PART FOUR

The Making of the Modern Watch

Nevertheless there are many different opinions touching the essence of time. Some say that it is the movement of a created thing; others the measure of the movement. . . .

—PASCAL

I

Style Conscious

Even as the clock underwent few mechanical changes during the past two hundred years, so the interior mechanism of the watch has gone without any major improvements in the past one hundred years or more. Most of the improvements have been toward design.

Design for what? For the down-to-earth purpose of creating more sales. Watchcase styling today is as important a factor as the movement itself. This is based on the attitudes and preferences of the public. The public became more concerned about watchcase design than the movement, which it took for granted—just as it was attracted to clocks not because of their movement, also taken for granted, but for the beauty of the case (or cabinet) design. Whether aware of it or not the public's taste was correct and justified. The movement in a watch costing $25 is often of the same quality as the movement in a $4,000 watch, the difference in price being the elaborate styling, the choice of case metal, and the gem decorations.

So alert to this important trend are the manufacturers today that they are directing their efforts to improve even the *shape* of the movement itself in order to assure more attractively formed cases. We shall see how fashion dominates the ancient craft of the watchmaker by visiting a modern factory, observing how the cases are styled, and then how the movements are made to fit them.

There are several outstanding watch factories in America and

Europe which might be considered, but the Gruen Watch Company has been selected because its spans both continents—its factory in Switzerland manufacturing the watch movements, its factory in Cincinnati, Ohio, assembling them into cases. A brief history of the firm is necessary because it traces style evolution from the cumbersome pocket watches, through the period of ladies' lapels and chatelaines, into the age of the wrist watch for both ladies and gentlemen.

It was founded by Dietrich Gruen, born 1847, who as a youth was apprenticed to one Martens, of Freiburg, Switzerland, one of the renowned horologists of his time. In those days apprenticeships were far different from what they are today. Instead of the apprentice receiving wages, the "master" required liberal pay for what he taught. Moreover, such a master took but few apprentices at a time and to be one was regarded as a high honor. It was the age of guild craftsmanship. Later, after having set himself up in business he went through the usual experience of many successful businessmen: organization, partnership, failure, finally taking into the firm his son, Fred G. Gruen, and later another son, George J. Gruen, who is Chairman of the Board of the present firm.

In 1898 the Gruen Watch Company moved to Cincinnati and began its intensive experience with the thing called "style." When the young generation of today thinks of the watch it has the wrist in mind. But we must realize there was a time, just before and early in the present century, when there were no wrist watches. We also must bear in mind that for a while all watch-movement companies in the United States sold their movements uncased and the jewelers purchased the movements and cases separately, just as today some of them buy diamonds separately and have them placed in their own specified ring settings. This firm, however, was selling both movements and cases, but sometimes the cases were for other watch movements. It was not until 1898 that it began selling its products as complete watches, and eventually all American firms were doing the same.

The big problem as watch manufacturers became style-conscious was, of course, milady's watch. Women were less interested in the utilitarian than the stylish. For a while the average woman wore what the trade calls a "six-o size," almost as large as a man's watch. It had a hunting case attached to a chain worn around the neck. Later milady's stylists thought up the watch pocket on the left side of the coat or even of the dress, and still later a smaller "o" size watch (meaning the diameter was 1 5/30 inches) was created by Gruen which became popular because it was lighter and daintier.

Then came the chatelaine watch. This was worn on the outside of the dress or coat but it was attached to a richly engraved pin, the design of the pin matching the design of the watch itself. The chatelaine, produced simultaneously by most American manufacturers, really launched "style" in watchmaking. These manufacturers soon discovered that the ladies were even less interested than ever in timekeeping and more in the attractiveness of the timepiece. Artists vied with each other in creating works of art, so that the watches were hand-chased and set with diamonds, rubies, sapphires, or all gems combined.

When it is borne in mind that the watches retained the hunting case (a cover over the dial of the watch which snapped open), that these cases were heavily chased and further burdened with precious but weighty jeweled ornaments, it is no wonder that women began to complain. On a suit such a watch might be quite attractive but as lighter dresses began to be worn and heavy undergarments were discarded for briefer and lighter ones, the watch inevitably showed signs of "dragging." This was particularly true in the evening when women wore flimsy dresses. The heavily embossed and bejewelled chatelaines simply pulled the upper part of the dress embarrassingly downward. The ladies therefore began to discard watches for wear on daytime or evening dresses, restricting them to suits or heavy winter dresses.

This was a challenge. For a time it seemed as though it would be necessary to discard the chatelaine and revert to the chain around the neck. Watchmakers throughout the world were aware of this problem and were experimenting with a watch that might be attached to a strap tied or buckled around the wrist or forearm. Very little headway was made at first in reducing the size of the movement—reducing the number of parts was out of the question—and efforts were restricted to reducing the bulk of the watchcases.

Attempts to introduce the lady's wrist watch into America were at first sporadic and mostly unsuccessful. Finally an open-faced watch that wound at "three o'clock" was perfected, and although the general consensus of watchmen was that it would be a failure it became popular in a short time.

Many improvements followed, including the octagon pocket watch, platinized dials with numerals in applied solid gold, and then the *cartouche*. The dictionary describes *cartouche* variously as "a cartridge box," "a scroll-shaped ornament," and "a tablet for receiving an inscription, formed like a sheet of paper with the edges rolled up." This describes the new watch form. It was highly significant. It embodied a really notable advance in the construction of movements for *small* watches. Into the oblong case of the cartouche was fitted an oblong movement instead of the usual round one typical of pocket watches. This provided more space, making possible greater size, strength, and accuracy of the parts without detracting from the daintiness or the *smallness* of the watchcase.

Later the quadron was introduced and this, which was a genuine rectangular men's watch movement, had many technical features which allowed all possible case space to be used to secure greater size and strength of parts. . . . "A real rugged strap watch movement for men," it was called. But for a long time the men were not interested. Efforts to introduce wrist watches for them proved failures. They scanned with chary eye reports that European men were wearing wrist watches. Now and then a man appeared in this country wearing one and he ran the risk of being laughed at or slapped daintily on the wrist. Gruen and other manufacturers strove to overcome this prejudice, producing cheaper models in silver. Still the American male remained recalcitrant.

Then along came World War I. The American male began to read reports about the usefulness of the wrist watch just before the "zero hour." At first he paid only passing though curious attention to them. But when Americans went into France, found themselves in the trenches, associating with English and French officers and noncoms, all of whom wore wrist watches as their most prized possessions, the tide began to turn.

(At five o'clock in the morning, as dawn streaked over "no-man's land," as the captain or lieutenant or sergeant glanced at the watch on his wrist, waiting for "zero hour," every man in the command looked anxiously towards his superior . . . the man with the wrist watch. This watch no longer was a piece of effeminate ornamentation: it was the symbol of life-and-death struggle.)

After that the popularity of the male wrist watch swept America. Some men who owned pocket watches even scrapped the big cases and had the movements placed in strap wrist cases. The return of the soldiers to the United States accelerated what at first was a fad, but later became an established and necessary part of a man's daily equipment. The pocket watch, while it did not become entirely obsolete, was now preferred only for dress wear in the evening or as a "gentleman's" rather formal daytime wear.

It was in 1935 that Benjamin S. Katz—and a new and dynamic conception of the wrist watch—came into the picture. The idea of style obsessed him. He was convinced the mechanism of the watch could be "bent" toward style appeal, and he proceeded to apply this revolutionary idea literally. The owner of a chain of six New York photography shops at the age of seventeen, co-organizer of the jewelry firm of Katz and Ogush, and an organizer and first President of the Jewelry Crafts Association—with this background he was thoroughly equipped to challenge the static, stultifying attitude of the industry toward change.

His association with the Katz and Ogush firm, of which he was President until he became head of the Gruen firm, had given him experience and impetus to his ideas concerning jewelry styles. This firm had expanded its operations from diamond and platinum jewelry to watches. At that time he was convinced of one thing: there is no excuse for watches unless they are properly styled, because if a man is interested merely in a timepiece then he ought to carry a small alarm clock around with him. People, he thought, are interested in style—otherwise, how do you account for the clothes they wear? Therefore the firm turned to the manufacture of highly styled watchcases for America's leading watch manufacturers, the prices ranging from less than $100 and up to $15,000 per watchcase.

When he was called upon to reorganize the Gruen Watch Company and become its president he took these ideas with him. He already was aware of this: prior to the advent of the wrist watch the average watch manufacturer made one or two styled watches, with a possible maximum of three; the only change in the style of these pocket watches was that of the engraving. This enabled both the manufacturer of movements and the case manufacturer to turn out very large quantities of one type of watch.

The reason style was not important before the era of the wrist watch was because the watch was concealed in a pocket. A man was not concerned about style, for example, when he had to unbutton an overocat, then his suit coat, reach into his vest, and pull out a watch on a chain to see what time it was—then carefully replace the watch. But wrist watches, because they were exposed, were bound to make the public style-conscious. Despite that, the industry for a time seemed only to remember that they never changed their pocket watch styles—so why change their wrist styles? Thus from year to year virtually all the watch companies showed practically the same styled watches with very few changes.

Mr. Katz, having been a manufacturer of expensive cases, was style-conscious. He brought that with him and his first job was to restyle the entire line from the bottom up, applying to watches costing as little as $25 the same ingenuity that had gone into $15,000 cases.

Of this he was convinced: you could not build a beautiful case properly styled around a large heavy, thick movement. Therefore movements were redesigned, with the thought in mind that the consumer did not wear a movement, rather wanted a beautiful watch, and expected the movements would be designed in a manner so that they could be properly styled as watches.

Soon manufacturers and importers had to compete not only on a quality basis but on a style basis. It became apparent to the industry that the consumer must be given an incentive to buy a new watch every two years because his or her old watch had gone out of style—and not because it failed to function, since the average good watch will function, if properly cared for, ten, twenty, thirty, or even forty years. Katz thought it particularly absurd for a man to expect a watch costing him $25, $50, or $75 or more to serve him for twenty years, functioning twenty-four hours a day, whereas he normally changes his automobile every two years, which costs him $1,000 or more and operates two or three hours a day or less. The answer, again, had to be new and unusual styling.

In 1935, therefore, the firm introduced the first curved wrist watch, made possible by the inventive genius of Henri Thiebaud of the Swiss plant. It changed the industry's conception of the wrist watch from one of style appeal as well as technical excellence. The aim now was to provide a watch that actually fitted the contour of the wrist. The movement of this curved watch, it is interesting to note, was not flat but curved in the same manner as the case. Within a short time nearly every watch company proclaimed a curved wrist watch, although they used flat movements in a curved case. But the curvex movement has remained exclusive with the Gruen firm.

Efforts now were made to improve the "curve" of the watch. Soon one was introduced with a curve of four-and-one-third times the curve of the original movement. Then curved ladies' wrist watches were perfected. Because of the tremendous interest this watch created, in the minds not only of the public but of American jewelers generally, Katz's organization introduced a wrist watch which proved not only a complete departure from anything attempted before but also a failure. It was a wristside type of watch, fitting on the inner side of the wrist. It was supposed to make it unnecessary for one to turn the top of the forearm toward the eye. All you had to do was to glance down at the side of the wrist to see the time. Despite a tremendous advertising campaign its manufacture was discontinued.

The curved watch was not enough to satisfy the stylists. They now turned their attention to other forms and out of many experiments came a very thin wrist watch. The principle of this watch is so simple it is a wonder the industry did not think of it before. Its construction is along the lines of cutting a tennis ball in half so that the top of the movement, where the dial rests, is built like a tennis ball. Thus, while the movement in the center of the axis, upon which the hands revolve, is as thin as the average movement, it slopes down all around in a bombé fashion; thus the sides and the ends of the movement are in many instances as thin as a half dollar, making the whole more susceptible to styling than ever before.

"We do not understand," says Mr. Katz, "why a watch cannot be a thing of beauty as well as utility and are insisting that all our watches be made with this thought in mind. To that end we have a complete staff of designers and technicians constantly working, not only on improving the quality of watches but creating new styles so often that the beautiful stylish watch of today will be the outdated watch of tomorrow—the same as women's clothes."

The men who sit behind the slanting draughtsman's boards in the watchcase factory know this. They know if beauty did not matter all the watch companies could discharge their high-priced case designers; they could settle for plain steel instead of beautifully chased platinum, gold, and gold-filled watches; they could tell the distributors of gem diamonds, rubies, and sapphires to go peddle their wares somewhere else. But they know also that "all is vanity," which is why the first important function in the case plant is design.

At one time this company alone had something like five hundred different designs "in the line." They ranged in prices from $30 to as high as $3,750. From twenty to thirty models are simultaneously "worked over" and studied. Out of that number perhaps less than five will be selected. Then actual cases are made from these five models and out of the five only one will be chosen for production. Even for the end pieces (the end pieces being the gold or gem-encrusted ornaments at two ends of the watch itself) as many as fifty sketches will be made in order to arrive at one satisfactory design.

Considerably more designs for women's wrist watches are made than for men's and this is because women expect more ornamentation. This statement may seem paradoxical in view of the fact that actually women are less concerned about the actual shape of a watch than are men. There are round, square, rectangular, tonneau, cushion, and other shapes. Men for the most part prefer the rectangular and the tonneau (the latter having curved sides and straight ends). All that women ask, on the other hand, is that the watch be "good looking." The shape is of secondary importance.

You hear the word "trend" often in this department. Studies are made of new types and styles in this country and abroad. Employes are encouraged to make suggestions. The important thing is to keep a trend from running into a rut. Once a long-used design has been dropped it is dead, although it may come back with modifications and, of course, will be reconsidered. But the experts also must consider that a trend is not necessarily revolutionary, or pointed toward the future, but on the contrary may suddenly turn around, like a rattled quarterback carrying the ball, and start scurrying back to a goal post—or design—of the past. This happens in all fashions, of course, but the designers must be prepared for it. In the watch business it seldom happens, the trend usually being toward something new.

The next step is the preparation of the dies. These must be so designed and constructed that they will not "thin out" the layer of gold. The tolerance must be narrowed down to almost nothing, because the bezel must fit the back of the case without any overlapping or "giving."

Cases are principally 14-carat gold, filled gold, or stainless steel. In this factory they are gold, filled gold, and platinum. "Filled gold" means that a bar of base metal is soldered to a layer of 10-carat gold (either on one side or on both sides, depending on the quality of the gold stock required). The base metal may be nickel, silver, or monel metal a high percentage of nickel mixed with copper). During the war silver was used because the other metals, being so necessary to the war program, were scarce.

The fine gold is purchased from the United States Mint. Being 24 carats it is alloyed with nickel, copper, zinc, or silver—depending upon whether the case is to be white, pink, or yellow gold. It must be thinned to a finer degree than gold for rings, for instance, because more precision is required. If the gold is not of the proper hardness it will roll out thinner or heavier than specified. The finished filled-gold stock must legally be at least .003 gold when rolled to its final thickness.

The proportion of the gold to the base metal is accurately controlled through annealing and rolling so that the finished stock is completed with the required—and specified—amount of gold. The gold is soldered to the plater's bars, which vary in thickness from one-half to one inch, in length from twelve to fifteen inches, and in width from an inch and a half to three inches. The bars are then reduced in thickness by passing through very large rolling mills. These are in a special room free from dust so as to avoid any imperfections in the metal. They are rolled again to various thicknesses, ranging from .024 to .01 of an inch.

After the stock has passed through the rolling mills it is now ready for the first blanking and forming operations. It goes to the big presses which shape out various case designs, oval, rectangular, round, etc. The receptacle for the crystal in these designs must not vary .001 of an inch in any one dimension. When they have been stamped they go to Inspection Control and if the latter's eagle eyes spot a fraction of difference back it goes to the case plant.

After the back, band, and bezel are completed in the Press Department they are finally inspected for all imperfections. The lugs for strap cases and end pieces or ornaments are also made in this department and are studied for accuracy. Then the Soldering and Assembling Department takes over. Lugs are welded to the bezels and the whole is put into an electric conveyor furnace and soldered. Backs and bands are assembled and soldered to the inside, thereby making the case a two-piece affair instead of three. All drilling of the spring holes to which the straps are attached are also completed in machine operations.

After this operation has been completed and the proper finish given to the inside of the backs, the two parts are assembled by snapping them together and are properly fitted to make a completely assembled watchcase. During the fitting operation it is necessary to burnish the sides and ends of the case to accomplish as nearly as possible an "invisible joint"—or as one expert called it, "seemingly seamless."

After another inspection the case goes to the Polishing and *Final Finishing* Department—a redundant term which the experts insist is correct in their business. There the entire case is polished and given whatever other additional touches are required or specified. The backs are emery-finished while the sides and top of the bezels are usually bright-polished. The two parts of the case are now placed on plating racks and washed thoroughly, rendering them ready for whatever flash plating is necessary to give the inside of the product the proper color. ("Flash plating," by the way, refers to a very thin layer of plating put on mainly for uniformity of color and not necessarily for wearing qualities. There is a reason for stressing this. The firm under discussion uses at the least filled gold and filled gold does not need plating for wearing purposes. Any article not made of filled gold, but electroplated for wearing qualities, will never be as satisfactory for the reason that all electroplating is porous and allows acids of the human body to get through the pores to the base metal. This causes a reaction and a lifting of the plate from the metal. All high-grade jewelry, including watchcases, are at least made of filled gold and are therefore far superior to any product that necessitates electroplating.)

The main point is to assure that the color of the inside of the case will match in color the outside. Either a yellow, pink, or rhodium plating solution is used. Rhodium is used on white gold-filled watchcases, pink and yellow on the respective colored cases.

As to what the public erroneously calls solid gold cases, these are actually 14-carat or 18-carat gold containing the following gold content: 14-carat contains 58.3 per cent fine gold (referred to as 24-carat gold) and 41.7 per cent of an alloy for hardness; 18-carat contains 75 per cent fine gold and 25 per cent alloy. For an ultrafine finish the cases are subject to a process known as mirror lapping. This consists of charging a tin lapping wheel with the proper compounds and working the watchcase against a lap until a perfect surface free of any irregularities has been obtained. There is no known process that gives as high a finish to a watchcase as this and it is used on the most expensive type of watchcases.

An important feature of all these operations is what Gruen calls "Gold Control." Gold is controlled between departments. That is, one department receiving the gold is charged for it, and when it turns the gold over to another department it must transfer the charge. In every instance the amount of gold going into a department must be balanced by the amount going out, minus any allowable loss in the manufacturing of the product. This is particularly true of the Press—or Stamping—Department, where the finished product and the remaining scrap must be returned to Gold Control. There the product and the scrap are checked.

Special efforts are made to save all possible gold. All waste water used in washing the gold is filtered and settled so as to save any gold which might flow into the sewer. All waste materials (paper, rags, sweepings) are burned and the gold dust refined from these ashes. All aprons worn by workers are laundered. Walls are washed. Even mop water from the floors goes into a special drain. All dust is collected and sifted for gold.

The final phase of case manufacture is the making of a watch crystal. Up to now there have been something like three hundred separate operations in the making of a watchcase. The making of a crystal is an involved process, consisting of cutting to shape, bending by heating, grinding, edging, and polishing.

Sheets of crystal-clear glass are cut into strips and then crosscut into rectangular or square pieces. From this there may be an operation in which the pieces are cut on two sides or ends or both sides and ends to form a curve, thus making tonneau or cushion-shaped crystals.

The cut glass is washed and inspected for any imperfections before proceeding to the heating or "dropping" operation. This consists of placing the glass on a mould shaped into specified curves and applying heat to the top of the glass, which causes the glass to bend and conform to the curvature of the mould. Now the glass is annealed to remove the strains and stresses due to the bending operations. Then it is placed into a stack with about thirty other crystals—for our "glass" now has become a "crystal." The stacking of these thirty crystals is accomplished by using a plaster of Paris cement inserted between each crystal. The stacks are mounted in grinding machines where they are ground to the specified sizes with limits no greater than .001 of an inch. After the grinding the stacks are separated and the individual crystal is bevelled on the bottom side so it has a smooth edge for pressing into the bezel of the watchcase.

After the bevelling process the edges of the crystal are polished to remove all roughness in order that there will be a minimum of friction created between the glass and the case when both meet in the fitting operation. The crystals are then inspected for curvature and any other defects which might cause distortion of the numerals on the dial of the watch.

Once the inspectors are satisfied, the completed watchcase goes to the Horological Department. There it will await the arrival of a movement which will make the case its home. To find out how the movement is made we must go to Switzerland.

2

The Watch and Its Adjustments

Before we go into the Swiss factory, where the movement is made, let us learn a little about the movement itself and how it is adjusted so as to keep accurate time. This will help us to understand more fully the semitechnical description of watchmaking operations in the next chapter.

The principle of operation of virtually all watches sold in the United States is the same, irrespective of the size and shape of their movements, the number of jewels they contain, their overall quality, or the country in which they were manufactured.

All watch movements contain:

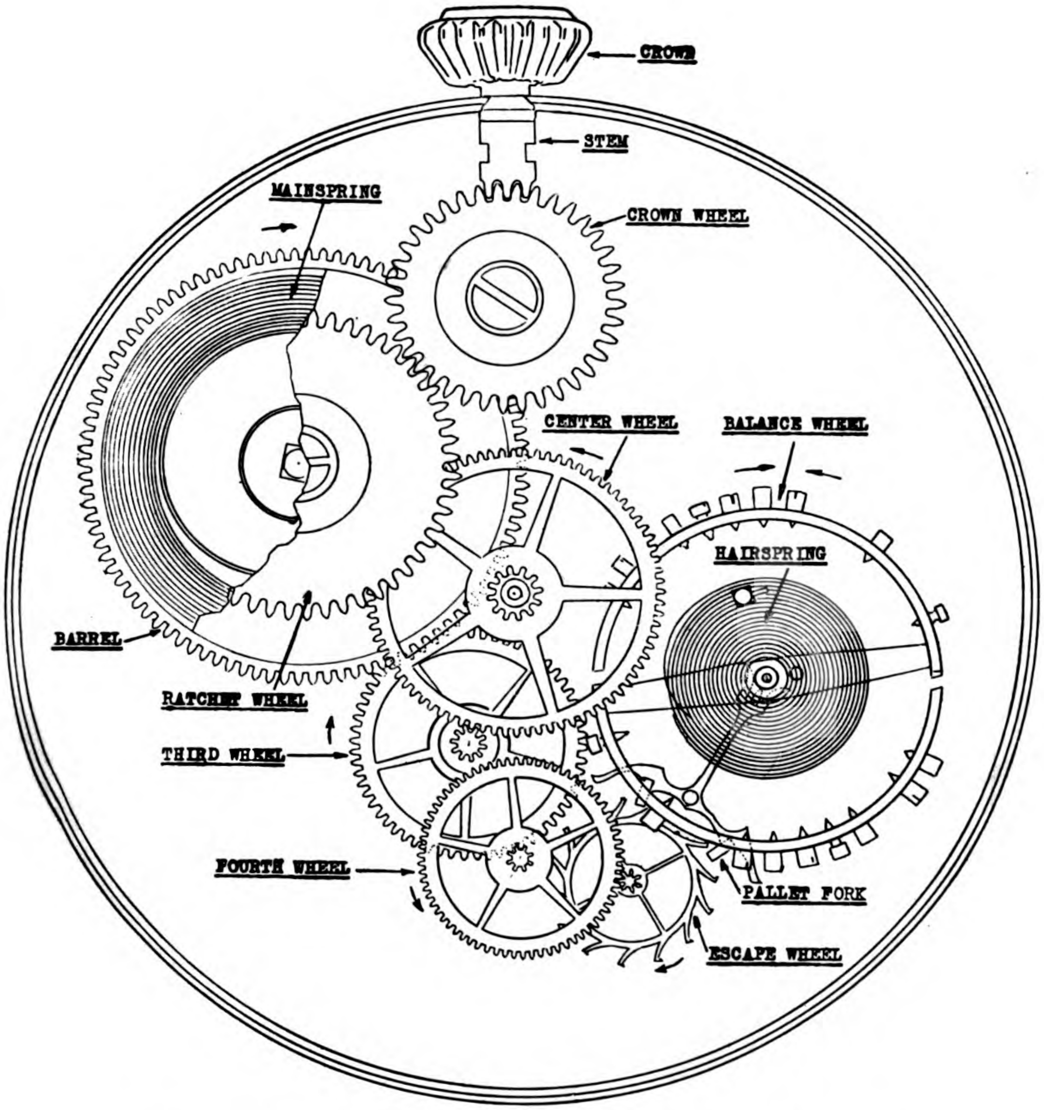
1. A driving mechanism to actuate the movement or, if you like, to supply the motive power.

2. The train of wheels, through which this power is transmitted.

3. The escapement which controls the rate at which the watch runs.

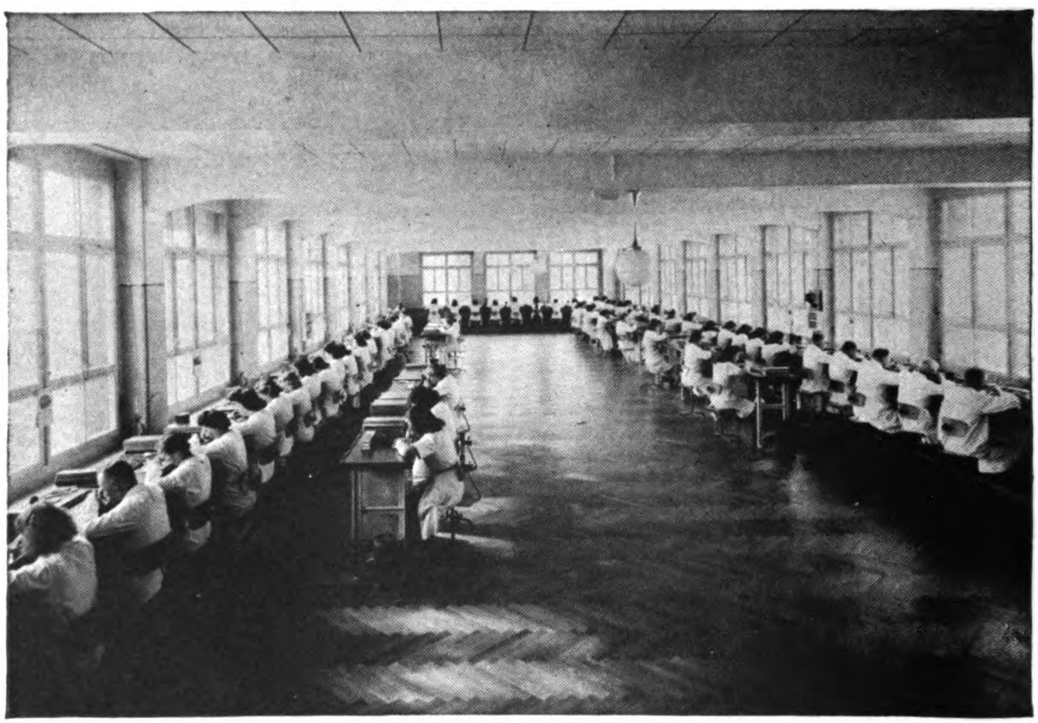
4. The indicating and winding mechanism.

The motive power is supplied by the uncoiling of a mainspring, which is generally rewound by hand. Almost all watches have five wheels in their train. The first of these wheels is the mainspring itself, which in most watches rotates once in eight hours. The next wheel rotates once an hour and each succeeding wheel rotates with greater frequency. The greatest friction is generated at the pivots of the faster-moving wheels, and at other points of contact between rapidly moving parts. The escapement is the

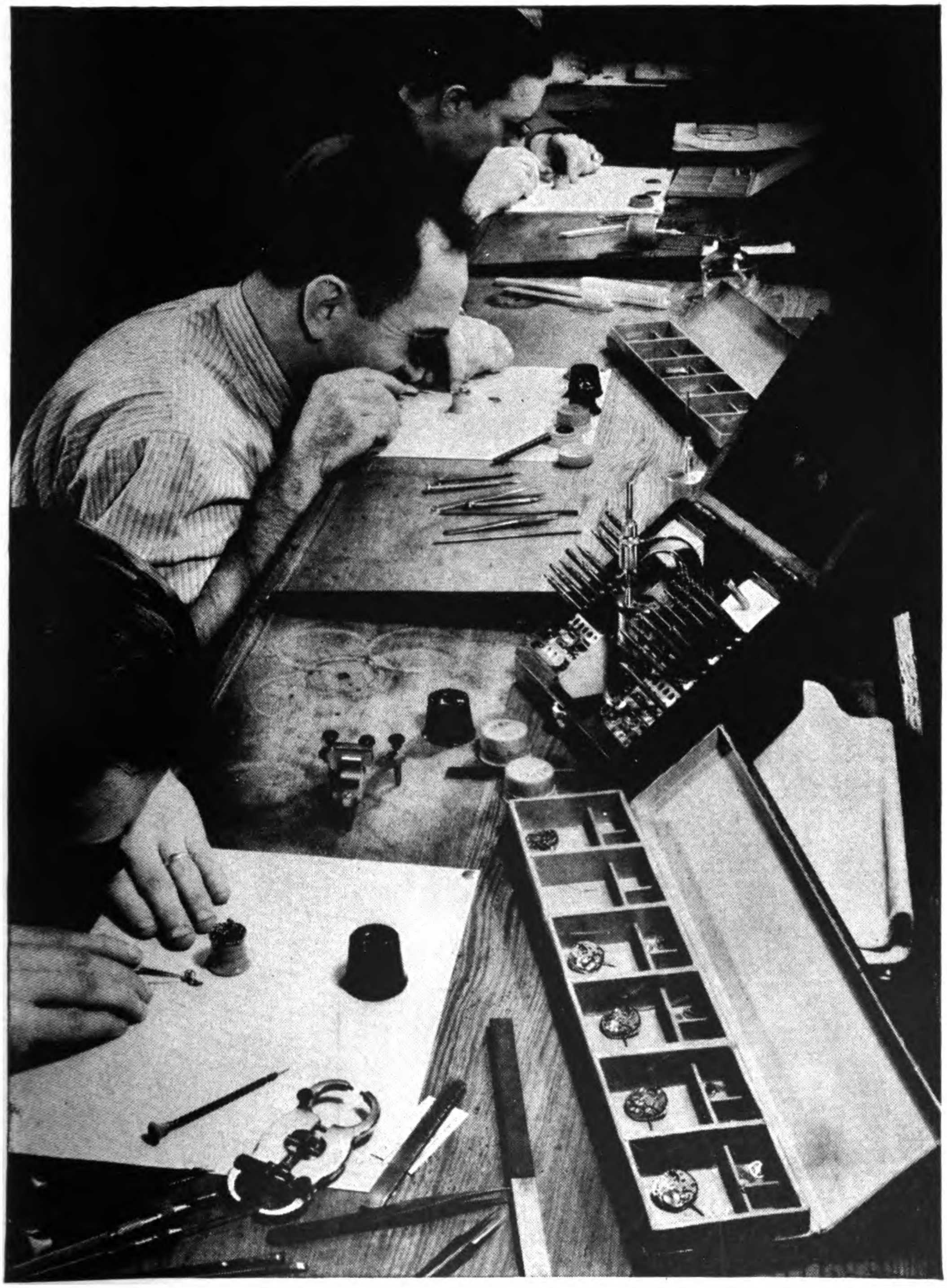


This line drawing shows the principal features in the operation of the modern watch, divided into (1) the driving mechanism, (2) train of wheels (3) escapement, and (4) indicating and winding mechanism. *Courtesy Gruen Watch Company.*

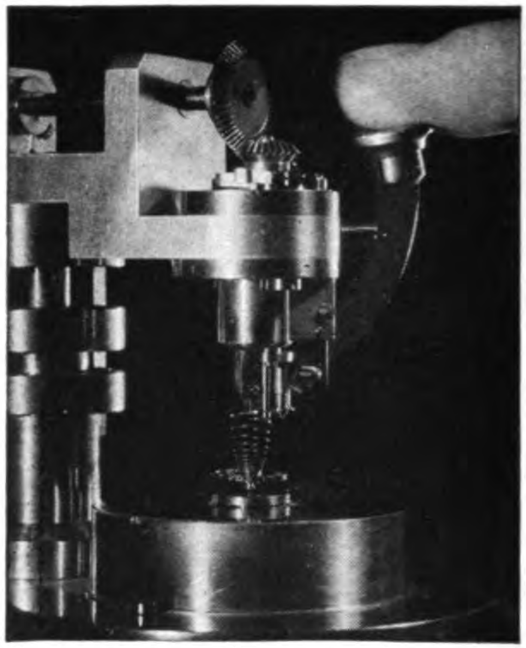
There are at least 125 parts in a watch movement. So "precision" is the word.



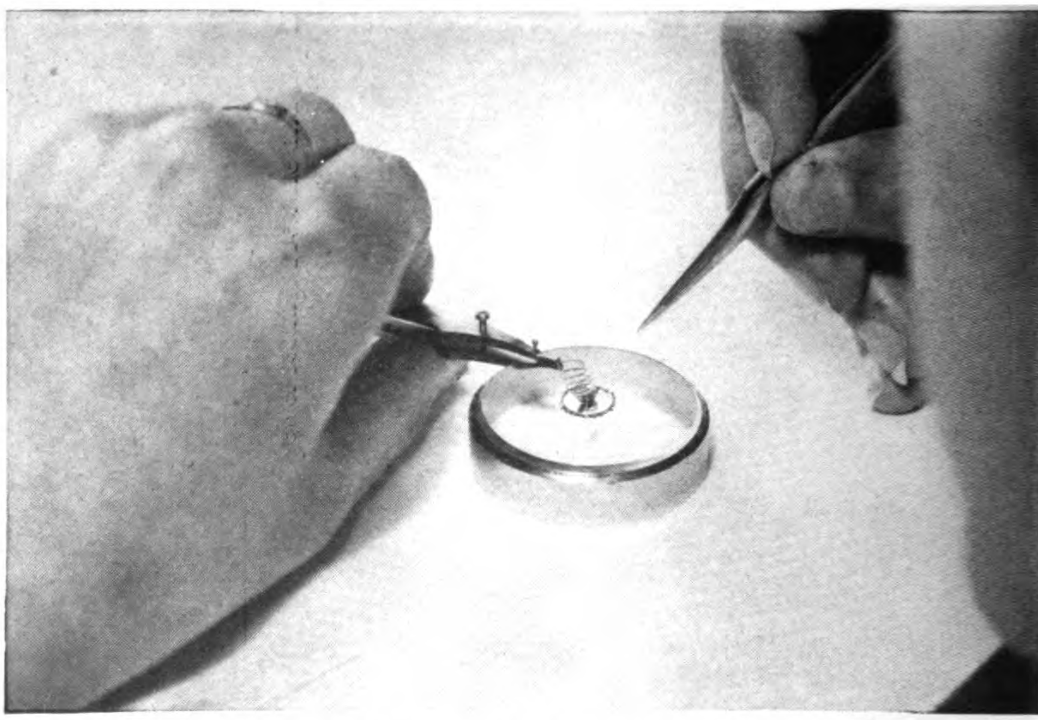
A section of a modern watch factory. It's not only clean—it's antiseptic. Light and cleanliness are paramount in the hairspring section of the Gruen factory.



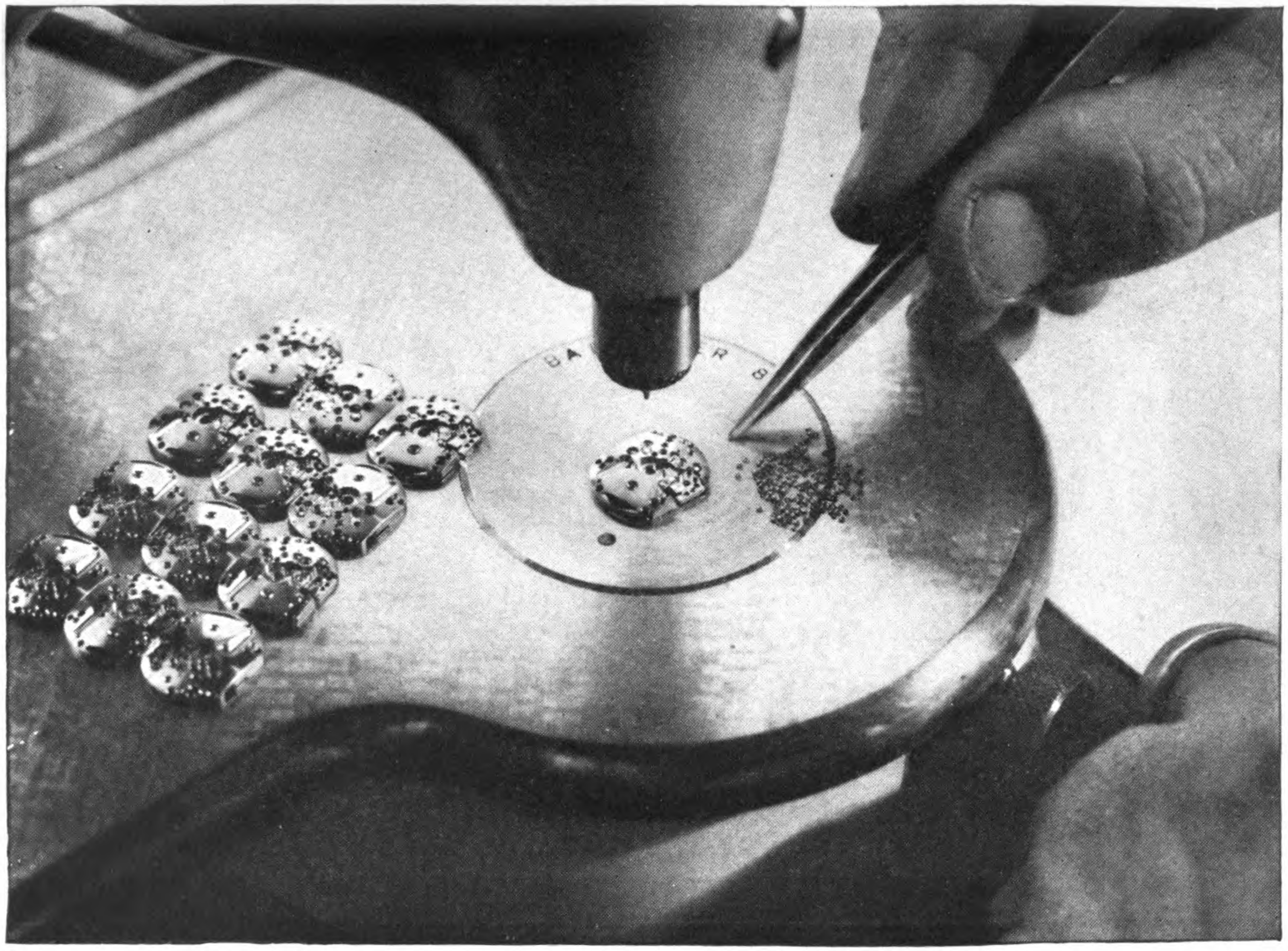
The assembly line. The ebauche moves to five watchmakers who assemble (1) the train; (2) the winding mechanism; (3) barrel and bridge; (4) escapement and (5) dial train and hands.



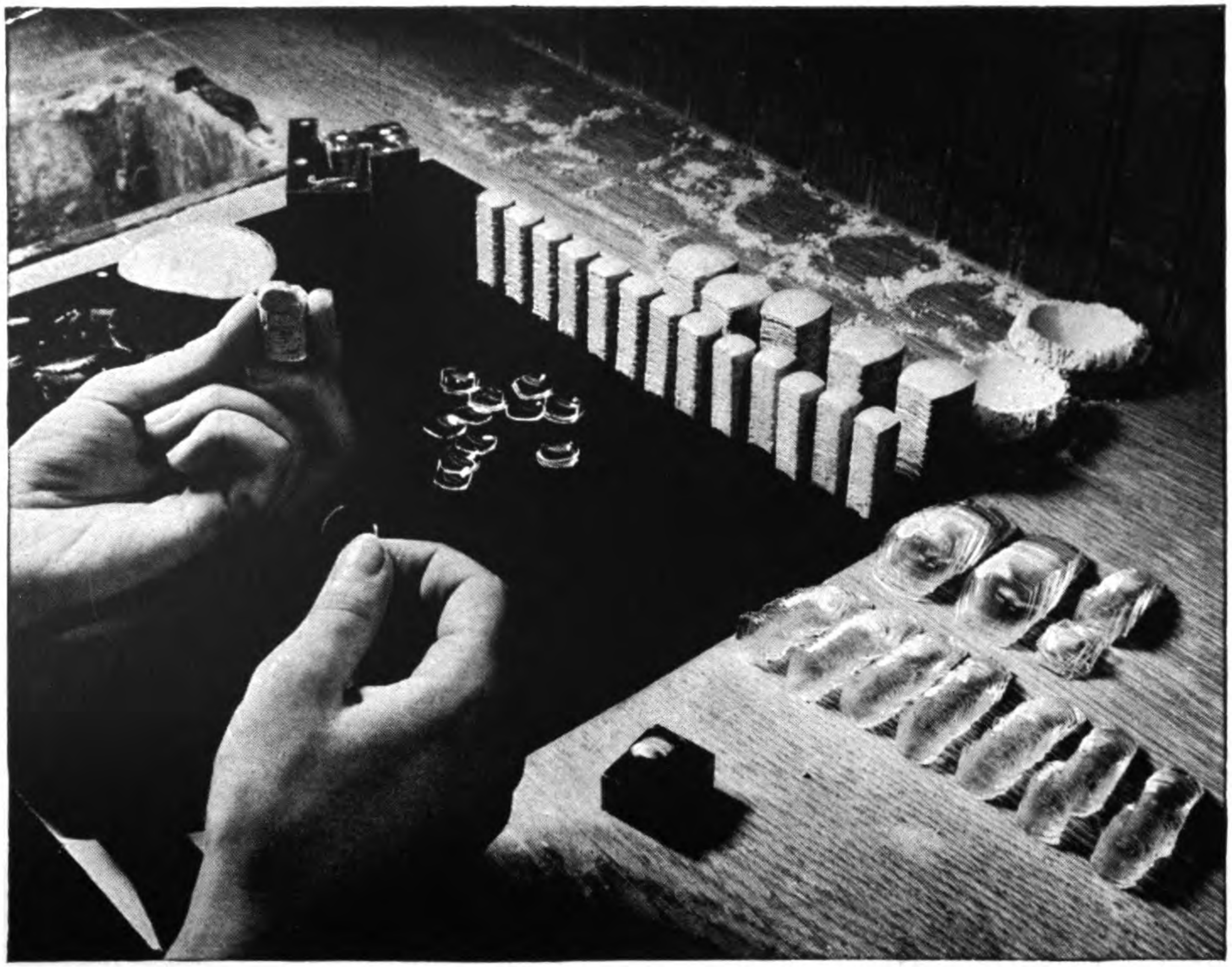
Balance wheel assembly is the heart of the watch. Its semi-circular motion is the mechanical operation which measures the beat of the second.



The hairspring is the motivating force of the balance wheel. Its metal component and tensile strength must be perfect since this supplies the force for 432,000 vibrations for the balance wheel per day of 157,680,000 vibrations per year.



Jewel setting. Pressure and depth of setting must be uniform on all.



Rough crystals are stuck together with plain plaster of paris in stacks of about twenty-five.

Stamping out blank case parts.

Miniature "spot" welding. The lug is welded onto the bezel of the case by a miniature welding process. These are the skeletons of the watch front.

These are modern wrist watches, men's and women's, showing the streamlined tendencies of the age.

mechanism that converts the circular force of the last wheel in the train (the escape wheel) into the oscillatory motion of the balance wheel which, in turn, governs the rates at which all the wheels in the train rotate.

Only two types of escapement are commonly found in watches sold in the United States: these are known as the jewelled lever escapement and the pin-lever escapement. Although the first type is found in all high-grade watch movements, such an escapement does not necessarily assure a high-quality movement. Some poor grades of movements containing jewelled lever escapements are, in fact, poorer timekeepers than some of the better quality movements containing pin-lever escapements. Customarily, pin-lever escapements have been used in cheap desk and alarm clocks and in inexpensive pocket and wrist watches. Watches of such construction are not usually expected to perform very precisely, particularly for extended periods of time.

The rotation of the hour, minute, and second hands of the watch is linked to the rotation of the wheels in the time train. The accuracy of the watch as a timekeeper, therefore, depends primarily on how nearly uniform the rates of rotation of these wheels can be maintained. Many forces operate to prevent absolute perfection, such as the diminishing power of the mainspring as it runs down, changes in the temperature of the air surrounding the watch, and changes of the position in which the watch is held. Watches can be constructed or adjusted, however, so as to eliminate almost all change in rate attributable to these causes.

Let us consider this matter of "adjustment" of the watch. It will point up in the next chapter the significance of modern watchmaking and how "adjustment" is no longer something that must be done after the watch is made. For the fact is that many of the movements made in Switzerland before they are shipped to the United States are not adjusted because the "adjustment" of isochronism and temperature is "built into" the mechanism itself.

A brief résumé of a report of the United States Tariff Commission on Watches will enlighten us. The object of this report, it is true, was to describe and analyze the various changes brought about by World War II which have a bearing on the competition in the United States between watches made wholly or almost wholly of domestic materials, and watches that contain foreign movements installed in either domestic or foreign cases. We are not interested here in the competitive phases of the report but it does happen to discuss the various kinds of watches and watch movements marketed in this country, including those made here and abroad; it also gives some attention to adjustment.

In spite of assumptions to the contrary, no watch maintains a constant rate. Therefore no watch can keep precisely correct time. If you know of one go to your nearest jeweler and he will put you and it on exhibit at the nearest county fair. You should win some kind of a prize. A type of pocket watch, it is true, does gain or lose no more than a few seconds in a twenty-four-hour period when used under the conditions for which these watches were designed. Others gain as much as several minutes in the first twelve hours after being wound and lose considerably more or less in the next twelve hours of running. Others behave so erratically they may gain as much as five minutes on some days and lose as many minutes or more on others.

A watch is a temperamental thing. It cannot give even a reasonably good performance unless the movement is properly designed and the various parts are cut, drilled, shaped to close dimensions, and finally, assembled and adjusted with skill and care.

Poor watches, including some that sell at high prices, may contain plates and bridges in which the pivot or jewel holes are neither round nor properly aligned; they may contain wheels that are out of true or gears that are irregularly cut, improperly shaped, or not in precise mesh; they may also have mainsprings or hairsprings that are too strong, too weak, too long, or too short; and they may be unskillfully assembled or improperly adjusted. But no matter how carefully a watch is made, some residual error in its rate remains.

A watch performance is rated on the basis of responses to three basic tests:

1. Isochronism
2. Temperature
3. Position

Electrical timing machines are generally used in making these tests. An operator places the watch movement in such a machine, which records a series of marks on a paper chart fastened to a revolving drum. The slope of the dotted line formed by these marks shows the watch's rate during the test period, and certain other characteristics of the marks reveal whether the movement is functioning properly. Each test period takes about thirty seconds. The total time spent in timing an individual movement depends principally upon the number of positions in which it is tested.

Now, what is isochronism in a watch? It refers to uniformity in the rate of a watch as it runs down after winding. The mainspring of a watch exerts its greatest force directly after the watch has been fully wound. This force is transmitted through the time train to the balance wheel, causing it to oscillate through an arc of about 500 to 550 degrees. As the mainspring runs down, the swing of the balance wheel decreases. After twenty-four hours of operation, the arc may be only 300 to 400 degrees and, after thirty to forty-five hours of running, the balance wheel will stop oscillating unless the mainspring has been rewound in the meantime.

The length of time required for a balance wheel to make a single swing varies with the amplitude of the swing. High-quality watches, however, are designed and adjusted in such a manner that the length of time required for a single swing, at any time during the first twenty-four hours after the watch is fully wound, will be virtually a constant. After twenty-four hours or more of running, most watches show a considerable change in rate. Even the best adjusted watch, therefore, will not maintain a uniform rate unless it is wound quite regularly.

The amplitude of swing of the balance wheel in any given watch, even directly after it has been wound, will not be the same under all conditions. Temperature, for example, exerts influence, and in several different ways. Watch plates, jewels, pinions, and wheels are made of materials that expand or contract at different rates with changes in temperature. Consequently, points of contact of moving parts of a watch alter with changes in temperature, and the energy transmitted to the balance wheel changes. Temperature affects the viscosity and lubricating value of the watch oil and the resilience of the mainspring, thereby also influencing the amplitude of the balance—or wheel oscillations. None of the particular effects of changes in temperature mentioned, however, materially influences the rate of a watch which is properly adjusted for isochronism.

A movement with a flat hairspring does not provide an isochronal rate. That is because of the constantly changing center of gravity of the balance-wheel assembly (the balance wheel plus the collet and hairspring) when it is in motion. The eccentric wanderings of this center of gravity, however, can be greatly reduced, in fact, virtually eliminated, by using a hairspring of precisely the correct number of coils and with properly shaped terminal coils. The shaping of hairspring terminals is the operation which is generally regarded as the adjustment for isochronism. As we shall see in a moment, this operation is intimately related to the other adjustment operations.

Let us consider that hairspring after it has been adjusted for isochronism. This spring contains precisely the correct number of coils; the last coil of the spring is bent up and over the plane of the other coils to form a so-called overcoil; and the first and last coils of the spring are in theory made to conform to mathematically formulated curves. In practice, the shapes of the overcoil and the terminal curves of the hairspring vary with individual manufacturers and to some extent with individual adjusters. Reasonably well-shaped overcoils and outer terminals are found in the hairsprings used in most good watch movements with jeweled lever escapements, but only the best movements contain theoretically corrected inner terminals on the hairsprings. The proper curving of the inside coil apparently requires more skill than the corresponding operation for the outside coil. Hairsprings containing an overcoil are usually referred to as Breguet hairsprings (after the French horologist, Abraham Louis Breguet, 1747–1823).

About temperature: A watch that is closely adjusted to isochronism will still show a considerable variation in rate with change in temperature unless the watch incorporates some suitable compensatory device. A watch that does not have such a device, but which is otherwise well made and fully adjusted, will have a variation in rate in a twenty-four-hour period of as much as five or six minutes with only ordinary changes in temperature. Inexpensive watches, particularly those with pin-lever escapements, do not generally incorporate any device to compensate for change in temperature.

According to the figures of the U.S. Tariff Commission's experts, over 80 per cent of the error in rate resulting from temperature change is caused by alteration in the elasticity of the hairspring (i.e., the spring becomes "weaker" when heated and "stronger" when cooled). Virtually all the remainder of the errors arising from variation in temperature are caused by the change in the physical dimensions of the balance wheel itself. Temperature change alters the length of the hairspring, but the effect of that change is offset by the effect of the accompanying changes in the thickness and width of the hairspring. One of the most satisfactory devices to compensate for temperature change is the cut bimetallic balance. Until recent years, it was in fact the only device commonly used for this purpose. A new device, which will be described shortly, has now largely replaced the cut balance.

Cut balances have steel arms and a cut bimetallic rim in which a number of screws are inserted. (The rim is tapped for many more screws than are actually inserted in order to allow for shifting the positions of some of them as explained later.) The inner segment of the bimetallic rim is of steel and the outer segment of brass, and these two segments are brazed together. Inasmuch as brass has a coefficient of expansion which is about 70 per cent greater than that of steel, an increase in temperature will cause the free ends of the rim to curve inward; and the temperature increase will also cause the arms and rim of the balance to elongate. A decrease in temperature will have the opposite effects.

When balance wheels are first assembled in a factory, the screws in the rim are arranged so that they provide the necessary temperature compensation. But if this arrangement causes the watch to have a slower rate at high temperatures than at low temperatures, some pairs of diametrically opposite screws are transferred to the loose ends of the rim. The rate of the watch at high temperatures will then be quickened because the loose ends of the rim to which screws have been transferred will move toward the center of the balance wheel and thereby reduce the moment of inertia of the wheel. If the initial arrangement of screws on the balance causes the watch to have a faster rate at high temperature than at low, opposite pairs of screws are shifted away from the loose ends of the rim.

In actual practice, watches with bimetallic balances are generally adjusted so that they will have approximately the same rates at only two temperatures, a high at about 35° C., and a low, at about 5° C. The rates at other temperatures may be quite different. The deviation in rate at a temperature midway between the "high" and "low" temperatures to which the watch is adjusted, say 20° C., is known as the middle-temperature error.

We have heard about isochronism and temperature. But a watch that has been adjusted to these two will still not be a good timekeeper unless it has been also adjusted to position. All watches operate at different rates when in different positions, but these differences are not large in well-adjusted watches. When a watch is on edge, the pivots are in contact with different parts of the jewels or plate holes than when the watch is rotated to some other position on its edge or is held horizontal; and the friction encountered by moving parts will consequently vary with the position of the watch. But the most important factor contributing to variation in a watch's rate in different position is lack of "poise" of the balance wheel.

A balance wheel is said to be perfectly poised when its center of mass coincides with its geometric center. The poising operation consists in distributing the weight of the balance wheel equally around the balance staff. In practice, this result is achieved approximately by first placing the balance wheel in a poising tool or pair of poising calipers which will allow the wheel to rotate freely on its staff or pivots, and then by reducing the weight of some screws on the rim of the balance wheel (or by increasing their weight by substituting heavier screws or by adding timing washers to some of them), so that the force of gravity will not operate to bring the rotating wheel to rest at any one point more than at any other.

One of the difficulties in the procedure is that the poise of the balance wheel may be disturbed by the addition of the collet and hairspring. And, unless the hairspring is shaped in the manner necessary to achieve approximate isochronism, the center of gravity of the balance wheel, inclusive of the collet and hairspring, will shift eccentrically as the balance wheel oscillates. In these circumstances, perfect poise of the balance cannot be attained. In small watches, however, satisfactory adjustment to position is accomplished about as well with flat hairsprings as with Breguet hairsprings.

A word about regulation: A watch that has been adjusted to isochronism, temperature, and position may maintain a virtually constant rate and yet it may still go too fast or too slow. All watches have some device for altering the rate. In most watches regulation is accomplished by changing the effective length of the hairspring. The last outside coil of the hairspring passes between two parallel pins, known as curb pins, which project down from one end of a pivoted regulator lever. Any lateral movement of this regulator bar in one direction increases the effective length of the hairspring and thus slows down the watch. Moving the regulator in an opposite direction has, of course, the opposite effect. The regulator in a new watch, or in one that has been properly overhauled, should be between the two extremes. High-quality pocket-size movements provide micrometer adjustment for the regulator lever but few wrist-watch movements contain micrometer regulators, although there have been some improvements lately.

Sometimes a watch consistently goes so fast or so slow that even a maximum movement of the regulator lever will not cause the watch to keep correct time. In such circumstances, some adjustments must be made on the balance wheel. An opposite pair of the so-called "mean-time screws" must each be screwed in or out to the same extent. Screwing them in speeds up the movement and screwing them out slows it down. If a correct rate cannot be achieved by such means, the weight of the screws must be altered either by undercutting or by the addition of timing washers.

A word about watch sizes. They are based on the width of the pillar plate of the watch movement. The pillar plate is the bottom plate of the movement to which the upper plate or upper partial plates, known as bridges, are fastened; the time train and escapement lie between the pillar plate and bridges. This plate is also the one to which the watch dial is fastened. But there is no necessary correlation between the size and shape of this plate and those of either the watch dial or the outside dimensions of the watchcase. The width of a pillar plate is the shortest distance across its surface through center. This dimension corresponds to the diameter of a round pillar plate and to the actual width of a rectangular plate.

Two systems of designating watch sizes are in common use: one is based on the English inch, the other on the French *ligne.* The system based on the English inch expresses sizes in a series of numbers in which 1 5/30 inches is also 0; larger sizes are expressed as the number of thirtieths of an inch in excess of size 0, i.e., size 1 is 1 6/30 inches, etc. But that is relatively unimportant. We are not going into such higher mathematics in this book. We are interested in only this: Does our watch keep time? We shall be interested in knowing that a small watch can keep as good time as a big watch. More important, we are equipped with a certain amount of knowledge which will be of help as we go into a factory up on a high hill in Switzerland.

3

The Hands of Precision

The hill is a long high serpentine stretch of foliage. At night its immensity suggests a huge thunder cloud dropped ominously upon the earth but in the morning it is a green curtain draped over the back of the little city of Bienne, Switzerland. It is dotted with red-topped homes, a white churchspire here and there, and what looks like a huge chalet. In reality this chalet is a factory where men and women are busily engaged in making Time captive in a small piece of mechanism which eventually will fit on a wrist or rest in a pocket.

Through the windows of the chalet you can see the distant glaciers of the Alps rise up from the eastern horizon. You are impressed with the thought there is something sharply clean about everything in this part of the world, about the whole atmosphere of Bienne. There is an antiseptic cleanliness inside the "chalet," too. That it is really a factory seems to be a remarkable coincidence. From the steps leading to the building to the top story this modern movement factory is one of efficient and shining compactness. Whether it be the assembly or manufacturing department, the vista is one of polished machines, bright shining floors fit for a bank, polished benches at which the workers toil in spotless smocks. This is the Swiss "home" of The Gruen Watch Company.

The impression of cleanliness is not an idle one. It has great micrometer regulators, although there have been some improvements lately.

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significance, for Bienne is a watch town. Cleanliness is not a fetish here. It is a necessity. It is the difference between the life and death of a watch. If a watch movement has one grain of dust it may mean it will not keep good time; it means the lack of precision. Without precision there is not truly a watch.

Let us take a brief glance at the word "precision" with respect to the watch. Let us say a man bets he can measure the distance from New York to Washington by using an ordinary yardstick. He says: "I will measure this distance by my yardstick and tell you precisely how many yards, feet, and inches it comes to." He comes up with this result: the distance between New York and Washington is 204 miles, 2 feet, and 7 inches. He is wrong. The distance is 204 miles, 2 feet, and 5 inches. But certainly, you say, one cannot quibble about two inches! Indeed you will be astonished at such a remarkably—even incredibly—accurate measurement. But consider a watch: if it fails to keep within a minute or two of the correct time over a period of six months you may think it is not an accurate watch. You will not say the man with the yardstick was inaccurate but you will say the watch is.

Thus the word in watch manufacturing must be precision. It must enter into every operation of so delicate a thing as a watch. One writer has said the engineers and mechanics in a watch factory spend all their time among tolerances that would drive a normal-sized machine shop crazy because to them tolerances of even a ten-thousandth of an inch are so common they are referred to as "tenths." This is true. But while there is such a word as "tolerance" in the creation of parts there is no such word as "tolerance" in the ultimate and finished product. The watch will not tolerate fractional differences. It will not willingly admit even a grain of dust because that grain of dust will destroy its goal of precision and accuracy.

If you understand this you will appreciate the reasons for the scrupulous cleanliness, not only of the Gruen factory, but of all the factories and homes and streets and public buildings in Bienne. This passion for precision occupies the attention of more than 28 per cent of the employed population of Switzerland—

considerably more than that percentage for Bienne. The manufacture of watch movements for export represents 25 per cent of the country's economy, ranking third next to chemical products and machinery. In a previous chapter we noted 875 watch, clock, and jewelry factories in Switzerland in 1943. Perhaps a comparative figure will indicate the size of the industry: while American watch manufacturers employ little more than 10,000, there are upwards of 80,000 watchworkers in the little country of the Alps.

We learned how the Swiss not only export movements to the United States but parts of movements. It is interesting to note here that Swiss manufacturers often depend upon individual concerns which specialize in "parts"—the hairspring, balance wheel, escapement, jewels, and such. The work on these individual parts may be carried on in a big factory (one of the biggest in Switzerland does nothing else but turn out hairsprings) or in small shops attached to homes. The latter do not represent "homework" in a technical sense. The Swiss insist upon having a small shop, clean, efficient, close to their home. There members of the family may work on parts later to be turned over to the large manufacturers. It is, of course, on a piecework basis. One man may devote his time to family, friends, the cinema, and the hairspring; another to his family, friends, the cinema, and the balance wheel.

The English, as we have seen, tried this system but they failed because they treated homeworking people poorly. This is not true in Switzerland. It explains why there are only sixty-five concerns manufacturing their own movements, and of those a large percentage only manufacture part of them, purchasing the important part called the *ébauché* for the balance of their production.

(The *ébauché* is sometimes identified with the word *esquisse,* which means an unfinished work or a sketch. This is somewhat misleading because the *ébauché* is equivalent to the chassis of an automobile, which is a complete part in itself. As one watch expert explained it: "It has everything—the collection of plates, the bridges, all waiting to be 'filled in' with the details." By "details" he meant the various wheels, springs, and other movements. All this is interesting because the entire watch industry is operated somewhat along the lines of the automotive industry thirty or forty years ago when the majority of manufacturers purchased the chassis, the motor, and the body from different manufacturers. The automobile men were merely assemblers. Only a few manufactured in the real sense their own cars. This applies to the watch industry today but the plant we are visiting manufactures its own *ébauché.*)

This point is stressed because many people are under the impression that so-called American importers of Swiss movements are strictly that and have no plants of their own, simply picking up what movements they can get from one Swiss maker or another.

The first thing to arouse curiosity about the employes in the factory is their footwear. They do not wear shoes but felt slippers. The worker, upon arrival in the cloakroom in the morning, changes to a clean smock and slippers. His or her shoes are left behind. This is not to protect the employee and his clothes from the dust and grime of the factory but to protect the factory from the dust and grime the worker may have brought in from the outside world. You cannot handle such delicate mechanisms as a hairspring, balance wheel, or any other part of a watch, including almost microscopically small screws, bolts, and pinions, and be a carrier of dust. The very word "dust" makes a watch manufacturer or assembler nervous.

That is why, as the worker enters his particular department, he finds everything spotlessly clean. He is expected to leave his own section of it the same way at the end of the day. In this factory there is no greater dereliction of duty than the lack of cleanliness. At the same time the factory is air-conditioned in order to prevent any trace of dampness entering into the movements.

The various operations of the factory can be divided into nine general parts. These are not the precise descriptions given me; they are interpretations of them from an American viewpoint, because the Swiss describe these things in a way which, even if faithfully translated, we might not understand. The divisions are these: (1) technical planning; (2) manufacture of tools and dies;

(3) manufacture of the *ébauché* and preparation for the assembly of parts; (4) actual preparation of parts (which can include both manufacture and purchase); (5) engraving; (6) manufacture of dials; (7) assembling; (8) cleaning; (9) inspection, inspection, and more inspection.

Behind these general divisions, of course, are numerous minute operations which hardly need be outlined here in detail. They are a part of a modern perfection of mass-production methods, combined with personal craftsmanship, all of which have enabled watch manufacturers in both Switzerland and America to sell watches at reasonable prices.

Before you go into the factory to find out the secrets of the modern watch, the Director-General of the plant explains briefly and pithily its meaning. He is Henri Thiebaud, thin, youngish, with the nervous energy of a mainspring, who has been the inspiration for several of the startling new designs of watches, as well as being responsible for the plant, with its clinical precision of a hospital or a medical laboratory, its determinedly clean walls, ceilings, and floors—and employees. He is as allergic to dirt as he is to noise.

He tells you that the watch movement is the nearest mechanical approximation to the "human movement." He draws a large circle on a sheet of paper and within that circle he draws smaller circles. They do not represent all the parts of the watch—only the essentials, just as a doctor will hastily outline the heart, the lungs, liver, kidneys, etc., without discussing the other vast number of physical items that make up the human system. He points to the mainspring and says, "That is the motor, the energy, the blood of a movement; the escapement assembly is the heart which controls the rate the life blood is pumped into the mechanism; the balance wheel is the center—perhaps you might say the liver—the train wheels are the transmission, or the arteries."

Then he brings you into the technical office. This is our first "division of operations." Men work over charts and drawing boards. They are concerned with designs, but not designs for beauty. They are essentially engineers, not draughtsmen; they are men born to be eternally dissatisfied with their most recent handiwork. There is always a new method to improve the arrangement of parts, particularly with respect to new designs for watchcases. In addition, various jewelers may write in to the "home office," expressing a desire for different sizes in wristwatch movements and they may state the form and the arrangement of parts.

"In other words," explains Director Thiebaud, "we do not know in this office what we like. We experiment, discard, test out designs until we are prepared to start with a new drawing, fixing the position for each wheel, the motor barrel, the escapement and the balance. After many tests we make a masterpiece —or model—and when satisfied with the movement our next step is to create the tools and dies, perfecting these so that they can be applied accurately to the production at hand."

So we come to the Division of Tool and Die Manufacture. Here you learn with a shock what real "tolerance" in the matter of precision really means. You see, for instance, an ultraprecision grinding machine which works to within .00004 of an inch in order to obtain complete accuracy in the delicate job of maneuvering with a watch movement.

This plant manufactures its own tools and dies because of the distinct nature of the parts and their arrangement in the watch movement. Thus they must be accurate tools and dies; for the men who use them, and who are responsible for the precision of the watch movement itself, must depend upon them implicitly. For each series of movements there are different tools and dies. The technicians in this division must have long training in acquiring skill in the use of such delicate equipment. They must know not only their tools but the properties of the metals they are dealing with. They must know, for instance, that the *ébauché* must be of brass alloy. After many experiments a special brass was adopted. It is subjected to a pressure of 50 tons by a special machine. Such a machine stamps out forms of the lower plate, the place for the winding pinion, and the position of the holes. The bridges are cut in the same way. (The bridges are sometimes incorrectly called the upper plate.) Eventually the wheels, pinions, and various parts which actually make up a watch movement will be mounted between this lower plate and the bridges which are held together by the bridge screws.

The *ébauché* now go to another department for drilling the holes to make way for the various parts. These are tiny holes. It must be remembered that altogether there are upwards of 200 individual parts in a modern wrist watch which, besides such major parts as the mainspring, hairspring, train wheels, escapement, and balance wheel, include infinitely tiny screws, pinions, arbors, jewels, etc.

How nerve-wracking a job this must be may be understood if one considers that the balance wheel in a lady's wrist watch is hardly any bigger than one of the capital O's used in this book type. Upon that "O" there are sixteen or eighteen screws to be placed and each screw must be small enough to fit into a hole hardly more than one-half the diameter of one of the periods used in the type on this page—(.) And if one of those tiny holes is not made in strict accordance with the prescribed tolerances the whole precision of the watch movement is thrown off balance.

One of the vital steps in the Manufacturing Department, aside from stamping on a serial number, is cleaning. Inspectors at the Gruen plant insist upon scrupulous cleaning of the *ébauché* to prevent the possibility of dust or any foreign matter. It is cleaned in a mixture called Trichlorichline, a derivative of trichloride which the dictionary rather awesomely describes as containing "three atoms of chloride in each molecule." Different parts are cleaned with different solutions, although not always as a dust preventive. For instance, jewels for the escape movement are cleaned in a special solution to assure a perfect surface of the jewel and therefore contribute to the precision of the movement as a whole.

The next and important step takes us to the Assembly Division. Now all the wheels, the springs, the pinions, the screws, and the jewels must be put into their proper place. Not the least important of these items—but the least understood by the general public—is the jewel. It is important because upon it depends to a great extent the accuracy of a watch. The primary purpose of jewels is not to gleam prettily but to provide hardness or resistance. Because of this hardness they furnish the best-known bearings for the wheels that turn hundreds of thousands of times with each day's operation of a watch. Their function is to lessen the friction and increase the accurate performance of a watch.

Before the invention of the watch jewel, the wheel pivots of a movement simply ran in the holes of the brass plates of the movement. But in 1704 a Swiss watchmaker, Nicholas Facio, then living in England, invented the art of piercing jewels for use in watches. The problem of boring a hole in one of these jewels was not a simple one. Today, for instance, they are bored with holes as small as .003 of an inch in diameter. Placing these jewels in the movement is such a delicate operation that it must always be performed under a magnifying glass.

Jewels have consisted of garnet, ruby, or sapphire and sometimes, but rarely, of diamond. Garnet proved to be too soft and is not used in high-grade movements because it is subject to greater wear and breakage. Most of the jewels used today are of the synthetic ruby variety. The synthetic ruby has proved to be superior to the product of Nature. Some optimistic scientists attempted to create synthetic diamonds but their efforts failed. The scientifically made ruby jewel is produced of the same chemical elements as the natural stone—that is, aluminum oxide (Al_2O_3) to which is added some chromium oxide to give it the reddish color of the ruby. This powder or alumine is fused or melted in a special oxyhydric furnace at an extremely high temperature into big droplets called *boules*, which are approximately 1½ inches in length and ½ inch in diameter. These *boules* are then cut into slabs of various thickness by means of a very thin bronze disk revolving at very high speeds and charged with diamond powder. The slabs are cut and polished further into smaller pieces until the desired final thickness and outside diameter are obtained. These now tiny gems must be so perfect that the final jewel cutting is one of the most exacting of the watchmaking crafts.

After they have been drilled with holes, a delicate operation in which special drills are used, the jewels are strung on a fine wire, also charged with diamond powder, and spun until the proper hole diameter and polish are obtained. In the case of jewels for the train wheels an oil reservoir is necessary and a small rotary lap cuts and polishes this cup in the jewel.

But the balance wheel jewels are really something to contemplate. Here the holes are further polished to make them ovalated, that is with the edge of the top and bottom of the hole rounded out in order to reduce the friction of the balance staff to a minimum. The length of the hole must be about equal to its diameter and the mean tolerance of such a hole must be about one-tenth of a human hair. This is because the balance turns 157,680,000 times a year in a watch—so it must have a perfect hole and cap jewels.

Many people wonder why a twenty-three-jeweled watch is more expensive than a twelve or ten. It ought to be obvious from what already has been said that the more jewels up to seventeen used in the proper places the less friction there is and the harder is the surface provided for the pivot to act against and to act as oil retainers. Intrinsically, as jewels, the rubies have no value whatsoever, but a good quality watch should have at least fifteen jewels: two balance hole jewels, two balance cap jewels, one roller table jewel, two pallet stones, two pallet arbor hole jewels, two escape wheel hole jewels, two fourth wheel hole jewels, and two third wheel hole jewels. A seventeen-jewel movement differs in that it has two cap jewels on the escape wheel upper and lower pivots. Actually the vast majority of quality watches—some authorities estimate more than 90 per cent—have either fifteen or seventeen—jewel movements. This is because many technicians question the actual value of additional jewels beyond seventeen. This school of thought maintains that jewels in excess of seventeen are strictly for merchandising purposes or to satisfy the fancy of the owner.

All jewels should be the frictional-bearing type and not, as in some low-priced watches, merely placed in a movement for show or advertising purposes. What, then, is friction jeweling? Well, for more than two hundred years train and balance jewels were set into holes in the plates and bridges. The excess metal around the holes was burnished or forced over the edge of the jewels. Another type of burnished jewel was set directly into a metal setting which, in turn, was fastened by screws into the plate or bridge. Burnished-in jewels had several disadvantages: if not perfectly round or true in diameter they resulted in an off-centered jewel, and if not of uniform thickness they resulted in considerable irregularities in the endshake of the pinions or wheels.

The system of the "friction-tight" jewel, was used for the first time in 1920 and now, more than two decades later, it has revolutionized the watchmaking technique. But promising as this process was in the beginning there still were certain deficiencies to overcome. Jewel manufacturers were not in a position to guarantee a jewel of exact and regular diameter that would be absolutely concentric to the hole. However this problem was overcome. By using new machines and dies of great precision modern technique is now able to accomplish: (1) jewels that are exact as to diameter, and which can be centered in the hole within .005 of a millimeter; and (2) strictly rectified jewel holes in the plate and bridges are assured.

The author has dwelt upon this at perhaps considerable length because of the general public's misunderstanding of the importance of jewels, so that in buying a watch, even if some of the things mentioned seem rather technical, inquiry may be made on these specific points.

Having put the jewel in its proper place let us now get to the larger items that go into the watch and make it tick.

Let us first of all recall what we learned in Chapter 2 of this part of the book: a watch movement consists of four distinct parts—the driving mechanism, the transmission mechanism, the controlling mechanism, and the indicating mechanism.

The heart of the driving mechanism is the mainspring, which is coiled in a circular metal box or barrel. The barrel has a cover and a barrel cap and both are mounted on what is called a barrel arbor. The inner end of the mainspring is attached to this arbor while the outer end fits against the inside run of the barrel. The majority of watches wind the mainspring by turning the arbor but in some the barrel is turned. When Peter Henlein made his first mainspring he hammered it out of a band of iron. The first steel mainspring was made about 1550 and since then the steel used in mainsprings has been improved by various methods and is of the highest quality.

During the winding of a mainspring there are several forces at work. First, the mainspring is being stretched, its elasticity becoming greater the more the spring is wound; second, it is being bent round the arbor, which causes the molecules on the inside to be compressed, while those on the outside are stretched; third, the mainspring is exerting a pressure or friction against itself and is constantly sliding against this pressure; fourth, the winding and unwinding of the mainspring causes a continual change of the bending point from one end of it to the other.

Because of all this, skillful fingers working a finely drawn steel ribbon, exact in width and thickness according to specifications, must carefully coil its length in perfectly widening circles. This must be done accurately to avoid too sharp a curve or inequalities that might tend to excess pull or pressure during its slow unwinding. Smooth, even tension, too, is needed for precision timekeeping. If the mainspring breaks there just isn't any timekeeping.

Which brings up the question: Why do mainsprings break? Some say it is a good deal of a mystery. Science up to this time has found no satisfactory answer to the question nor an absolute and definite cure or prevention for such breakage. It is commonly accepted that atmospheric changes and electrical disturbances and the molecular construction of the steel have great influence in causing such a break. A softer spring, which also means one of lower grade, may be more secure against breakage and even can be guaranteed not to break if it is soft enough, but such a spring will cause other more serious trouble. It is easily disturbed by shock or strain.

The mainsprings used in this plant are of Swedish steel and are hand-rubbed by skilled workmen. Great effort is made to gauge them accurately as to width, length, and thickness. Furthermore, they must fit into the mainspring barrel (as the "house" of the mainspring is called) without any alterations and must be evenly tempered by a special process to assure uniform hardness, thereby reducing the setting of the springs. The highly finished, ovalated, or cross-curved surface also reduces the friction between the coils, resulting in a minimum of breakage, and the riveted tongue-end is designed for proper security.

The transmission mechanism is better known as the "train." It consists of a series of wheels and pinions for transmitting the power from the mainspring barrel to the balance wheel (the balance wheel being a part of the control mechanism). As the wound-up mainspring unwinds from the barrel arbor, the power is transmitted from the barrel (sometimes called the main wheel) to the center pinion, to which is attached the center wheel. The center wheel transmits the power to the third pinion carrying the third wheel, which in turn engages in the fourth pinion carrying the fourth wheel. This transmits the power to the escape pinion carrying the escape wheel.

Up to this point the power has been of a rotary nature, in that the wheels are rotating, each wheel revolving more rapidly and in a different direction from the preceding one, and with the power diminishing correspondingly. The inclined surfaces of the impulse face of the escape wheel teeth now transmit the power to the impulse face of the pallet stones, which transmit the impulses through action of the pallet fork to the roller jewel, which gives the final vibratory motion of the balance wheel. This proves that what is lost in the original power of the mainspring is gained in the speed of the balance wheel, which indicates that a maximum of efficiency is obtained on a minimum of power.

When you hear of an "18,000 train" it means the balance wheel will make 18,000 complete vibrations in one hour. If the balance wheel exceeds 18,000 vibrations for an 18,000 train the movement will gain in time and if less it will lose. A train of this construction will require the fourth wheel (in any watch with a second hand on the fourth pinion) to make a complete revolution in one minute and since five vibrations of the balance wheel are made each second, the second dial will be evenly divided into sixty spaces, indicating the seconds. The 18,000 train is known as the standard train and is used in practically all movements today. Formerly there were many "fast" trains such as 19,333, 19,440, 20,160, 20,222, and 20,940 vibrations, which were used in very small watches. However, with the many technical advances made in watchmaking, such as friction-type jeweling, improved gear-cutting technique, and modern machines and equipment, the present-day movements can be made with the standard 18,000 vibration train.

No machine can place the wheels of transmission in a precision watch. This is a job for careful fingers. There must be an exact distance between the centers of all watch wheels. Each tiny wheel destined for a fine watch is examined under a magnifying glass for imperfections. Each is also checked for "tooth" accuracy and center point location. For unless there is a perfect relationship between the revolutions of all wheels in a watch, precision timekeeping is impossible. As an added safeguard to accuracy, wheel clearance is never allowed to exceed .00078 of an inch. Perfection of fit, therefore, is one of the watchmaker's most exacting duties.

As to the controlling mechanism, it has been said this is the same as the escapement. That is an understatement since the escape wheel, the balance wheel, and the hairspring interpenetrate in their functions. The balance wheel, as a matter of fact, is the governing part or regulator of a watch. It was first used in 1600 and was merely a crude wheel of any kind of material. The complete balance wheel assembly is composed of the balance wheel itself, the balance staff, roller table, and hairspring. There are two types of balance wheels—the cut bimetallic and the solid rim or monometallic wheels.

A few additional facts about the hairspring are deserving of attention at this point. The hairspring is a simple, delicate, circular spring whose object is to give a constant harmonic motion (to and fro, back and forth) to the balance wheel. At first (as far back as 1690) all forms were considered and tried: the plain flat, the two-flat superimposed, the cylindrical, conical, and spherical. The only survivals today are the cylindrical for the chronometer and the flat for watches.

Formerly hairsprings were made primarily of steel but there were numerous other types made of various metallic composition. Conoruma, however, has a new significance. As an alloy of various metals it is supposed to produce a hairspring with "invariable elasticity," creating the least possible thermal error. Remember that a hairspring is subject to rust, but not like steel; it is subject to magnetism, but not like ordinary steel. The bimetallic cut-rim balance, with its uncertainties, therefore becomes no longer essential. As an identification and explanation of the advantages of Conoruma hairsprings and monometallic uncut balances, all movements which carry these features are marked on the balance bridge: Conoruma. This means: CO—Compensation; NO—no; RU—Rust or; MA—Magnetism. This in turn means the hairspring will not vary materially with temperature, it is impervious to rust, and is nonmagnetic.

In fitting a hairspring, the first procedure is to determine the number of vibrations of the balance wheel per hour. There used to be a complicated system but today electronic equipment is used which assures greater accuracy and speed. Our only interest here, however, is in the selection of the proper hairspring. Scarcely visible to the naked eye, most hairsprings have a width of .002 of an inch, and a thickness of .0005 of an inch. Think of the skill and care required of the swift, sure hands which must place this delicate part! It is the heart of the watch. Its function is to keep the watch running at a constant speed. Upon its quality and upon its timing depends the accuracy of the watch. One pound of steel may make as much as eight miles of hairspring. Once five grades of steel were used for this manufacture; today many, many more grades are used.

In Gruen's Swiss factory women are largely employed to mount the hairspring. This is because they know how to handle a delicate and nerve-wracking job. It calls for patience, and watchmakers have found that in this work women have the extreme patience necessary. Girls are trained for three years in a special technical school in Switzerland just for this single operation.

We now come to the escapement, which someone has called the beginning of the end of the controlling mechanism. We shall see that it has to play ball with the balance wheel and hairspring. It consists of a toothed escape wheel, the pallet fork complete with a receiving and discharging stone, a guard pin, a pallet arbor, and the roller table. The purpose of all these related parts is to allow the power of the mainspring to be intermittently transmitted through the train wheels to the balance wheel, where the power is dispelled at a uniform rate. Let us stress again that many forget the complete balance wheel assembly is the actual timekeeping unit of the watch—not the escapement. The accurate rating of the movement is dependent upon the period of vibration of the balance wheel. The power of the mainspring is stopped and released every one-fifth of a second by the locking and unlocking of the pallet stones with the locking faces of the escape wheel teeth.

Let us recall that the first known escapement was the verge invented by Henlein in 1500; early types were the cylinder, the virgule, the duplex, the chronometer or detent. All these, as we learned, gave the power impulse directly from the escape wheel to the balance wheel with no fork and the impulses were not altogether uniform. We can also recall that the popular lever escapement was invented by the English horologist Thomas Mudge about 1750. From these recollections let us note there have been many variations and types of lever escapement. To name but a few: ratchet tooth, rack, pin pallet, pin wheel, two pin, two plane, cylindrical, pointed pallet, resilient detached, repellent or anti-detached, and the present detached type.

As to the present detached type there are actually two kinds: The "equidistant" has the *locking* faces of the pallets an equal distance from the pallet center. The *lifting* action on this escapement is unequal. The "circular" escapement has the central portion of the *lifting* faces of the pallets an equal distance from the pallet center. The *locking* faces on this escapement are an unequal distance from the pallet center, causing an unequal and increasing locking resistance. In recent years a compromise has been developed between the circular and equidistant escapements. It is favored over the other two because it lessens the resistance to unlocking, a fault on the circular, and minimizes the lifting error of the equidistant. This is accomplished by making pallet centers closer to the locking corners.

There is one term in connection with the escapement that deserves a little consideration. Let us define a "banking pin": It is a solid or adjustable perpendicular pin or screw to allow the pallet fork to rest against at the end of its course. A movement is said to "overbank" when the roller jewel strikes outside the pallet fork due to excessive motion of the balance wheel. This factory has perfected its escapement without a banking pin. Due to the new technique employed in the manufacture of watches here, the old style banking pins have been eliminated. The walls of the lower plate themselves or the sides of the pallet bridge act as the banking pins. Experience has taught this firm that with the former banking-pin type of escapement someone invariably moved the pins one way or the other, thereby throwing the entire escapement out of adjustment. This new type of escapement has proved satisfactory due to the fact that it is more secure. The reason for this statement is that the walls of the lower plate or sides of the pallet lever bridge are more solid than the usual banking pins. There is no more wear with this type of escapement than the older type. The escapement is properly adjusted before leaving the factory.

The next step is the indicating mechanism, which is simply the "dial train of a movement." As its name implies the dial train is under the dial of the top side of the lower plate—or close to the dial itself. Its function is to indicate the proper time by transmitting the power of the center wheel to the cannon pinion carrying the minute hand, which in turn makes one revolution per hour. This, in turn, meshes with the minute wheel, whose pinion engages the hour wheel carrying the hour hand and this makes one revolution every twelve hours. When the stem is pulled out the clutch pinion engages with the intermediate wheel, which meshes with the minute wheel and other parts of the dial train, permitting the hour and minute hands to be set backward or forward, according to whether your watch is fast or slow.

The two most common winding and setting arrangements are the stem-and-lever set and the stem wind-and-set. The lever set is the older of the two and the setting of the hands is executed by pulling out a small lever from the dial. A short lever or cam attached to the lever proper disengages the winding and throws the mechanism into the setting position. This type is required on all railroad watches. The stem wind-and-set is operated by pulling out the crown, and the setting mechanism under the dial automatically goes into the setting position locked so that it cannot slip or become disengaged. On some, the stem and crown are held in position by means of a spring sleeve, while in others the stem is one entire piece with the crown attached.

The dial itself is the graduated plate or disk on the movement indicating the motion of the hands. The dial "feet" are short pieces of wire soldered to the back of a watch dial which fit into corresponding holes in the lower plate and keep the dial in its proper position. The dial is held secure by screws in the edge of the lower plate.

When the dial is put on, the holes must line up with the center post and the fourth wheel pivot. It must be perfectly tight so that when the watch is turned over it will not drop from the plate and touch the second hand. The hour wheel must be tested to see that it is free and that the endshake and sideshake are correct. If the dial is perfectly flat and the hour wheel has too much endshake it is necessary to check the hour wheel pipe. The top of the pipe then must come close to the minute-hand shoulder on the cannon pinion and if there is too much space at this point a dial washer is required.

"Hands," of course, are the revolving pointers used to indicate the elapsed time on the dials of watches. When fitting hands the first step is the second hand which should be friction-tight when it is pressed close to the dial, but have sufficient clearance. The movement should be allowed to run for a full minute and the second hand watched carefully to see that it does not touch anywhere on the second-bit dial. Although the second hand must be fitted tightly, it should be possible to turn it backwards to set the movement to the exact second.

The next step is to put on the hour hand. This calls for a tapered hole to conform to the one in the hour wheel pipe, so that when it is pressed into place it will be rigid and not rock from side to side with the slightest pressure. The freedom of the hour wheel is tested again, as an hour hand put on too tightly will often contract the hour wheel pipe and cause it to bind. The hour hand then is fashioned to run as close to the second hand as possible, allowing the proper clearance, the test always being made with the second hand raised as high as the endshake of the fourth wheel will allow.

The minute hand is pressed down as far as possible on the cannon pinion and must be tight. This hand also must be straight, excepting at the end where it must be curved down to conform with the curvature of the crystal. The hands are then tested with the bezel closed and if there is not the proper clearance the crystal may press down on the minute hand. If such a condition exists and the hands have been adjusted properly the only remedy is to fit a higher crystal to the bezel.

In the creation of beautiful watches the dial plays an important part. Its color, its style lend much to the distinction and beauty of a timepiece. That is why dials are subjected to the same careful attention and inspection as the movements themselves. The dial is often made of coin silver. Plate numerals (indicating hours, minutes, and sometimes seconds) are pressed out of the silver under 500-tons pressure. The numerals are then plated with gold.

We have considered the jewels, various movements, and the dial of the watch. These items, together with the pinions and screws are now ready to be assembled. Details of other assembly operations are hardly of importance here in view of the attention already given to the individual parts. But three outstanding facts do impress a visitor to the plant.

The first is the perpetual cleaning of parts.

The next is the constant rigid inspection and reinspection of every operation, even down to the placing of the tiniest screw.

The third is the fact that temperature and isochronal adjustments are actually "built in" the movements. This is enormously important. The Tariff Commission explains it best in its own elaborate but clean-cut logic:

> Probably the most important horological development in recent years is the monometallic uncut balance wheel with a hair-spring made of Elinvar or some similar nickel-steel alloy. Watches incorporating such a balance wheel and hairspring were first used in Europe, but at present most manufacturers of quality jeweled watches, both in Europe and in the United States, employ them in most of their watches.
>
> It [the balance wheel] is made of an alloy whose dimensions change very little with changes in temperature. The hairspring used in conjunction with it has the same outward appearance as the steel hairsprings . . . but has quite different characteristics.
>
> The elasticity of the new type of hairspring is little affected by the changes in temperature to which watches are ordinarily exposed. The new type of hairspring in conjunction with the new type of balance wheel, therefore, obviates the need for any mechanical temperature adjustment in the watch. The temperature adjustment is, in a sense, accomplished in the making of the alloys which go into the balance wheel and into the hairspring. Moreover, a properly designed watch which incorporates this new balance wheel hair-spring combination has virtually no middle temperature error. A further advantage is that the alloys used in these new type balance wheels and hairsprings are little affected by magnetism and are not subject to rust, as are the steel hairspring and the steel parts of a bimetallic balance wheel.

Then the Tariff Commission concludes: "This technological development renders largely obsolete the provision in the Tariff Act of 1930 which imposes a supplementary duty computed on the basis of two adjustments on watch movements which have been adjusted to temperature and which are so stamped. There is no longer any need to 'adjust' a watch to temperature in the sense that was contemplated when the last tariff act was written."

This is important to watch men. It means elimination of the problem of adjustment, whether in Switzerland or the United States. So the remaining operations now are regulation and assembly. But in order to find out about that we must pack our bags and return to Time Hill, Cincinnati, U.S.A.

4

A Watch is Born

The armored cars drive up to the hill in Cincinnati. They unload as many as 50,000 watch movements in a single shipment, the watches being encased in zinc-lined boxes. Sometimes there are as few as 6,000 movements. The head of the Inventory Control Department checks them in. In classifying them they are broken down into type of movement, grade, and style of dial, then arranged in bins by date—the date of their departure from Switzerland. The oldest movements must be cleared first, for in normal times there are as many as 150,000 movements on hand in the Gruen Company's plant.

Once duly classified, the movements are sent to what is known as the Quality Control Laboratory for checking. The head of this department will "spot-check" three or four watches from one group and inspect and test them. This laboratory is the nerve center of the factory. During the many days and many processes of testing and regulating, retesting and reregulating, the burden of the watch movement's accuracy rests with Quality Control. It is an Ellis Island or immigration depot and every movement is an immigrant subject to rigid examination before being accepted. Unlike many laboratories it is not concerned with theory; it is interested only in the practical question of whether the watch works accurately. If its engineers suspect anything is wrong with the minutest part of the movement that part is photographed in color through a microscope and enlarged 1,000 times, its image thrown upon a screen where it is studied.

If the results of those studies do not please the engineers, the watch movement and the enlarged photo will be sent back to Switzerland so that faults may be corrected.

In spite of its importance it is not easy to isolate Quality Control and study it as a unit. Although a department in itself, its activities interpenetrate every other part of the factory. Whether it be the Order Department, the Horological (or Production) Department, or the Watchcase-Manufacturing Plant, there is the constant need for a checkup with Quality Control. It is the czar and as such tests and passes upon the final job.

One of the most important departments is Horological. This may be said to be divided into two parts: Production and Service. Under Production are Casing, Testing and Inspection, Accessories, and Stock Correction (the latter usually meaning cleaning and oiling of the movements). Under Service are the Material and Repair Departments, which service the jewelers of the country.

In the meantime, as we will recall, the watchcase is resting in the Horological Department, waiting for the movement to be set in it. With the arrival of the movement the two are "joined together," to use a sentimental redundancy, and now the watch receives its severest test. First it is inspected thoroughly to ascertain whether the movement and the crystal fit the case properly. If it passes this test then it must be decided whether it winds correctly.

The watch then is sent along to a winder who sits at an automatic winding machine. The watch is tested, set and wound, and retested with special timing devices. The latter are governed by signals broadcast from the Bureau of Standards by short wave. Twice a day the correct time from the Bureau in Washington is carried to every department in the factory. Over a twenty-four period the watch is judged for its preliminary accuracy. But bear in mind the word "preliminary." The ordeal is not yet over.

The first twenty-four hours pass. Inspection also has covered the dial, checking to find out whether it contains any scratches or needs to be straightened to conform with the case; whether the crown is true (meaning that when you wind it, it does not wobble) or whether it is "too close"—meaning it must be at least .005 to .015 of an inch away from the case itself.

After twenty-four hours of running on the second day the watch is brought out again to Inspection and rewound and again checked for fast or slow possibilities. Back it goes to the vault —if all is well; if all is not well, the movement which has been amiss is removed and corrected.

On the third day it is tested again for accuracy of running. After Inspection gives the watch an agreeable nod it goes to the Accessory Department. There it is checked in and fitted with such accessories as straps or bracelets.

Even after the last step, however, all watches are subject to that uncompromising tyrant of the factory, Quality Control. The inspector of this department, as we know, is constantly checking and testing, rechecking and retesting, taking apart and examining watches which previously had passed all other tests. Then the inspector finally scratches on a typed form: "O.K."

A watch is born.

But like everything else born it must have occasional proper care and attention if it is to continue in good shape. That is why the Service Department covers material and repair. Material has on hand at all times about 6,000 different parts for at least 175 movements of all sizes. Service has on hand some of the finest workmen in the world, prepared to act as doctors to sick watches returned to the factory by jewelers, who in turn have sometimes received them from careless owners.

The biggest headaches which the Service Department must endure are broken balance staffs, stems, mainsprings, and hairsprings, and dried-up oils. Also: "Why does my watch go too fast or too slow?" As a matter of fact it might be of interest to present here, from Gruen's List of Repair Problems, what it calls *Miscellaneous Repair Questions and Answers,* for the information of the general public.

First it asks: "What are some of the unusual faults that will cause a watch to retard its motion or even to stop when it is apparently in good order?"

The answers are:

1. A balance wheel screw has become loosened and touches some parts of the movement in certain positions.
2. Some of the bridges touch the case, causing a pressure to reduce the train or balance wheel endshake.
3. Banking pins are improperly aligned.
4. The teeth of the hour wheel catch in one of the notches in the barrel cover.
5. The socket of the second hand rubs on the countersink of the dial.
6. The inner end of the mainspring binds against the inside of the barrel.

Another question: "What are some of the most common faults that cause a watch to be erratic in its performance?"

The answers are:

1. Slightly bent or burred balance pivots
2. Balance not properly poised
3. Hairspring rubbing on balance arm or balance bridge
4. Magnetized (rare)
5. Oil on the hairspring
6. Loose roller jewel
7. Loose cannon pinion
8. Hands rubbing on dial or glass

There are several facts they tell you at the factory—which sometimes collide with popular conceptions. First, there is no such thing as winding a watch too tight. One theory against this is that if wound too tight the oil is squeezed out and too much tension is put on the escapement and there is danger of breaking the hook which holds the mainspring. This is not generally accepted by horologists although it is admitted it is best to wind a watch the same time every day, whether in the morning or the evening. Regularity is important. You can set a watch backward as well as forward unless, of course, it is a complicated watch, such as one with a chronometer escapement. You should not tamper with it too much and you snould keep it clear of dirt and dust, as well as avoiding bumps or sudden changes in temperature. There is one belief that a watch will go wrong or even stop at a high altitude, especially in an airplane. This might be true in a small plane where the temperature and atmosphere has not been adjusted to normal. But most persons who have done much flying in airliners, particularly at high altitudes across the Atlantic Ocean, find their watches are hardly affected at all.

One of the biggest jobs in the Service Department, however, is cleaning and servicing. To do this workers must remove the dial and hands, and the balance wheel from the movement and then from the bridge, being careful not to distort the hairspring. They must release the train power by disengaging the click from the ratchet wheel, at the same time keeping pressure on the crown so the mainspring will not release too quickly, as damage can be done by letting it fly back without proper check maintained on the winding assembly. Then the cap jewel is removed from the balance bridge and after that the pallet fork, the escape wheel, and other train wheels.

In taking the movement completely apart all cap jewels are removed, the parts(except screws and mainspring) being placed in a small container and dipped in cleaning solution. The parts are held for about one minute in this solution and then put in benzine and rinsed out thoroughly. After this, all parts are put in another jar of clean benzine, brushed carefully and immediately placed in a third jar of clean benzine for a final rinse.

It may be interesting to the reader to note the subsequent operations because they not only show us how intricate and delicate the mechanism of a watch is but also answer the question: "Why does it take so long to repair and clean my watch?" So many laymen are curious about what happens to their watches in the repair shop that the writer requested of Gruen a list of rules to its workmen, but paraphrased so as to be understandable to the layman. As a contribution to the patience of watch owners they are listed here:

A. Remove the balance and train wheels and all other parts individually from the benzine and dry them with a Selvet or linen cloth thoroughly. After going through this process:

1. Peg all jewel holes and other bearings from both sides until all traces of gummy oil and dirt have disappeared. Also, clean all cap jewels which can be done by buffing or rubbing with peg wood.

2. Clean all pivots with pith.

3. Brush all parts lightly with a soft brush, just enough to remove the lint and peg wood shavings. Using the brush in excess will only get grit and dust back into the jewels and bearing holes.

4. When the mainspring is taken out of the barrel it should be handled carefully and no attempt made to straighten it out if somewhat bent. Do not put mainspring in benzine. One of the best methods of cleaning a mainspring is to fold a strip of chamois or tissue paper over the outside coil and move it along carefully until the inside coil is reached, being careful not to bend the spring while doing so.

B. Now that all the parts have been cleaned:

1. Inspect all pivots, pinions, and wheels. See that pivots are polished, straight, and clean. See that no pinions or wheels are defective.

2. Inspect all jewels for tightness, cracked or chipped holes, and cleanness.

3. Assemble barrel without mainspring to see that the barrel is true and free.

4. Replace all cap jewels; be sure cap-jewel screws are tight and not too long.

5. Oil all jewels with cap jewels. This operation should be done with the utmost care as it is important to give the right quantity of oil. The consequence of too much oil at this point is as bad as the lack of oil.

C. For applying the oil:

1. Oil should be kept in a glass or agate oil-cup. Change at least twice a week and keep covered at all times except when in use.

2. The oiler itself should be made out of steel or gold. Do not use brass. Always use an eyeglass when applying oil.

3. In order to penetrate the oil into the cap jewel take a fine pointed gold wire and insert it through the hole jewel. Providing the jewels are set properly this will form a small ring on the cap jewel which should be somewhat larger than the cup in the hole jewel. Only then will the oil not spread and disappear. Do not consider the job done until each cap jewel has been inspected for the proper amount of oil.

Incidentally, as a rule watch-oils are made from petroleum, mineral, vegetable (such as seed or nut), animal, or fish oils. The most widely used type is that made by processing the fats from the jaws of a porpoise. Also, several synthetic oils have been developed in recent years, some of which are made from various basic chemicals or, in other words, a highly complex molecular process. Such a lubricant will never evaporate, corrode, leave a gummy residue, or have any of the other disadvantageous characteristics of regular-type watch oils.

The characteristics and various properties of a *good* watch oil are: (1) chemical stability, meaning that it retains its body or makeup and will not break down in a short time under normal or adverse conditions; (2) noncorrosiveness, meaning it will not chemically affect the metal parts or jewels of a watch or in itself be affected by these parts so that it will decompose; (3) no spreading tendency, meaning it has a maximum tendency to stay in one place and not spread from pivots and jewels; (4) low volatility, that it has a minimum evaporation point at various temperatures; (5) good lubrication, meaning it has a maximum friction-reducing property; (6) correct viscosity, which finally means it is the degree or measure of "stickiness" or adhesiveness and is suitable at both high and low temperatures.

D. Assembling train:

1. See that all the wheels drop, at the same time check the endshake, spin train, and see if wheels are true and free.

2. Assemble mainspring barrel with mainspring and arbor. Be sure to replace the barrel cap properly—see that the barrel and

mainspring are free and check for the amount of turns of the mainspring in the barrel. Assemble barrel to the watch.

3. Put oil on each impulse surface on pallet stones and assemble to the watch. Check escapement. See that pallet is free and check endshake.

4. Oil center post, lower center pivot, and lower third pivot. Assemble cannon pinion—winding and setting parts, oil properly, assemble dial train, check winding and setting and cannon pinion.

5. Oil upper pallet hole jewel in order to apply the proper amount of oil; take the smallest oiler; dip in oil, but instead of putting the oil right on to the jewel, touch first a piece of tissue paper and then place the oiler on this pallet hole jewel. This will give just the right amount of oil on your pivot.

6. Assemble the balance wheel to the watch; check for trueness and endshake. Check the hairspring, regulator pins, guard-pin action, and see if watch is in beat.

7. Oil the rest of the train jewels. Also oil several teeth of the escape wheel.

8. Check again all screws for tightness.

9. Assemble dial and hands.

10. Time the watch.

Watch men will hope that the reader, having gone through this list, will understand the complicated nature of watch repairing and cleaning. They realize it should no longer be the mystery to laymen it has been. In any event the preceding pages have, we hope, lifted the veil.

Such is the story of the watch. Given good care it is a friend and companion and a guide to man. It informs him how much time he has for his business or pleasures. It tells him how late it is.

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