is to *h*. Therefore the magnetic pin (N) will pull the tooth to a rest position directly over itself.

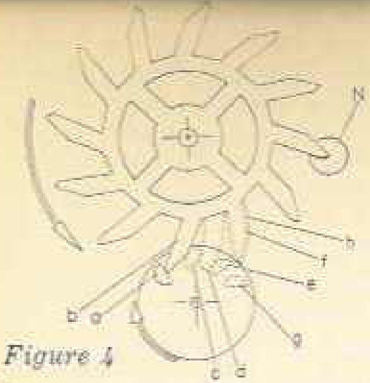


Figure 4

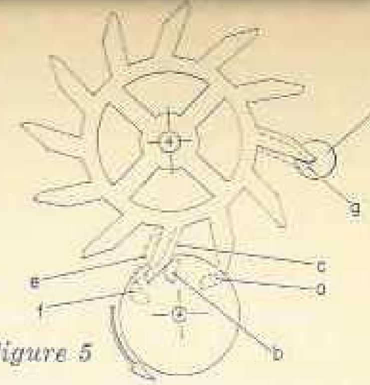


Figure 5

When the balance makes its return voyage, as shown in Figure 5, the jewel (*a*) will pass by the nearest tooth, but as it approaches position *b*, it will contact a tooth (*c*). Since the backs of these teeth are especially slanted the curved back of the jewel will move the tooth only as far as position *e*. The jewel pin (at position *f*) can now drop off and continue. The tooth at N has only been pushed backward a short distance (to position *g*), not out of range of the magnetic pin (N) which again attracts and holds it. (This impulse jewel is not the same as the contact jewel cam. There are three jewels on the balance staff, each serving a distinctly different purpose. I will explain in detail later.)

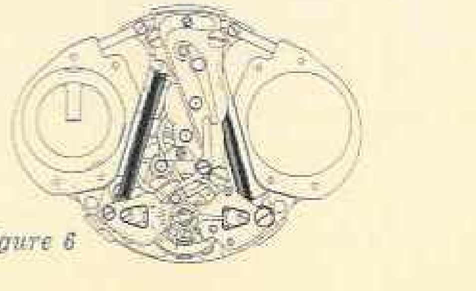


Figure 6

Figure 6 shows a line drawing of the movement. The circular discs on the side of the movement are the batteries in their insulated receptacles. The two stationary coils are shown clearly. Also illustrated is the Incabloc-protected balance pivoting arrangement. The upper balance pivot is supported by a bridge rather than by the usual balance cock. The hairspring is Nivarox, Breguet. The outer regulator pin is bent out sharply to prevent entangling of the hairspring's coils.

There is no winding mechanism but the setting mechanism is interesting and its functions are important. It is shown in Figures 7 and 8. Figure 7 shows a general schematic of the setting mechanism which automatically stops the balance in an open-circuit position and, at the same time, locks the indicating train. The hand-setting mechanism is a "back-wind" arrangement with an arbor (C) connected to the key (A) by a square and secured by a screw. To lock it either in the setting or neutral position, the arbor has a knuckle groove into which the bolt spring (E) fits. In this figure, the watch is in the going position and the arbor has been pushed down so that the knuckle is under the bolt spring, which now rests in the upper groove. The lower end of the arbor contains the hand setting wheel (D) which is now slightly below and out of gear with the minute wheel (F) shown in the downside-up position. In this position, the dial train is free from the arbor and the hands cannot be turned manually.

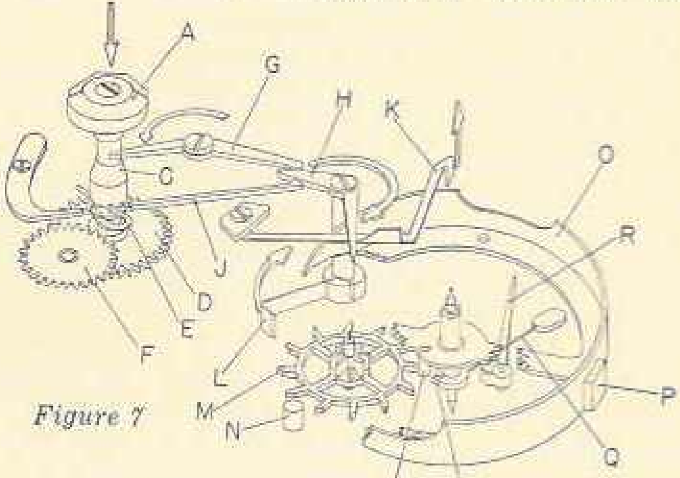


Figure 7

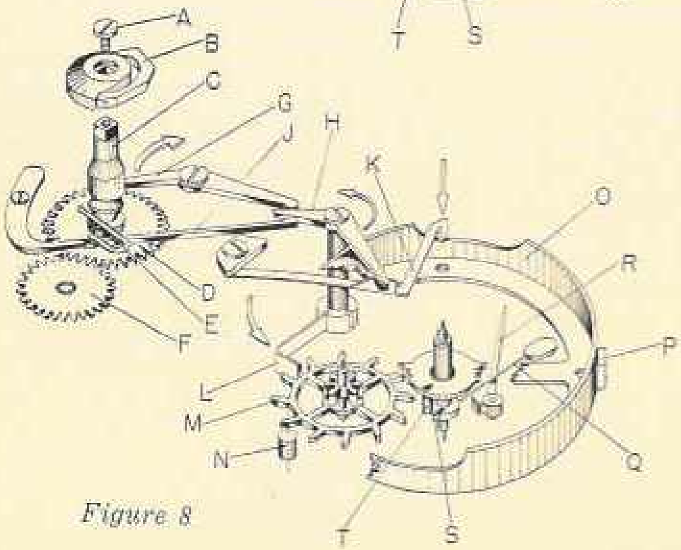


Figure 8

The balance locking arrangement is related to the position of the arbor (C). In the cycle pictured in Figure 7, the balance and train are free to move. Notice the slanted part of the arbor and its upper neck and thicker lower diameter. In this sequence, the arbor lever (G) has its left arm resting against the thin part of the arbor and its right arm resting against the locking lever (H). The lever spring (J) maintains its tension so that, through the locking lever, the arbor lever's left arm is always pressed against the arbor. The locking lever (H) is locked to its arbor and pivots with it. The upper part of this arbor has its right wing hold down the tension of the balance stop spring (K). The lower extremity of this arbor has a train-locking arm (L) which is shown clear of the teeth of the wheel (M).

In this sequence, it is interesting to note the position of the balance jewel (T) which is about to move a tooth of the count wheel (M). O is the balance and P the magnetizable balance horn. Q is the contact spring, R the contact regulating lever S the contact cam jewel. In this figure, the contact, as shown between S, Q and R, is open.

Locking the Balance

In Figure 8, the alternate sequence is shown. A is the arbor and the key screw. Notice that the key and button are streamlined and fit into a recess in the case back; there is no crown on the edge of the watch case and in this respect is similar to Accutron's setting mechanism. The case back presents a smooth, streamlined surface when the watch is in the running position. In this figure the arbor has been pulled upward by the hinged key. The front edge of this key (B) is undercut to allow a fingernail to swivel the key into an upright position. The arbor (C) is now shown pulled up so that the setting wheel (D) is engaged with the minute wheel (F). The bolt spring (E) has locked itself in the lower groove of the knuckle and positioned the arbor with it. The arbor lever (G) has its left arm against the lower, thicker part of the arbor (C). This causes it to move outward, in the direction of the arrow. In turn, its right arm causes the locking lever (H) to twist counterclockwise, in the direction of the arrow. The locking lever's right arm slides along the slanted lip of the balance stop spring (K), causing it to move downward. The edge of the balance stop spring rides down the curved cut in the balance rim, presses against it and stops the balance in the open-circuit position. Thus battery drainage is prevented. This is accomplished when the balance is prevented from moving, the balance cam(s), which is attached underneath the balance and moves with it is prevented from touching the contact spring (Q) which, in turn, does not contact the regulating lever. Thus the circuit is not closed and the batteries are not in use.

At the same time, the lower extension of the locking lever's arbor containing the train locking arm (L) has turned counterclockwise, in the direction of the arrow, causing the locking lever arm to move in between the teeth of the count wheel, preventing any movement of the train. Notice that in this sequence, the balance jewel (T) is clear of the count wheel and the balance cam jewel (S) is clear of the contact spring and lever. The permanent magnetic pin (N) situated in the count wheel bridge, is really above one tooth but is shown here as being under for the sake of clarity.

FIGURE 9 shows a general view of the balance unit and should help to fill in some additional details of operation and adjustment.

The balance (O) is made of two metals. The inner rim and arm are of non-magnetic nickel-silver while the outer rim, with the horns, is composed of Mumetal, an alloy of very high magnetic permeability. It contains, roughly, 75 per cent nickel, 5 per cent copper, 2 per cent chromium and minute quantities of iron and carbon. This combination allows a greater attraction by the electromagnetic stators (D1 and D2). The Mumetal horns (P1 and P2), each at a different level, are shown during the closed circuit position, under the influence of the magnetic pull of the stators.

At this point the contact cam jewel (S) has just forced the contact spring (Q), which is grounded at its base, to make contact with the nose of the contact lever (R). This has completed the circuit, energizing the coils which create the magnetic pull of the stators on the horns. However, just beyond the point pictured, the cam jewel (S) will pass the contact spring (Q); the released spring will jump back to its neutral position and break the circuit, allowing the balance to continue under its own momentum. At the same time, the balance jewel (T) will contact a tooth of the steel count wheel (M) and move it the distance of one tooth, or 1/12th around. The magnetic pin (N), situated in the count wheel bridge, will hold the wheel in place by exerting a magnetic influence on the tooth directly below it.

Figure 9. A general view of the balance movement. The outer rim and horns of the balance (P1 and P2) are lined with Mumetal, an alloy of high magnetic permeability which allows a greater attraction by the electro-magnetic stators (D1 and D2).

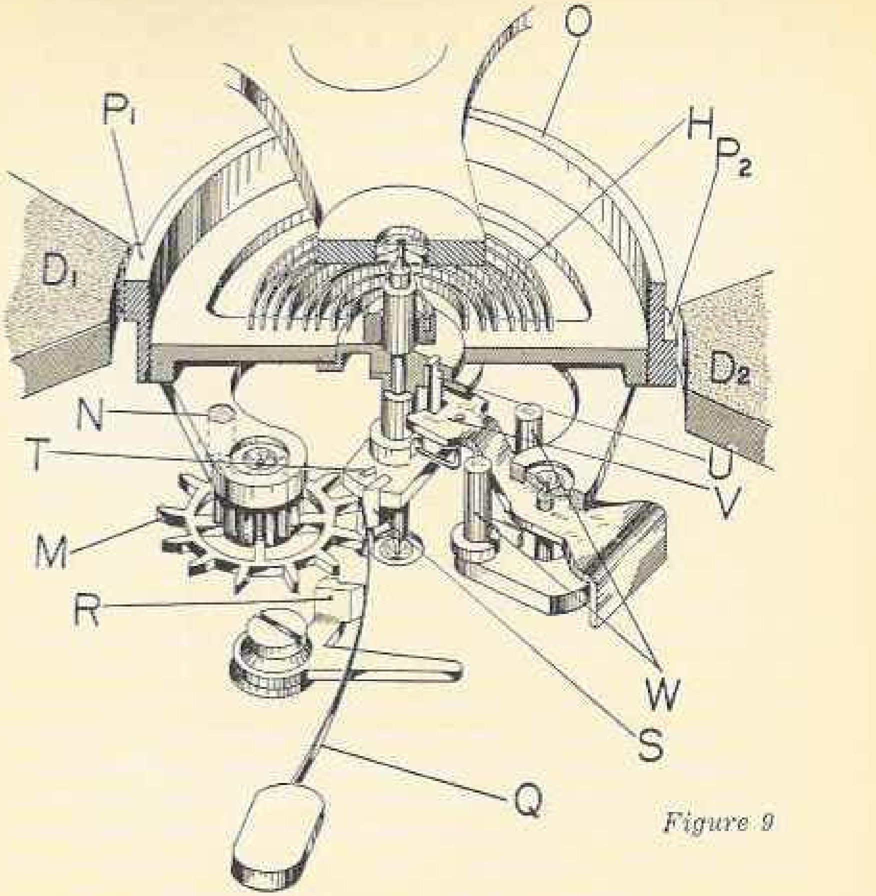


Figure 9

The balance's motion is designed to move a total of 540 degrees (¾ around in each direction). As the balance returns, the contact cam (S) will merely flip past the spring (Q) which does not touch the contact regulating lever (R) unless pushed there by the contact cam (S). The balance is therefore impelled or pulled in the clockwise direction only. If the balance had an amplitude of over 365 degrees, or just over one full turn, the contact cam jewel (S) would, in the same cycle, again push the spring against the contact lever, creating a one-way motor and causing much damage to the hairspring (H) and very erratic timing. To prevent this over-amplitude of the balance, a traditional fork and roller jewel with safety roller are used. In Figure 9, the amplitude control roller jewel and the safety roller with its crescent, below, are identified by the letter U. The fork and guard finger (V) pivots between two magnetic banking pins (W) which keep the fork against either of the pins, depending on the direction in which the balance is turning. Thus, should the balance develop an over-motion, or very high amplitude, the roller jewel (U) will merely rebound on the outside of the fork's horns.

Regulating the Impulse

Actually, the impulse is controlled by the length of time the balance is under the magnetic influence of the stators. This can be regulated by moving the arm of the contact regulating lever (R) to cause contact between the contact spring (Q) and the contact lever to take place sooner or later in the cycle of the balance movement and to last longer or shorter. If the lever is moved clockwise, the contact lasts longer and the balance motion is increased. If the arm is turned counterclockwise, the contact comes later and lasts for a shorter duration, lessening the time of magnetic pull and reducing amplitude. Thus there are three jewels in the balance: the contact cam jewel (S) which causes the spring (Q) to touch the contact regulating lever (R) and close the circuit; the balance wheel jewel (T) that is positioned to move a tooth of the count wheel; and the traditional type of roller jewel (U) that has the function of preventing over-motion.

Figure 10. A view of the dial side of the movement. The batteries are on the flanks.

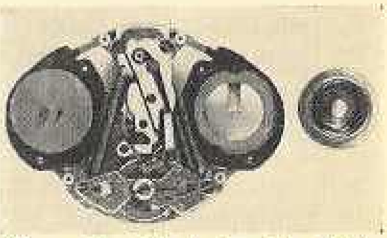


Figure 11. The train side of the movement. The right battery has been removed from its socket and turned over to show its negative pole centerpiece.

Figure 10 shows a photograph of the dial side of the movement, flanked by its two batteries. This movement is 27 mm, or about 12 lignes, and equivalent to the American 4/0 size system of measurement. Complete specifications will be detailed later. In Figure 11, the movement is pictured on the train side with one battery removed and turned over to show its negative pole centerpiece. Each battery is encased in a heavy machined brass casing and, Lip says, is absolutely leakproof during and after its lifetime. Notice, also, the insulating battery receptacles and the series of levers relating to Figures 7 and 8.

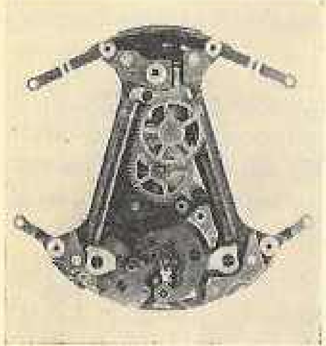


Figure 12. The movement with the train and balance bridges and battery receptacles removed. The count wheel, the contact spring, the regulating contact lever and the amplitude limiting fork can be seen.

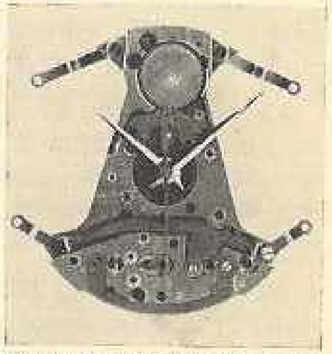


Figure 13. The dial side of the movement without the batteries and battery receptacles. The minute wheel teeth are bevelled for easy meshing with the arbor's hand-setting wheel.

Figure 12 shows the movement with the train and balance bridges and battery receptacles removed. The count wheel, the contact spring, the regulating contact lever and the amplitude limiting fork can be seen. Compare this with Figure 9. Notice the stationary electrical coils and their stators which flank the balance. Figure 13 shows the same disassembly from the dial side, with the sweep second, minute and hour hands in place. You can see that the minute wheel teeth are bevelled so that they will mesh easily with the arbor's hand-setting wheel during the hand-setting operation. The hand-setting wheel also has bevelled teeth to aid in engagement.

The Lip electric watch beats 18,000 times an hour, the same as a traditional mainspring wound watch. Because the impulse is in one direction only, the second hand makes an advance every 2/5th of a second. The Watchmaster timing machine, however, will record a true horizontal line, the same as with any standard 18,000-beat watch. With continuous tape machines, such as the Vibrograph, the New Watchmaster, Paulson or Greiner, the line should be continuous and straight.

SPECIFICATIONS

Here are the detailed specifications of the new Lip electric watch:

Case: The total diameter is 27.8 mm and the casing diameter is 27 mm. The height of the case over the yoke screw is 5.4 mm and the height over the pinion is 6.6 mm. The maximum height, arbor setting screw is 9.4 mm.

Quality: In accordance with NHS 56334 and Cetehor standards, the Lip electric watch has 17 functional jewels of grade A quality. The screw heads and yokes are highly polished and the plate and bridges are nickel.

Electrical parts: The two coils of enameled wire, 5,000 turns, have a diameter of 0.025 mm, a Mumetal core, and are polarized by a magnet. The balance has a Mumetal outer lining. The moving contact consists of a wire pressing on a regulator which enables adjustment of the balance amplitude.

Mechanical parts: The balance has a total diameter of 8.9 mm and a hole diameter of 1.9 mm. The Mumetal lining is 1.8 mm high. The balance also has nickel-silver arms and grade A pivots. The watch beats at 18,000 vibrations an hour; the second hand moves every 2/5th of a second (on alternate swings of the balance).

Hairspring: The Nivarox 2 (1.50 cg) hairspring has a Breguet outer terminal and mechanical collecting.

Wheels and pinions: The movement has a specially shaped steel driving wheel and rustproof steel pinions with polished leaves. The pivoting has been effected after the rustproof bath. The watch also has gilded brass wheels.

Amplitude limiting device: This consists of a magnetically positioned special steel fork and guard finger with the traditional roller jewel and safety roller.

Batteries: The watch consumes an average of seven microamperes of electrical energy under a voltage of 1.5 volts. The batteries have a diameter of 11.3 mm and are 3.2 mm high. Lip says they are absolutely leakproof during and after discharge of energy. The voltage at start of use is 1.5 volts; at end of use, 1.3 volts. The batteries maintain a regular voltage during discharge time, with a voltage deviation of less than 0.05 volt over a period of a week. Average life, for batteries stored less than six months, is one year. In no case should the batteries be permitted to become short-circuited, even for a brief instant.

They would deteriorate very rapidly.

The use of two batteries in parallel produces a stabilization phenomenon. The voltage of the two batteries in parallel is about 1.3 volts at the outset, then the voltage increases and becomes stabilized. This phenomenon, is even more pronounced with stored batteries. For connection in parallel, both batteries must have the same voltage, that is why Lip advises never to pair a new battery with an old battery. Both would deteriorate.

Chronometric qualities: Since the impulse is delivered only once during a complete cycle, as in a marine chronometer escapement, it is possible to regulate the isochronism by adjusting the position of the impulse in relation to the line of centers, or neutral point of the hairspring.

Amplitude: With the watch in the flat position, the balance motion is regulated at 270° in each direction for a battery having a voltage of 1.5 volts. This amplitude remains practically constant as to power and regulating effects of the contact (if the amplitude decreases, the contact time is longer; thus if the impulse lasts longer and the balance receives more power, it tends to rectify itself and recover its proper amplitude).

Servicing data: Do not attempt to make any adjustments unless you are familiar with its operation. Pay particular attention to properly aligning the regulating contact, adjustments for tolerances and clearances, adjusting the cam precisely and obtaining proper voltage issuance and following strict standards of workmanship.

Changing batteries: In order to achieve proper voltage balance, *both* batteries must be changed at the same time. Figure 14 shows bottom of the case with the three streamlined gasketed caps. The key for hand setting is at the figure 9 position on the dial. The other two caps are spring-loaded contact covers for each of the batteries. To remove these caps and the batteries, a spanner wrench or one that fits diametrically set holes as in waterproof wrenches will loosen these caps. When replacing the batteries, make certain that the negative pole of the battery faces downward so that it will contact the center point of the contact spring and fit its socket. Screw on the bottom cap and lock it at its joint, being careful not to short-circuit the battery.

Setting the hand: Like the Accutron, the hand setting is accomplished by lifting up the front groove of the hinged piece into an upright position. Pulling upwards on this and twisting it will move the hands. This also locks the train and balance and previous electrical drainage or short-circuiting.

Starting the watch: Most often the watch will start by itself after the hands have been set. If it doesn't, twist the watch slightly in a fast action.

Storage: It is preferable to install the batteries at the time of giving it to the wearer. It is possible however to store the watch without exhausting the batteries by pulling the setting arbor into the handsetting position. This opens the contacts and at mentioned earlier, stops the balance and locks the train.

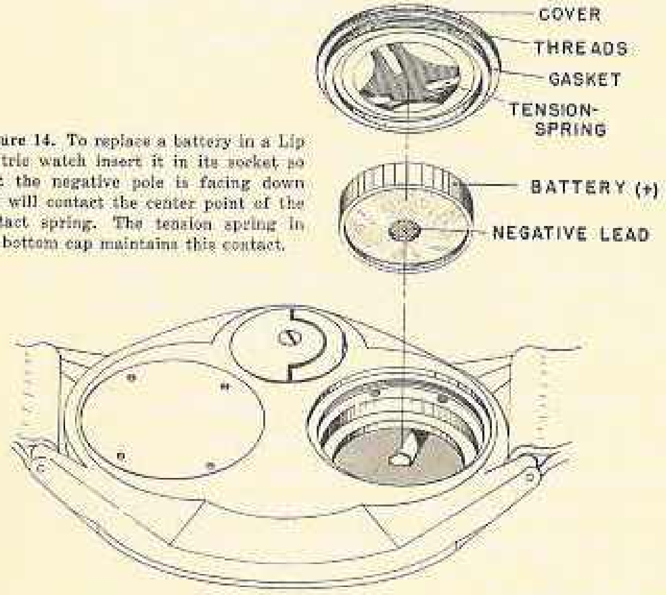
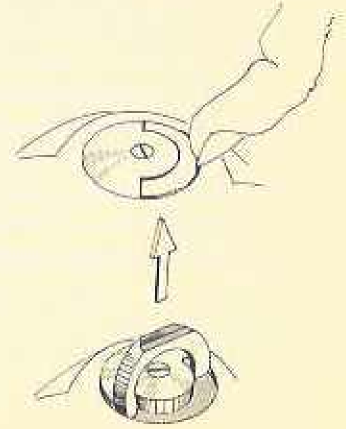


Figure 14. To replace a battery in a Lip electric watch insert it in its socket so that the negative pole is facing down and will contact the center point of the contact spring. The tension spring in the bottom cap maintains this contact.

Figures 15 and 16. To set the hands, pull the half-ring on the case back to an upright position and turn in any direction. Pulling the key up also locks the train and balance and prevents battery drainage when the watch is not in use.



THE SWISS ELECTRIC WATCH

The Swiss electric watch produced by LeLanderon is widely used. This is because many companies market it under their own names, and because of its price, merchandising and efficiency.

It is as close to traditional timepieces in structure and appearance as any electric watch can be. It has parts, for instance, which resemble an escape wheel, pallet and fork—although these do not perform the same functions.

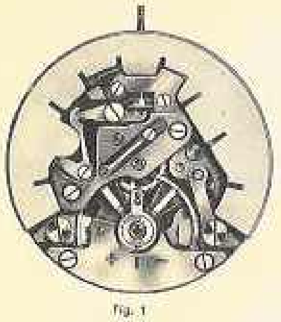


Fig. 1

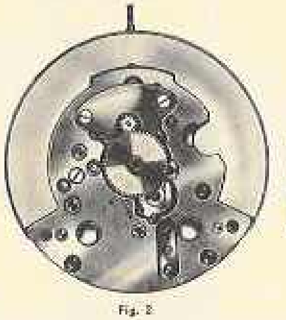
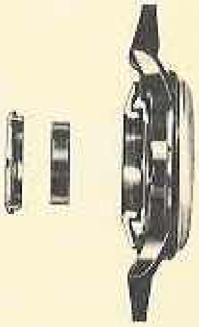


Fig. 2



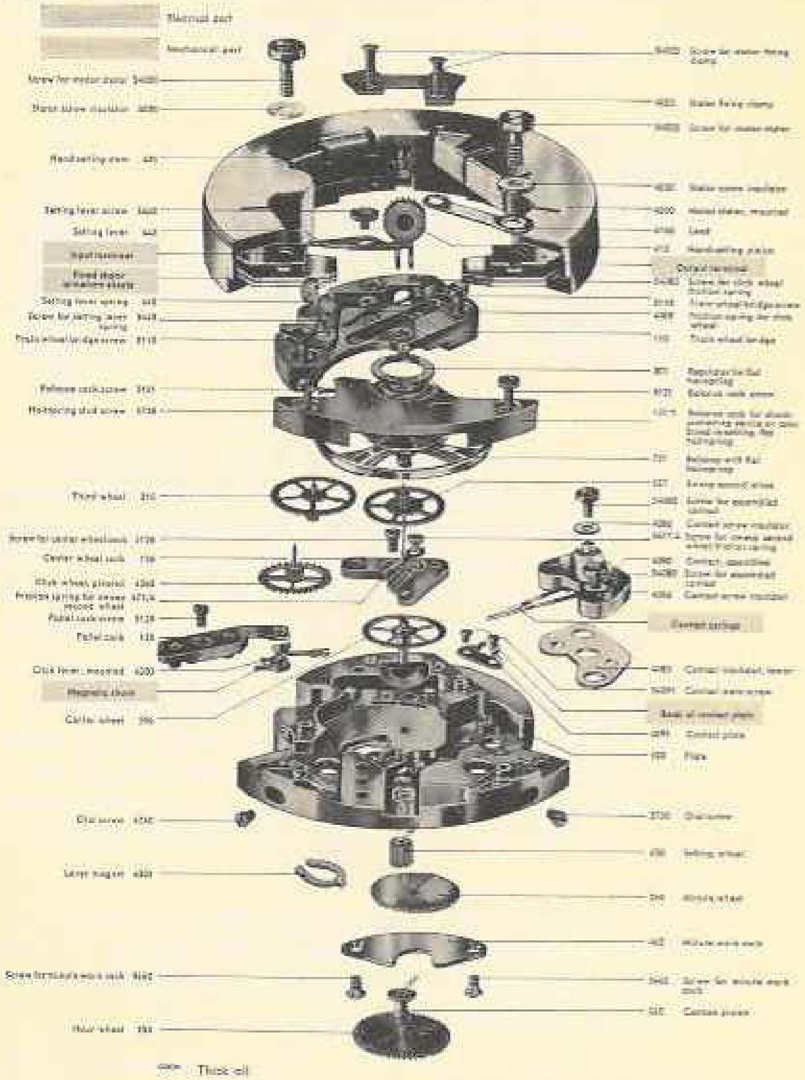
Figures 1 and *2* show the movement and dial sides of the watch. Unlike the Lip or Hamilton electric watches, this model's sweep seconds hand shows true minutes and seconds each minute. The watch's balance vibrates at the traditional rate of 18,000 beats an hour, and the seconds hand advances in increments of a fifth of a second each beat. It will thus indicate true minutes.

Another feature of the watch is that its battery does not rest in the movement but in a recess in the case back. (*Figure 3*). It can thus be replaced without disturbing the rest of the watch. This feature also eliminates the possibility of damage to the movement, should the cell become leaky or otherwise deteriorate. The figure shows the cell screw cover, the electric cell and the back itself.

The watch balance is a motor type, propelled by electromagnets situated on the movement at either side of the balance. The electrical power is supplied by a Mallory WD-4 cell of between 1.35 and 1.5 volts for cal. 4750; WD-5 cell for cal. 4751.

Figure 4 shows an exploded view of the movement. The electrical unit has a coil of 17,000 turns of insulated copper wire .04 mm thick, wound around a curved bobbin. The bobbin's core is Mumetal, a permeable alloy ideal for electromagnetic duty since it will "absorb" much magnetism, yet demagnetize when the current is terminated or interrupted.

The components of the watch



Unit Sealed

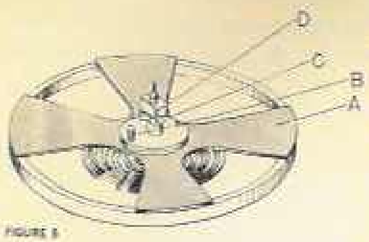


FIGURE 5

The unit, identified as motor stator 4020 in chart, is sealed in molded plastic (nylon) and is not shown in detail. The seal protects the unit and allows it to be immersed in the usual cleaning solutions without damage.

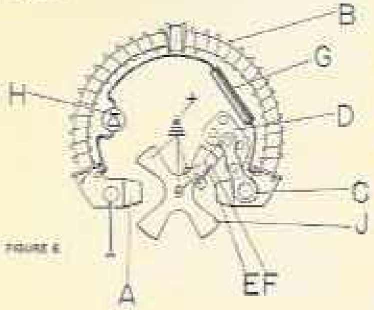


FIGURE 6

Sealed within it, across the coil terminals, are a resistor and a germanium diode to suppress the spark of parting electrical contacts. This, as will be explained later, reduces wear and carbonization at points where the "make" and "break" of contacts take place.

Figure 5 shows the balance (bottom view) which is similar to an ordinary screwless balance with the usual flat hairspring. Soldered to the bottom, however, is an additional four-winged section (*A*) of mumetal, the rotor. The roller jewel (*B*), unlike the D-shaped jewel-pin in mainspring watches, is cylindrical. Moreover, it does not receive power from the pallet fork, but instead imparts motion to it.

Above the level of the cylindrical jewel pin is a safety roller (*C*), which functions as in traditional watches, to prevent overbanking. Mounted above it is an additional part, the contact roller, which provides a necessary electrical contact. For this purpose a high-conducting metal tab is attached to one of its flat sides. This can be seen at *D* in *Figure 5*.

Figure 6 shows a schematic view of the electromagnetic system. The stator wings *A* rest close under the rotor wings of the balance, and are separated from them by an air gap. Around the stator is the coil *B*, each end of which terminates at one of the stator wings. A metal lead *C* goes from the stator to the contact unit *D* and the springs *E* and *F*, which are touched by the tab on the contact roller. G is the resistor, connected in series with the diode *H*, the ends of which are connected across the two terminals of the coil stator.

The electric circuit begins at the energy cell (+) and travels into the hairspring stud through the balance staff, and into the contact roller (*C*, *Figure 5*). When, as part of the balance motion, the tab on the contact roller makes contact with the contact springs *E* and *F*, the electrical circuit is completed and the coil is energized. The stator arms, now electromagnets, attract the rotor wings *J*. As the balance continues its excursion, the contact is broken, and the balance continues in its arc by momentum alone.

Contact System

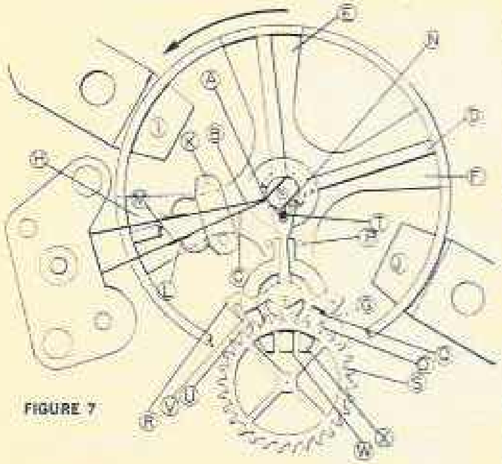


FIGURE 7

The electrical contact system and the method of moving the train of wheels are different from other electrics such as Lip, Hamilton or Elgin because the electrical circuit is completed with each swing of the balance in each direction. *Figure 7, 8 and 9* illustrate the principles involved.

In *Figure 7*, the balance is turning counter clockwise. The tab *A* on contact roller has made contact with contact springs *B* and *C*, and the circuit has been completed.

The contact springs normally are curved slightly inwards towards each other, and when they press upon each other, as here, they present a straight but slightly tensed appearance.

Fastened underneath the four thin arms *D* of the balance is the magnetically permeable rotor section with its four wings marked *E*, *F*, *G* and *H*. Situated on the movement, and projecting a bit underneath the balance, clearing it by a small margin, are the fixed armature stator sheets, *I* and *J*, diametically opposite each other.

In *Figure 7*, what appears to be a banking for the contact springs *B* and *C*, is really an additional means of assuring electrical contact and a provision for "breaking" the circuit without spark or deterioration to important parts. This unit is composed of a contact plate *K*, and the beaks of the plate, *L*. Situated in the mid-section of each of the contact springs *B* and *C* are reinforced sections *M*.

Since the electrical circuit is complete, the coil has become an electromagnet. This causes its armature sheets *I* and *J* to attract the rotor wings *E* and *G*.

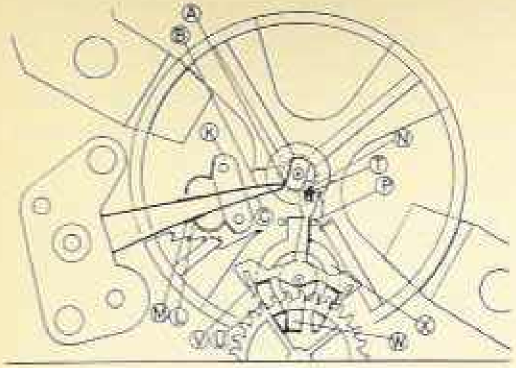


FIGURE 8

In *Figure 8*, the balance has been drawn further counterclockwise by this attraction. The contact tab *A* has passed contact with spring *B*, which is now idle. The circuit is complete, however, because the tab still makes contact with spring *C*. In addition, the tab has forced the contact spring *C* over a bit, and now its reinforced section *M* is making contact with the beak *L* of the contact plate *K*. The contact plate is grounded, and when the springs make contact with the plate *K* through *L*, the circuit is reinforced.

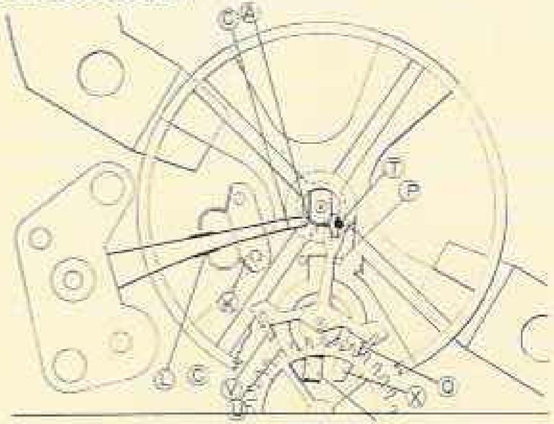


FIGURE 9

In *Figure 9*, the contact tab *A* is just about to drop off from the contact spring *C*. If it were not for the contact plate, the circuit would be broken when this occurred, and despite the presence of a resistor and diode for spark suppression, a light sparking would still appear. This would deteriorate the tips of the springs, shorten them, and upset the adjustment. However, the circuit is not broken at that location even though tab *A* has parted from the contact springs because for a split second, spring *C* is still in contact with the beak *L* of the contact plate *K*. The spring now returns to its original position against the contact spring *B* and free from contact plate beak *L* and tab *A*, and the circuit is broken. Thus, any sparking that does take place occurs at the plate and the reinforced portion of the springs at *M*.

Balance Continues

Once the circuit is broken this way there is no magnetic power to deter or propel the balance, which continues by momentum in the counter-clockwise direction. The hairspring then brings the balance to a stop and begins to return it in a clockwise direction, and it reenacts the same set of "make and breaks" in a reverse sequence.

As the balance returns to its original position it first contacts the spring *C* and completes the circuit. The coil is energized, the electromagnetized stator sheets attract the rotor wings underneath the balance nearest them, and accelerate the balance in the clockwise direction. As the balance continues this motion, the tab *A* pushes spring *B* into contact with the other beak of the contact unit *K*, augmenting the electrical circuit and providing for a "sparkless" break in the new direction. To complete the cycle, then, spring *C* flips off contact from the contact tab *A* and parts from it. Then, spring *B* parts contact with the contact tab. And the circuit is broken when spring *B* parts from the beak of the contact unit at its reinforced section, *M*.

Indexing

So far, we have explained the electrical system and principle. Now we can show how the hands are moved by the balance.

Since the balance in electric watches is considered the motor, it is this unit which must drive the train of wheels, and through it, the hands. The term "indexing," therefore, will be used here to indicate the movement of a tooth in the train of gears by the action of the balance.

Parts will now be called by their functional names, rather than by the terms associated with their traditional, lever watch counterparts. Therefore, *R* in *Figure 7*, which resembles a pallet, is officially the *click lever*, and the wheel with which it works, resembling a new form of escape wheel *S*, is the *click wheel*. *T*, which resembles a roller jewel, is the *indexing pin*.

In *Figure 7*, the indexing pin *T* has entered the fork slot of the click lever *R*. The click-lever jewel *Q* is flush with the surface of the tooth *O* of the click wheel *S*. When the indexing pin *T* on the balance moves the click lever over (*Figure 8*), the slanted surface of the click lever jewel *Q* will move the click wheel clockwise. The index jewel pin *T* has not yet left the click lever slot, nor has the lever fork reached the banking pin *P*. The guard finger *N* is still inside the crescent of the safety roller on the motor balance.

In *Figure 9*, the motor-balance has moved further so that the indexing jewel pin *T* is just about clear of the click lever's fork slot, and the lever has made contact with the banking pin *P*. The click lever jewel *Q* has entered more deeply into the click wheel, but has not moved it any further.

The tooth *U*, however, is positioned directly under the thick lever jewel *V*. Now, when the balance returns in the clockwise direction, and the indexing jewel *T* enters the click lever fork slot, the click lever jewel *V* will enter upon the left-hand, slanted top of the click wheel tooth *U* and move the clickwheel one unit clockwise. Attached to the click wheel is a pinion (not shown), enmeshed with a wheel upon which is mounted the sweep seconds hand. Each movement of the click lever thus moves the seconds hand one fifth of a second forward.

Magnetic Banking

In mainspring watches, where the train wheels move the balance, the lever is held against the banking pins and guard finger, clear of the safety roller's edge by the angle of draw and the incidence of angles between the pallet jewels and the escape teeth. Since these conditions don't obtain in electric watches, the banking action is performed magnetically.

Fastened to the underside of the click lever (*R*, *Figure 7*) and moving with it, is a magnetic shunt *W* made of permeable metal. Below the magnetic shunt and fastened to the movement is the lever magnet *X*. This is the only permanent magnet in the watch.

In Figure 7, the tab of the magnetic shunt is centered between the prongs of the horseshoe lever magnet *X*. When the indexing jewel moves the click fork, the tab of the magnetic shunt *W* is drawn to the left prong of the lever magnet (*Figure 8*).

When the indexing pin *T* leaves the click lever fork slot, it will permit the magnetic shunt tab to be drawn as far as it can, overlapping the prong of the lever magnet (*Figure 9*). At the same time, the click lever fork will come to rest against the banking pin as shown.

When the balance returns in the clockwise direction, the indexing pin will move the click lever away from its magnetic banking and cause the extending tab of the magnetic shunt to be drawn towards the right prong of the horseshoe lever magnet *X*. To prevent the click wheel from moving by itself, a tension or friction spring is positioned on the train bridge, directly above the upper click wheel hole jewel. This presses upon the upper click wheel pivot, much as a backlash spring presses against a sweep fourth pivot.

BEFORE BEGINNING a rundown of overhauling and servicing procedures, it will be useful to show the hack action by which the watch is stopped.

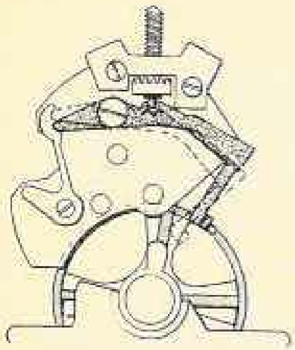


Fig. 10. Stopping of the watch by a hack action.

Figure 10 shows the stem connected to a simple wheel resembling the lower half of a clutch wheel turned around. When the stem is in the normal position, shown here by the dotted outline of the blocking lever, the balance may turn freely. When the stem is pulled into the setting position, the lever blocks the balance in such a way that the circuit is incomplete, and no current flows from the energy cell.

This allows the watch to be set to the seconds, and also permits it to be stored without any drain on the life of the cell.

It is important to understand the function of this and all parts heretofore described, so that repairs, replacements and adjustments can be made more easily.

Servicing

Replacing the dry cell: Unscrew the lid of the cell compartment with a coin. It should come apart as shown in Figure 11. When fitting the new cell, the positive (+) side should press against the "+" mark engraved on the back of the cell compartment lid. Be certain that strict cleanliness is observed. When checking the voltage of a new (Mallory WD-4, 5) dry cell, a voltmeter should indicate 1.35 volts, but an excess of 0.2 volts in a new cell is acceptable.

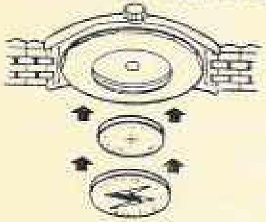


Fig. 11. Replacing the case back battery cell.


Fig. 12. Two "crowns" of the accumulator watch.

Should the electrical source be an accumulator instead of a dry cell, the watch will have two crowns, as in Figure 12. The crown on the right sets the hands. The one on the left covers the recharging socket. To recharge the accumulator, place a new 1.5-volt flashlight battery in the charger (*Figure 13*) as shown, and keep it in contact from 10 to 12 hours.

Tools Needed


Fig. 13. Recharging the accumulator-type watch.

Tools and materials needed for repairs and adjustments: Movement holder, testing block movement holder for the complete movement and a movement holder with battery. Also recommended are rounded, anti-magnetic tweezers with polished insides, for use in adjusting the contact springs.

In addition, instruments for checking the electrical system, such as a volt-ohmmeter with a minimum internal resistance of 20,000 ohms per volt, will be needed. Most materials jobbers have reasonably priced meters to fit these specifications.

The rate of the Swiss Electric may be checked on a conventional watch-rate recorder since the watch has a regular rate of 18,000 beats per hour.

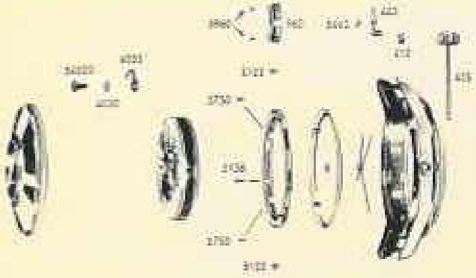


Fig. 17. Removing movement (battery type) from the watch case.

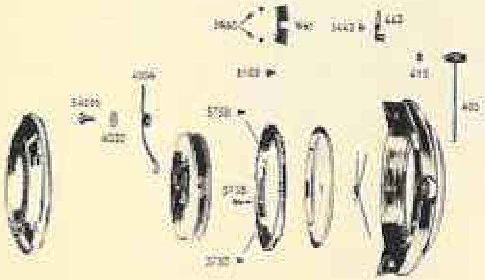


Fig. 18. Removing movement (accumulator type) from watch case.

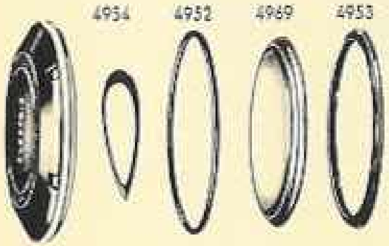
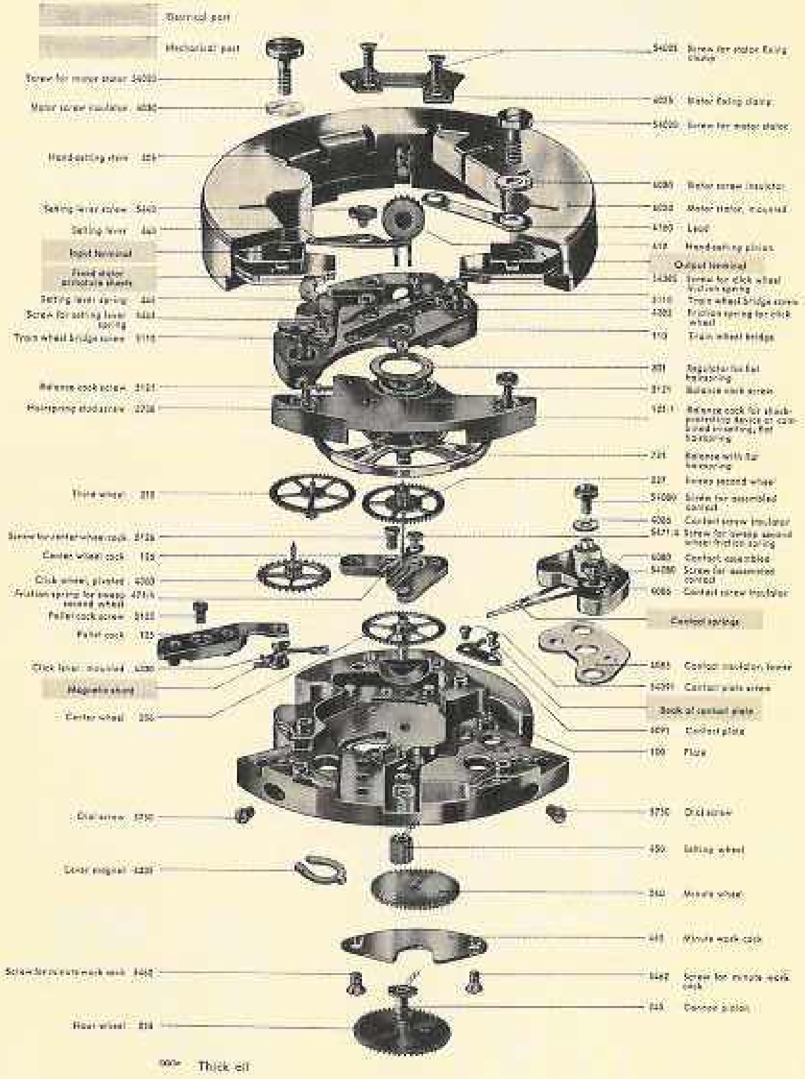


Fig. 19. Replacing the accumulator.

The components of the watch



Removing Case

Removing the movement from the case (battery type): Refer to Figure 17. First remove the cell. Then unscrew the back of the case, remove the feed bridle (4035) and the setting lever (443). Withdraw the handsetting stem (405) and the handsetting pinion (412). Remove the two special case screws (5102) and take the movement out of the case, placing it dial side up on the flat side of the movement holder. Now remove the hands and dial and case bridle (960), loosen the screw of the plate-enlargement ring (5158) and finally withdraw the plate-enlargement ring.

Removing the movement from the case (accumulator type): Refer to Figure 18. Remove the back of the case, but do *not* remove the accumulator. Then remove the feed bridle (4036) of the accumulator and the setting lever (443) and follow the same procedure as in removing the battery type case.

Replacing the accumulator: If the accumulator is oxidized, swollen, or no longer takes a fresh charge, it should be replaced. Referring to Figure 19 unscrew the clamping ring (4953) for the accumulator and then remove the accumulator (4969) itself. Finally, remove the waterproof joint of the accumulator compartment (4952) and the compensation ring (4954).

To reassemble the accumulator, merely reverse the dismantling order, making certain that all parts are clean.

Disassembling Movement

Refer to the exploded view of the Swiss Electric. Place the movement holder and disassemble the hand-setting mechanism and balance shock protectors. Remove the balance cock (121/1) and the balance (721), the pallet cock (125) and the click lever (4330). Now, unscrew the lead (4160), remove the stator fixing clamp (4025) and *carefully* withdraw the motor stator (4020). If there are stator wedges between the laminations of the motor stator and the plate, *carefully* separate the one on the output terminal side of the stator from the one on the input terminal side. This precaution is to avoid interchanging them when assembling the movement.

To complete the disassembly, remove the friction spring for the click wheel (4385), the train wheel bridge (110) and the train wheels, and the center wheel cock (126) and the center wheel (206).

The following parts may be left intact, attached to the plate:

The assembled contact (4080); the contact plate (4091); and the lever magnet (4335). Also, the setting lever spring (445) may be left on the train wheel bridge, and the friction spring of the sweep second wheel (471/4) may be left on the center wheel cock.

Cleaning

Except for the motor stator (4020), all parts of the movement may be cleaned in the watch cleaning machine. The last rinse should consist of isopropulic alcohol or a non-oil based rinsing solution, while preceding baths may be of the usual commercial type. Drying should be done in warm air, and boxwood or cornwood should never be used. If filing particles adhere to the lever magnet (4335), use cellophane tape to remove them.

After any cleaning the click lever (4330) and the click wheel should be given a coating of epilame. Do not apply the epilame to the assembled contact (4080), the contact plate (4091) or the balance (721), since this is liable to insulate the points of electrical contact.

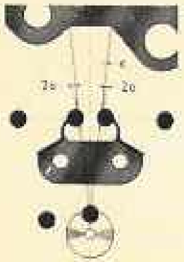


Fig. 20. Clean contact points at "a," "b," "c."

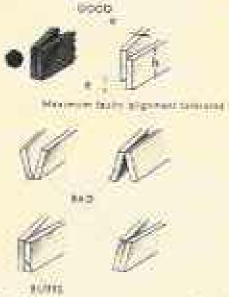


Fig. 21. Align springs flush as in "a" above.

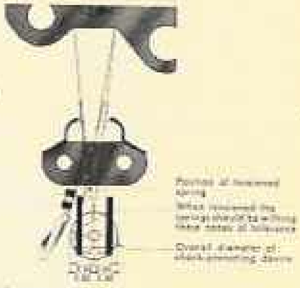


Fig. 22. Check tension pressure so that spring is 0.4 to 0.6 mm away from jewel's center hole.

Before assembling the movement check all the parts and their conditions, replacing any which appear faulty. If any parts in the balance are found to be defective, such as pivots, the finger contact or rollers, then the complete balance should be replaced, since the balance staff cannot be replaced by the watchmaker. Only genuine repair parts should be used.

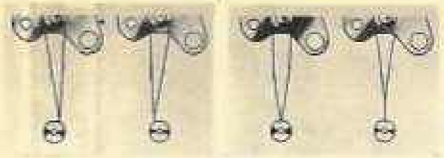


Fig. 23. The blades of the contact springs in each of the above four drawings are all incorrectly aligned or tensioned.

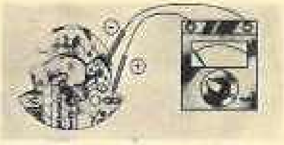


Fig. 24. Check if contact, assembled, is insulated from plate.

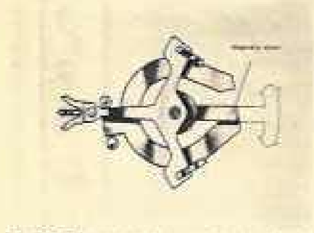


Fig. 25. The recoil of the magnetic shunt must be equal in both directions.

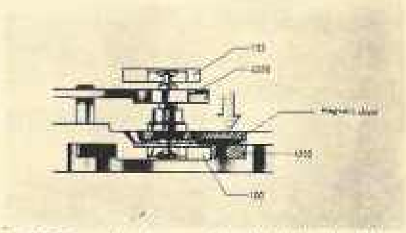


Fig. 26. The recoil can be corrected by bending the shunt down toward the magnet (part 4335) as shown.

Checking and Adjusting

Checking and adjusting the contact mechanism: Place the movement on the side of the movement holder intended to take the main plate. Check for clean contacts at points (a), (b) and (c) of Figure 20. Check the tips of the contact springs with care and, if necessary, correct them to the position shown at (a) in Figure 21 with a pair of contact tweezers. See that the contact springs are correctly centered. The point at which they touch should be in line with the hole in the balance jewel (*Figure 20*).

Check the tension (pressure exerted by the springs as their tips press against each other) of the contact springs (*Figure 22*) as follows: Holding one spring by its free end, draw it away with a pair of tweezers. This releases the other spring, which should automatically shift about 0.4 to 0.6 mm away from the hole of the balance jewel. The amount of this shift should be between half and two thirds the total radius of the shock protecting device. Check the tension of the other spring in the same way.

The space between the contact springs and the beaks of the contact plate should be adjusted by bending the beaks slightly. The space should be equal to twice the thickness of a spring (*2e, Figure 20*). To check this space and the tips of the contact springs, use a pivot loupe, stronger than 10X.

When correctly tensioned and centered, the contact springs should be straight. Springs which are shaped as in Figure 23, bent to one side or the other, or "bowlegged" or "knock kneed" through faulty tensioning, will not work satisfactorily. Finally, make certain that the assembled contact is insulated from the plate. This can be tested by placing the leads of an ohmmeter at the places indicated in Figure 24. The meter should read infinite resistance, practically no reaction from the insulated contact.

Checking the Draw

Checking and adjusting the magnetic recall or draw: Refer to Figure 25. Check the condition of the click lever pivots (4330) and the corresponding jewel holes. Assemble the click lever only. Check the endshake but do not disturb the banking pins or the "pallet" jewels. Now check to see if the magnetic recall or "draw" is the same on both sides by moving the fork of the click lever away from the banking pin. If it is not the same on both sides, equalize the recall by moving the shunt located under the click lever. This can be done only when the click lever is assembled and in the movement. If the recall is too weak it can be adjusted by bending the shunt down towards the lever magnet, which is also done when the click lever is assembled, as in Figure 26.

To identify the parts which are mentioned, see the exploded view.

Train Wheel Assembly

To assemble the train of wheels, first remove the click lever (4330). Now, put the center wheel (206) and center wheel cock (126) in place, and make sure that the center wheel runs true.

Oil the upper center wheel pivot and the upper sweep second wheel pivot (227). Then, assemble the click wheel (4360), sweep second wheel and third wheel (210). Put the train wheel bridge (110) in place, and before tightening the screw, check the tension of the sweep second wheel friction spring (471/4) by lifting the train wheel bridge 0.05 mm. The sweep second wheel should

then run free of endshake.

If the shoulder of the sweep second wheel pivot presses against its jewel, the tension of the friction spring is too great. On the other hand, if there is any clearance between the shoulder and the jewel, the tension is too weak. Screw down the bridge and check that the wheels run free and straight, but do not lubricate the sweep second pivot friction spring.

Before fitting the friction spring of the click wheel (4385), check its tension as follows: Place the spring in position by turning it, and screw it down. If the tension is correct, the end which normally presses on the click wheel pivot will project beyond the surface of the train wheel bridge by about 0.05 mm. If need be, correct it to this position and replace the spring so that it presses against the tip of the click wheel pivot.

Stator and Lead

Before mounting the motor-stator and lead, check the stator for insulation by putting one ohmmeter probe in contact with the input terminal, and the other probe in contact with the laminations. The measured resistance should be infinite, practically no reading at all on the meter.

Check that the contact-protecting diode and resistor (incapsulated in nylon with the stator coil) are in good order. Touch the (+) probe of the ohmmeter to the input terminal and the (—) plug to the output terminal, and mark down the reading. Reverse the position of the probes to get a second reading, and subtract the smaller figure from the larger. The difference should be between 250 and 700 ohms. If there is no difference, then either the *diode or the resistor does not work properly, and the stator unit must be replaced.* If, because of this, the contact finger and the beaks of the contact are burned out the complete balance and the contact plate must be replaced.

When assembling the motor-stator, be sure to insert the stator wedges, if any, on the proper side. Assemble the lead (4160) on the output post. Be sure that there are insulators (4030) under each screw of the motor-stator.

To test the unit, follow the procedures indicated in Figures 27 and 28.

CHECKPOINTS FOR TESTING THE CONTINUITY OF THE CIRCUIT

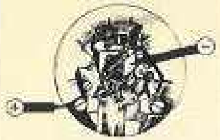
Probe Position	Meter Reading	Interpretation
	R=infinite reading	Circuit is in order
	R=0 ohms	Short circuit on input terminal
	R=1500 to 2200 ohms	Short circuit on output terminal assembled contact

FIGURE 27

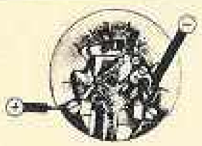
Probe Position	Meter Reading	Interpretation
	R=1500 to 2200 ohms	Circuit is in order
	R=0 ohms	Short circuit on input terminal of motor-stator and on output terminal (or on the assembled contact)
	R=infinite reading	Motor-stator useless, broken winding. Replace stator unit

FIGURE 28

Short Circuits

Among the most frequent reasons for short circuits on the input post are a missing insulator (4030), a current supply bridle (4035 or 4036) which touches the thread of the stator screw (54020) or foreign matter between the motor-stator and the post.

On the output post, shorts may be caused by a missing insulator, a lead (4160) which touches the thread of the stator screw or foreign matter such as filings between the screw and output post.

If a short occurs on the assembled contact, it is likely that an insulator (4086 or 4085) is missing, that the contact springs touch one or both beaks of the contact plate (4091) or that foreign matter is between the contact assembly screws (54080) or the contact assembly and the plate (100).

To assemble the setting parts, first replace the hand-setting pinion (412), lubricate the hand-setting stem (405) and insert it. Then, screw the setting lever (443) in place and oil the functioning part of the setting lever spring (445).

The click wheel (4360) is oiled by applying a small amount to every third or fourth tooth, after which the click lever (4330) is replaced.

Assembling Dial Train

Oil the post of the setting wheel and minute wheel. Replace the dial train and fix the minute work cock (462). Check the side- and end-shakes and turning freedom before oiling the center wheel (206). Also oil the cannon pinion (245) and replace it, being careful not to damage the minute wheel teeth and making certain that friction on the pinion is *less* than in a mainspring watch.

Assembling Balance

Mark the position of the stud on the balance in ink. Besides recording its position, this will also help to check on the balance amplitude. Oil and replace the balance jewels, making certain that the contact finger is clean and upright, and replace the balance.

Check the endshake of the balance, which should not exceed 0.01 mm if the watch is to run without noise in the oblique positions. Check the fork, roller, finger and contact spring interaction.

Check the air gap (the space between the armature soldered to the underside of the balance, and the terminals of the stator). This should be between 0.09 and 0.17 mm, or one-half to three-quarters the thickness of the armature, as in (B) of Figure 29.

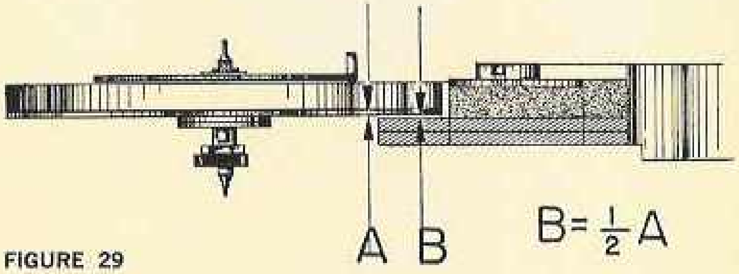


FIGURE 29

By adding stator wedges (4040) between the plate and terminals, the air gap can be adjusted. Stator wedges of 0.02 mm, 0.04 mm and 0.06 mm are available.

Now pass the complete watch movement through a demagnetizer. This will not harm or diminish the magnetic properties of the click lever, which contains the only permanent magnet in the watch.

Oil the balance pivots, the third wheel pivots (210), the sweep second wheel pivots (227), and the click wheel pivot (4360). To oil the upper pivot of the click wheel, raise the friction spring (4385) and drop a little oil around the pivot. Withdrawing the oiler, apply the rest of the oil drop to the lower surface of the friction spring, where it is in contact with the click wheel pivot.

Checking Movement

Check the freedom of the balance by turning it as far as it will go and releasing it. Then count the number of complete oscillations to the moment when the train wheels stop. This should be between 30 and 35 (about six or seven seconds).

If the number is smaller, the electrical consumption will be too high. So be sure that the movement has been properly demagnetized, and that the stem is not in the setting position. Check the air gap, endshakes, lubrication of the movement and cleanliness in general.

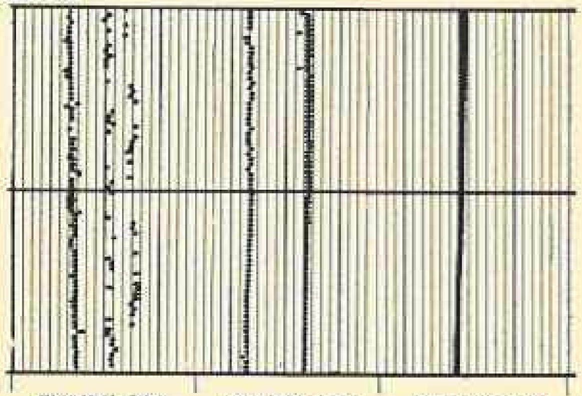


FIGURE 30A FIGURE 30B FIGURE 30C

If the dots are out of alignment (*Figure 30, A and B*) on the instantaneous rate tracing of the timing machine, the magnetic return action is improperly adjusted. A well adjusted and aligned watch should draw a tracing as in Figure 30, C. For adjustment, see, "Checking and Adjusting."

Replace the plate-enlargement ring (158), and mount on it the casing bridle (960) and the two special screws (5102), depending on the case model, and replace the hour wheel (225), keeping its dial washer under slight tension. In replacing with a new dial washer, make certain that the new one isn't under excessive tension.

Final Assembly

Fit the dial and hands. Remove the setting lever (443), the hand setting stem and the setting pinion (412) to fit the movement into the case, and replace the parts—stem, pinion and lever—and tighten the movement with the special fixing screw.

Fit the current supply bridle (4035 or 4036) with regard to the case model. Check the voltage of the battery. Then recase, using the reverse procedure of decasing.

Oscilloscope Useful

Some watchmakers are now using an oscilloscope for checking and trouble shooting electric and electronic watches. When the movement or watch is placed on the oscilloscope holder, a "trace" or "scope pattern," shows on the face of the tube, much the same way as an image is traced on the screen of a television tube. This "scope pattern" represents the flow of current in the contact system.

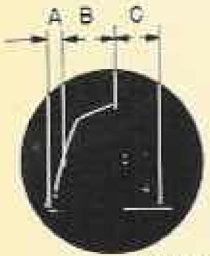


FIGURE 31

FIGURE 32

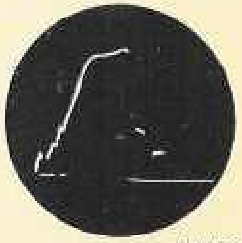


FIGURE 33

FIGURE 34

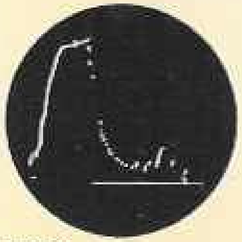


FIGURE 35

FIGURE 36

Figure 31 shows a very good trace. Such a pattern is characteristically divided into three phases. Phase "A" represents the initial single contact made between the contact finger and the contact springs. As the current reaches a peak for this contact, it enters the "B" phase which adds to the first contact current a reinforcement from the contact between one of the springs and the corresponding beak of the plate.

Phase "C" represents the "rebound" when the spring finally parts from the contact finger and vibrates. This damping vibration causes a few, very brief contacts between the springs and the beaks of the contact plate.

Figure 32 shows a scope pattern which indicates badly centered contacts. A series of non-superimposed images appears, formed of alternately large and small images. To correct this disorder, center the springs.

The scope pattern in Figure 33 indicates that the contact between the contact finger and springs is faulty. The line corresponding to the "A" or single contact phase is broken in several places. Remedy: check the contact finger and the tips of the springs as well as the tension of the springs. Note that the contact between the finger and the springs is often faulty on only one side, so that poor oscilloscope images as this one will alternate with good ones.

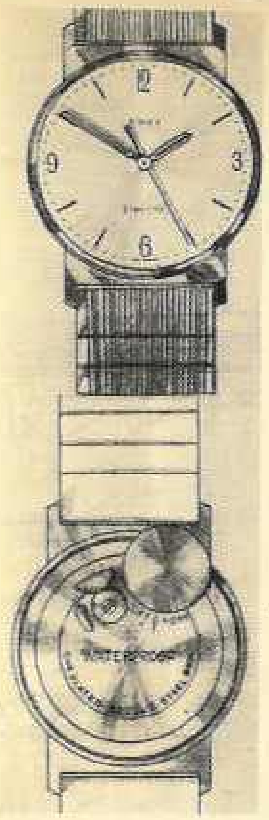
The trace in Figure 34 indicates that the contact has been broken at the start of the double contact phase. To correct this, check the cleanliness of the springs and the contact plate beaks, and check the distance between them.

Figure 35 indicates excessive rebounding. To correct this, check the cleanliness of the contact plate beaks and springs, the tension of the springs and their distance from the beaks.

Figure 36 shows an assortment of poor contacts and other defects. Check the entire contact assembly, including tensions, cleanliness, spring centering and shape, and distances, following the instructions of previous articles.

While some of what has been described may see strange and complicated, the Swiss electric is actually a simple watch, and close examination of it will dispel any doubts. Were an apprentice to be instructed in such a watch before mainspring and escapement watches, he would master the repair of this electric very quickly.

THE TIMEX ELECTRIC *(DUROWE)*



FIGURES 1 and 2

Dial and case back sides of the Timex electric watch. Battery lid can be pried off to replace batteries. Hand setting button is pulled out to set hands, also opens the electrical circuit for storage.

THE TIMEX CALIBRE 861 is the lowest-priced electric watch on the market. It has some novel and noteworthy features.

Like all electrics, this one has a battery for its energy source. The movement comes out of the one-piece case after the crystal has been removed by a crystal constrictor. The battery may be removed by prying off a waterproof snap-on lid, shown in Figure 2. This is done with a case knife. A setting button, also shown in Figure 2, is pulled out to set the hands.

The movement (*Figure 3*) is 30.5 mm in diameter, with the edge of the battery extending an additional 2.5 mm. This is allowed for in the case design.

The watch beats 21,600 vibrations per hour, or six beats per second, but the seconds hand jumps ahead in full second increments. The watch has a hack mechanism to stop the balance and to break the electrical cir-

FIGURE 3

The Timex movement with battery removed and negative contact visible in the battery recess.

cuit. This permits setting the hands to the second and allows storage without drain on the energy cell.

Electrical System

A flat, hollow, electromagnetic coil is mounted on the balance (similar to Hamilton) to act against a strong, flat sector-magnet and a shunt. The contact mechanism consists of a roller pin on the moving balance, which acts upon a contact spring on the movement.

The balance has an unconventionally "Y" shape, with the tail of the "Y" carrying a concentric rim sector, diametrically opposite the mounted, washer-shaped coil. The balance is shown bottom side up in Figure 4.

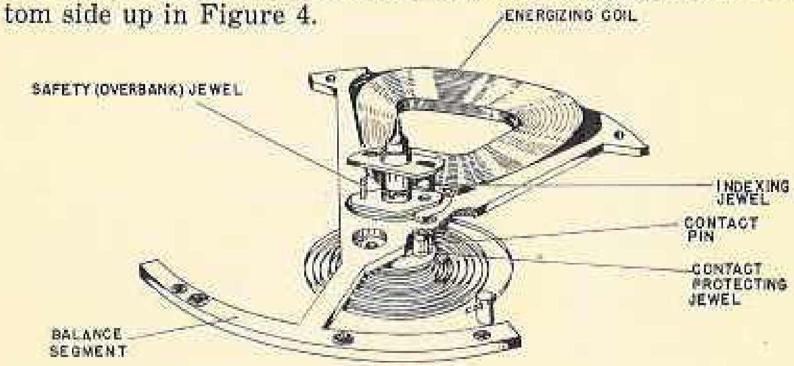


FIGURE 4

Y-shaped balance of the Timex electric is of large diameter, overlaps center of the movement. Energizing coil is fixed by epoxy to arms of the Y. Four jewels serve to index train gears, insulate, aid against overbanking.

It is a motor balance, containing four jewels and one metal pin. The D-shaped indexing jewel moves the index wheel one notch with each complete oscillation. The cylindrical, thin safety jewel is at a lower level than the indexing jewel, and almost diametrically opposite it. It works with the fork of the overbanking lever. Insulating the metal contact pin from the balance is a hole-jewel into which the contact pin is set.

Directly behind the contact pin and parallel to it is a wide, D-shaped contact-protecting jewel which acts as a guard and a "wipe" for the contacts. Since the coil is hollow, little sparking will occur at the contact breaks. Whatever carbonization does appear on the contact spring will be wiped off before the spring contacts the metal pin in front of the jewel.

North Poles

The coil winding and contacts are so arranged that a North magnetic pole is presented to the strong, permanent magnet on the movement below.

This permanent magnet (*Figure 5*) is designed so that its South pole is in the center, while both ends are magnetically North. Thus, when the balance coil moves to either end of the magnet, the contact circuit is completed and the coil obtains the same polarity as the end of the permanent magnet. Since like charges repel, the coil is pushed in the direction indicated as it moves over either end of the magnet and the balance receives a magnetic impulse in each direction.

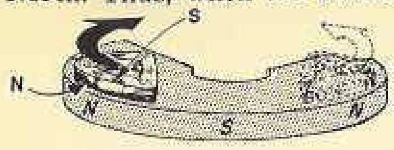


FIGURE 5

Permanent magnet situated in main plate of the movement has one South pole at center, North pole at each end. Coil provides a North pole on bottom, South pole on top, causing balance to be pushed from each wing section of magnet in direction of arrow.

Function and Servicing

Figure 6 shows how to remove the movement for servicing or regulation. Before doing this, extricate the battery and unscrew the setting button screw to remove the setting button.

Remove the crystal, turn the watch dial side down, and the movement should drop out. If it doesn't, a push on the setting arbor through the back of the case will force the movement outward.

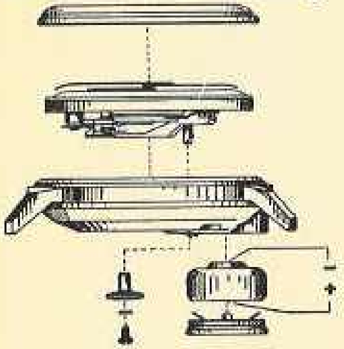


FIGURE 6

Removing movement. Crystal must first be removed with a constrictor. Negative lead (–) is battery's top dome, positive lead (+) is battery casing.

If the watch case has no battery lid, the battery and its components can be removed from the recess in the case back, and the movement dropped out as before. Never attempt to remove the case back itself on any model, since it is fixed in place with epoxy resin.

Once the movement is uncased, place it on a movement rest and remove the upper shunt (*A in Figure 7*). The function of the shunt is to contain the magnetic lines of force and to shield the hairspring from them. As you remove the shunt bridge, take care not to misplace the cup-shaped washer under the large screw on the right.

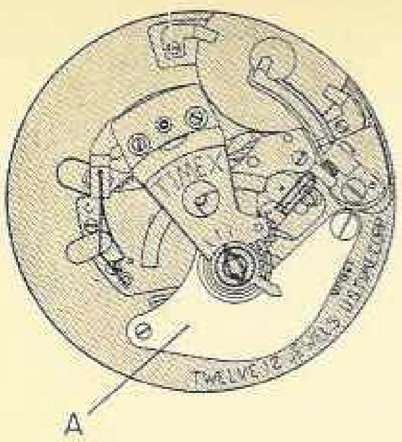


FIGURE 7

Shunt bridge protects the hairspring from electromagnetic coil on balance, contains lines of force of coil and permanent magnet.

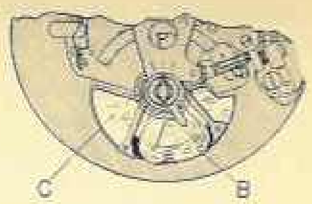


FIGURE 8

When shunt bridge is removed, the balance, coil and sector-shaped permanent magnet below are visible.

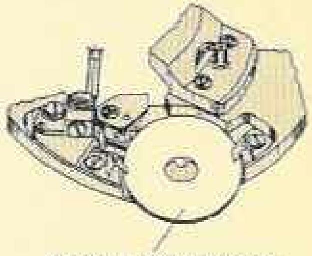


FIGURE 9

Before replacing battery, make certain that plastic insulating cap is in position shown.

When the shunt bridge is off the movement the construction of the driving parts can be seen more clearly. The large balance (*Figure 8*) with its driving coil (*B*) and the large, sector-shaped magnet (*C*) under the balance can also be seen.

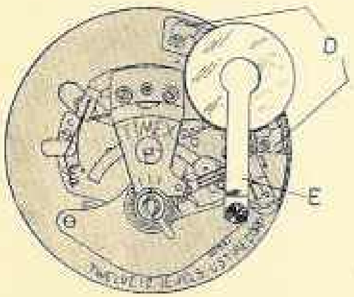


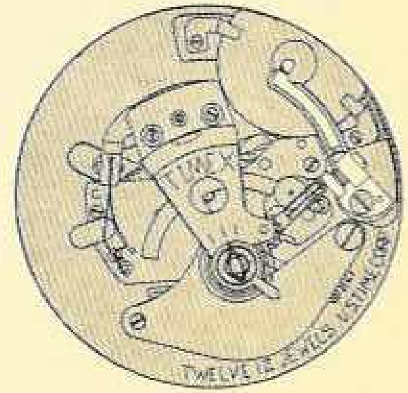
FIGURE 10

To observe watch in action outside case, place battery clamp E over flat end of the dry cell.

The battery may now be clamped to the movement. Make certain that the battery insulating cap is at the position shown in Figure 9. The battery can be clamped in place by a holding spring (*E in Figure* 10), supplied on request from Timex

FIGURE 11

Negative contact unit is insulated from movement. Battery is placed over the prong of this contact, blue dome downward. Do not allow shaded and unshaded sections to connect.



Connections

Be certain that the negative battery lead (center dot in the curved, blue top section of the bottom) touches the battery contact spring, which is insulated from the movement. The positive battery lead (metal casing) must touch the two side battery springs, which are grounded to the side of the movement. Never cause any metallic connection between the shaded and unshaded parts shown in Figure 11, as this will short-circuit and shorten the life of the battery.

For earlier Timex electric models, the same procedures are followed, except that the battery insulator and the two side battery springs are not used.

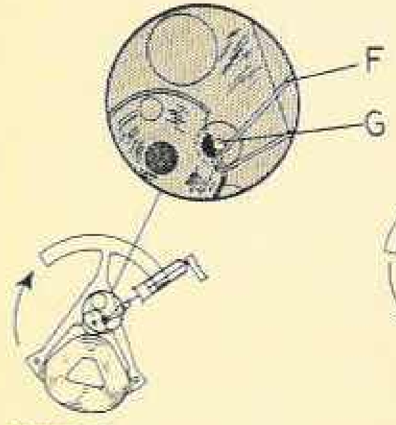


FIGURE 12

During the clockwise action of balance, the contact guard jewel behind the contact pin G keeps the loop contact F away from pin until balance coil is over proper part of permanent magnet.

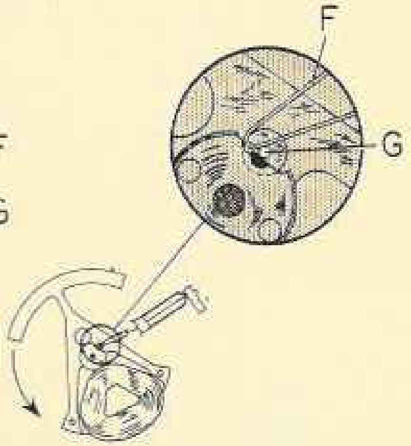


FIGURE 13

The inset shows enlarged view of loop contact and depicts purpose of the guard jewel.

Figures 12 and 13 show how the looped contact spring (*F*) makes contact with the contact pin (*G*), connected to the terminal of the balance coil. The contact spring is first touched by the edge of the D-shaped jewel behind the contact pin. This keeps the circuit open until the coil is in position over a wing of the magnet below. The looped spring (*F*) then flips off the D-jewel and onto the contact pin (*G*), completing the circuit. The coil is energized and propelled further along in the same arc it was traversing at the point of contact.

The D-shaped jewel performs the dual function of wiping away carbonization from the looped spring and delaying contact until the coil is over a North pole extreme of the permanent magnet. If any work is to be carried out on the movement, the battery must be removed to prevent the possibility of a short circuit.

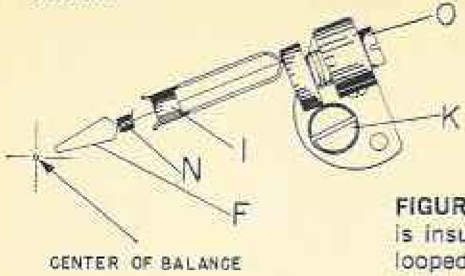


FIGURE 14. Contact spring assembly is insulated from the movement. Point looped front spring directly to center of balance. Do not dismantle unit.

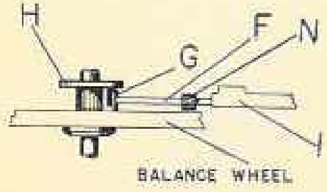


FIGURE 15. Contact unit must be level and centered between roller plate H and balance wheel. Make sure that it remains perfectly horizontal.

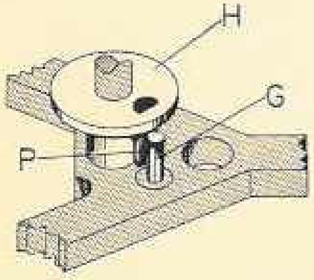


FIGURE 16. Detailed view of contact pin G and its contact-wiping guard jewel P, held in roller plate H.

Figure 14 shows the contact spring assembly. The contact spring must point exactly to the center of the balance staff and should be centered horizontally between the contact disc (*H, Figure 15*) and the balance wheel.

The forked spring protector (*I*) should be adjusted so that the contact spring is exactly in the center. The contact spring itself demands very careful treatment. Don't scratch or deform it. Don't rub, grind or polish it. In short, treat it just as you would a hairspring.

After removing the large screw (*K*) and the insulating washer beneath it, pull out the complete contact spring assembly and the insulating plate. You need not further dismantle the *loose* damping spring (*N*) and the spring protector. The contact adjusting screw (*O*) is fixed in place and should not be turned.

Remove the balance cock and the balance wheel with the same delicacy you would any watch. Be particularly careful when you remove this unit, since the balance's lowest roller may be stuck against the overbanking lever, with its safety pin jewel underneath the lever. Be equally careful with the contact pin (*G, Figure 15*). This pin is protected by the contact guard jewel behind it, as well as by the roller plate above (*H, Figures 15 and 16*).

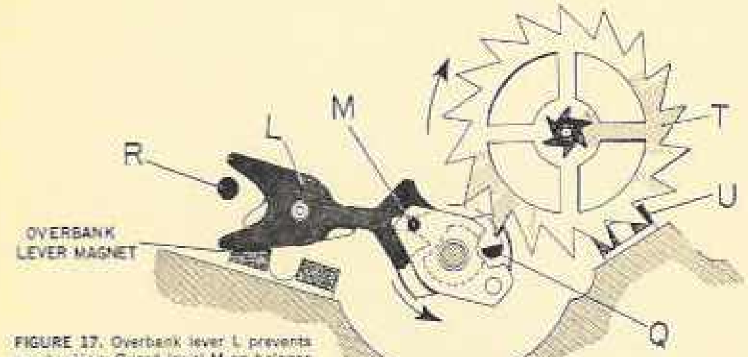


FIGURE 17. Overbank lever L prevents overbanking. Guard jewel M on balance shifts so that alternate parts of lever fork lock in place over magnets. Pin R limits lever's arc. Indexing jewel Q is about to move one tooth of index wheel T, which is limited to one tooth at a time by double magnets U.

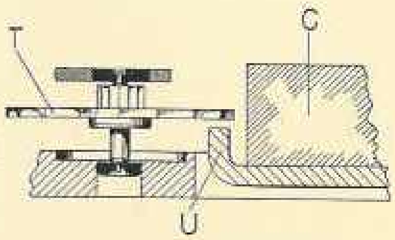


FIGURE 18. Side view of indexing wheel T and positioning magnet U, which is attached to permanent magnet C.

Overbanking Mechanism

Figure 17 shows the mechanism to prevent overbanking, used in the calibre 861. It is absent in earlier calibres. The overbank lever (*L*) is operated by the jewel (*M*) on the balance assembly, and is limited in its motion by magnets. It pivots in a hole near the fork.

When the overbank lever is in the position shown, the magnet on the left attracts it. When the lever shifts over to the other side, the front of its fork is attracted and retained. The overbanking pin (*R*) limits the amplitude of the lever in the same way a banking pin does in a conventional watch. The safety guard overbanking action is similar to that in a clock with balances. No guard finger is needed.

Gear Train

Next inspect the gear train. It is driven by the D-shaped index jewel (*Q, Figure 17*) on the balance assembly. This jewel moves the index wheel (*T*) one tooth with every oscillation of the balance.

As long as the index jewel is not in contact with it, the index wheel is held in rest position by magnetic attraction between it and the arm of the lower shunt (*U, Figures 17 and 18*).

In Figure 19 we see how the indexing works to move the seconds hand ahead in full second increments. The balance vibrates 21,600 times an hour, or six times a second. The indexing jewel on the balance moves a tooth of the index wheel one notch on every other vibration, i.e., when the balance turns in the counterclockwise direction. Thus, a tooth of the index wheel (*T*) jumps one space every third of a second.

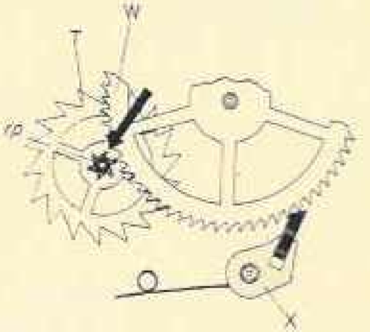


FIGURE 19A. Indexing sequence, by which sweep seconds hand jumps ahead in second increments, begins as ratchet pinion rp is moved toward position against tooth of sweep wheel W. Sweep wheel teeth are concave to allow considerable leeway for ratchet pinion. Wheel is held in position by jump jewel X. Wheel T is held by magnet.

In figure 19A, the shaded arrow points to the rachet shaped pinion (*rp*) of the index wheel. The sweep second wheel (*W*) has teeth cut to allow considerable movement of this pinion.

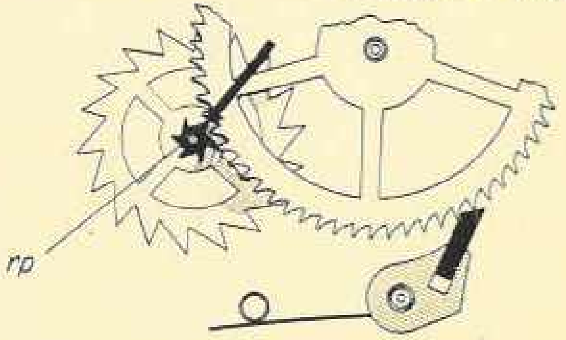


FIGURE 19B. Tooth of index wheel has moved one space. Ratchet pinion now midway between wheel W teeth (arrow).

In Figure 19B, the index wheel has moved one tooth (observe the spoke of the wheel). Notice that the tooth of the rachet pinion is midway between teeth of the sweep second wheel, as indicated by the arrow.

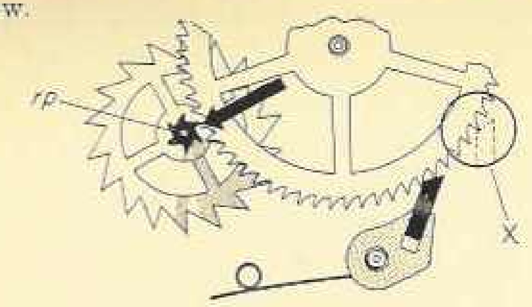


FIGURE 19C. One more indexing and ratchet pinion comes to rest against flank of next sweep wheel tooth. On next indexing, spring-loaded jump jewel is pushed aside (see inset) and then moves sweep wheel one-second space. This happens at every third indexing of wheel T and at every sixth oscillation of the 21,600 vibration balance.

In Figure 19C another index wheel tooth has advanced, lodging a ratchet pinion tooth against a sweep second wheel tooth. The next index tooth to advance will cause the pinion to move the sweep second wheel. At this point, the spring-loaded pawl jewel (*X*) will be pushed aside (see inset). This will cause the pawl jewel to jump the sweep second wheel a full tooth, much in the same way the calendar dial of a calendar watch jumps.

Do not try to adjust the index wheel pinion to the index wheel. This has been done at the factory, and the relationship is critical. When assembling, do not increase the air gap between the index wheel and the lower shunt arm. If the sweep second wheel is adjusted, the tension of the spring-loaded jump or pawl jewel should not be changed. It is also pre-adjusted.

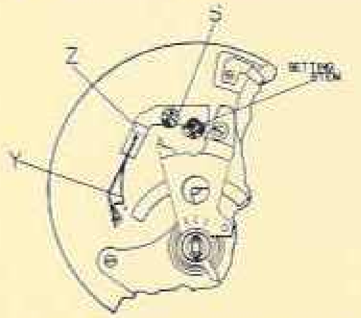


FIGURE 20. Hand setting system stops watch at split second, allows storage without power loss. Setting stem has a conical section which is raised or lowered to shift setting bar Z, pivoted at S. Spring Y is kept away from moving balance when in running position.

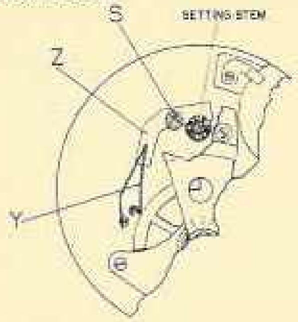


FIGURE 21. When hand-setting stem is pulled out, conical section pushes right arm of lever Z up, lower section swings inward. Spring Y, pivoted at S, swings in toward balance and is held by pin which catches spring's hook. Front corner of hook catches pin protruding from balance and stops it in open-circuit position.

Hack-Device Simple

The function of the hand-setting device and hack mechanism is very simple, and needs no further explanation. The balance-stopping spring (*Y, Figures 20 and 21*) contacts the balance-stopping pin only when the setting stem is pulled out.

The balance stop lever which holds screw S in Figure 20 has a left hand thread. After removal of the balance stop-lever assembly (Z) and the other parts, only the magnet (*C, Figure 22*) and the lower shunt bridge (*V*) remain on the movement. Don't try to remove them from the plate.

Cleaning and Oiling

Clean the movement in the normal manner, with regular solutions. Clean the balance and contacts carefully, with new, clean solutions. *Do not clean the battery with any liquid.* If necessary it can be wiped with a clean, dry cloth.

Then remove any particles adhering to the magnet. A piece of cellophane tape rolled to a point is useful for this. However, don't do this once the balance is assembled, as you may sever the lead wires of the balance coil. The rest of the movement must also be free of particles, especially steel and nickle, which would stick to the magnets. Large iron or steel tools should not be applied to the magnet and, needless to say, the watch should *not* be demagnetized.

Lubricate the jewel bearings, train pivots and balance when assembling. Also oil the jewel bearing and pivots of the over-banking lever and dial train. The other non-jeweled wheel bearings need no oiling, since the gear train is not stressed as in mainspring watches.

The spring-loaded jump jewel on the sweep second wheel should be oiled so that the teeth become covered with a very thin film. Lubricate the bearing surface of the balance stop lever at the screw, the conical parts of the setting stem and the bearing of the setting stem in the balance cock.

Never oil the contact pin on the balance, the contact ring assembly (spring, damping ring, etc.), the index jewel or the teeth of the index wheel.

Timing

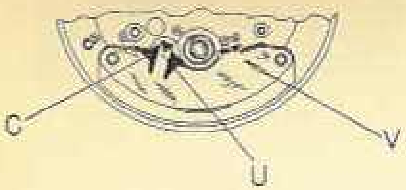


FIGURE 22. In dismantling watch, never try to take apart magnet **C**, lower shunt bridge **V** or magnet **U** which positions the index wheel.

The Timex electric runs best if the hairspring is in light permanent contact with the *inside* edge of the regular key. Don't tamper with this adjustment. On the conventional drum timing machine this watch will show six separate lines. The direction, rather than the character of the lines is important for regulation.

Wavy lines, which will be produced on a continuous tape machine don't indicate poor balance amplitude. They are typical of watches with direct gearing between the balance and train wheels, and do not indicate anything wrong with the timing. The average inclination of the lines indicates the rate.

Repair

When repair is needed, first remove the battery from the watch case and check its voltage. A strength of less than 1.2 volts is too low. Replace any battery which has been in use for a year, regardless of its strength. Its useful life is about over.

Don't short circuit the battery, either inside or out of the watch, by careless handling or by careless metallic connections between the poles.

When assembling the battery in the watch, it is most important that the plastic battery insulating cap be in its proper place. For those interested in the resistance of the balance coil, it is about 2000 ohms.

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vealing its design and method of operation. In teaching the use of a transistor, the Junghans, Ato, Kundo, Semca battery clocks are used as mediums of instruction. The Diehl battery clock repair process serves as a model of instruction in the simple operation of a small D.C. motor. Other types of battery clocks are used where it fits the instructions so that the book also serves as a manual for the repair of the most popular battery clocks as well.

Meters will be used constantly by the watchmaker in the future, and Mr. Fried explains their use in detailed instruction with simple, easy-to-understand drawings.

In the book's main section, the repair of every electric watch is undertaken. Accutron, Benrus, Elgin, Hamilton, Lip, Swiss Landeron, Timex (Laco) are all covered, each as a separate chapter. Each chapter is a separate manual for the repair of that particular watch. The use of proper tools, test equipment, trouble-shooting, adjustment, repair, cleaning methods and precautions are comprehensively covered.

In the exposition of each watch, both the principle of its (electric-electronic) operation as well as the correct repair procedures are followed so that the watchmaker can intelligently approach the successful repair of each watch without fear or reservation.

This book should serve as a bench manual and a must for every watchmaker who intends to service or is now servicing electric watches and clocks. It should serve as a standard text for the student and as a reference for his teacher as well as a guide for group instruction or seminars. Reading this book should also prepare the watchmaker for the repair of all future electric watches since it teaches principles as well.