GRUEN

Watchmaking Institute

HOME OF GRUEN . . . THE PRECISION WATCH

Watch Training Program

A complete course in watch cleaning and repairing

GRUEN

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The Gruen Watch Company
Time Hill, Cincinnati 6, Ohio

July 1, 1946

RULES AND REGULATIONS
OF
THE GRUEN WATCHMAKING INSTITUTE
TIME HILL, CINCINNATI 6, OHIO

1. HOURS OF WORK - The hours of work of the Institute are from 8:00 A.M. - 12 noon and from 1:00 P.M. to 5:00 P.M., Monday through Friday.

   (a) A trainee must telephone before 9:00 A.M. that he will be absent due to illness or other valid cause.
   (b) No one is to leave early or be absent any period of school hours unless a valid excuse is given before leaving.
   (c) If a trainee is late more than 15 minutes, he will be deducted 1 hour's time.

2. NEATNESS

   (a) Your own tools and working area must be kept in a neat condition. This also applies to other equipment and benches that you may use.
   (b) Do not leave chucks, drills, and other tools on these benches, but return them to the office immediately.
   (c) Benches must be covered every night and bench lights put out at noon and at closing. Every Friday evening all benches are to be cleaned thoroughly and tools replaced in the bench drawers.
   (d) No eating at benches during school hours.

3. MATERIAL HOUSE TRIPS - Only 1 trip per day at 1:00 P.M. will be made to obtain material parts, and only 1 trainee shall go to town.

4. TIMING MACHINE - The timing machine will be in operation at 10:00 A.M. and 3:00 P.M., and only by Mrs. Burgess and not by the trainees. The watches must be put in movement cartons and these placed in the wire basket on the back of the office door at these specified times. No special rush jobs will be permitted.

5. TELEPHONE CALLS - Personal telephone calls, both incoming or outgoing, will be limited to the hour from 11:00 A.M. to noon, except in case of extreme emergency.

6. SMOKING - Smoking will be confined to 2 rest periods of 10 minutes each, at 10:00 A.M. and 3:00 P.M. No smoking at benches, and see that butts and matches are thoroughly extinguished and placed in waste paper receptacles and not on the floor.

7. VOCATIONAL SCHOOL - October through April, trainees are expected to attend the Vocational High School on Iowa Street - every Wednesday afternoon from 3:00 P.M. to 5:00 P.M. - to study mathematics and mechanical drawing. Unwarranted absences will be reported to the Veterans Administration.

8. MISCELLANEOUS

   (a) No visiting from bench to bench. Do not lean on another trainee's bench, as it is very annoying and sometimes very expensive.
   (b) No loud talking or whistling during school hours. Work diligently and in silence.
   (c) Do not show a half-finished job to the instructor, but complete the work and then have it inspected.

THE GRUEN WATCH COMPANY
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Course of Study for Watch Training Program

1. Make tools (see separate list)
2. Turn and finish square shoulder pivots 2 each .30, .24, .18, .14, and .12 m/m
3. Turn and finish cone shoulder pivots, 2 each .15, .14, .13, .11 and .10 m/m.
4. Turn various balance staffs to measurements.
5. Stake balance wheel to staff.
6. True balances.
7. Poise balances.
8. Level and circle hairsprings.
9. How to collet, overcoil and true hairsprings.
10. Fitting of train jewels.
11. Setting end stones.
12. Fitting of balance jewels.
13. Cutting jewel settings.
14. Level, center and circle hairsprings in movement.
15. Fitting and selecting proper mainsprings.
16. Turning pinions.
17. Fitting a train wheel on pinion.
18. Depthing of wheels.
19. Calculation of watch trains.
20. Study and set up escapements.
21. Fitting guard pins.
22. Fitting roller jewels.
23. Clean and oil watches.
24. Fit ready made balance staffs to movements.
25. Set up escapements in movements.
26. Bush and upright holes.
27. Fitting jewels to movements.
28. Friction jeweling - selection and fitting.
29. Make setting repairs.
30. Make stems to fit movements.
31. Make platescrews and polish.
32. Polish regulator, cap jewel and winding parts.
33. Make a clutch lever to fit movement.
34. Fit dial and hands.
35. Fit movements to cases.
36. Turn balance staffs to fit movements.
37. Fit regulator pins.
38. How to vibrate a hairspring.
39. Select flat hairspring, collet, stud and overcoil fit to movement.
40. Time and regulate a watch.
41. Review of general repairs on smaller watches.

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THE GRUEN WATCHMAKING INSTITUTE
TIME HILL, CINCINNATI 6, OHIO

A BRIEF HISTORY OF THE WATCH

Ever since our primitive forefathers measured their daily tasks by the march of the sun across the sky, time-telling has held a vital place in everything great and small that man has done.

If you are carrying a watch in your pocket or on your wrist, place it before you so that you can better understand the romance and wonder of its story. Hidden within its platinum, gold, silver, or stainless steel case is a tale as fascinating as the Arabian Nights. Surrounding its delicate pinions, springs, and wheels is the whole history of astronomy ... the story of man's progress and invention.

Let us review this fascinating story. It begins countless centuries ago, with the men whom we call "cave-dwellers". As the sun moved, these men noticed that the shadows cast by the cliffs also moved. Then they saw that the shadow of a tree fell in a certain place on the ground, or on a stone. Soon they realized that one stone would mark only one point in the long march of the shadow; therefore, why not use two stones - or even a number of them - to divide the day into parts? Thus the ancients came to mark time by shadows of objects that came between the ground and the sun.

We come down the ages, now, to 4000 B.C. and the very beginnings of recorded history ... down to the magician-priests of Babylon and Chaldea. These wise men of old gave much of their time to the study of the heavens. It was they who created the first calendar, who first divided the year into months, days, and hours.

As time passed and living became more complex, new needs arose. Time-telling became more exact, and by 1500 B.C. the Egyptians had invented a shadow-clock made like a T-square. In 900 B.C. came the sun dial, which enabled men to tell time with a fair degree of accuracy whenever the sun shone. Obviously, however, the sun dial was not completely adequate, and so men searched on.

The outgrowth of this need for a constant, more accurate time-keeper was the clepsydra or "water thief", developed around 600 B.C. The first clepsydra was very simple - merely a vessel filled with water, with a small hole in the bottom through which the water dropped. As the water ran out it passed the hour markings on the vessel, thus indicating the time. However, the clepsydra, too, had its limitations. When the reservoir was full, the water ran faster than it did when it was nearly empty. As a result, by 250 B.C. the early clepsydra had given place to a water clock with a dial which was operated by a floating ratchet.

There were many new improvements in the centuries that followed. During the next fifteen hundred years, the hour glass, the Roman lamp-clock and King Alfred's graduated candle came into being. As life quickened and the center of civilization shifted farther north, the mechanical clock was invented. The early clock of about 1300 A.D. was a mechanism of weights and wheels, capable of striking the hours. But even after it was well established, many people still clung to the old clepsydra, just as many favored the manuscripts of the ancient monks long after the invention of movable printing types.

In 1621 came the pendulum clock; in 1679, the experimental incline-plane clock; in 1826, the public clock with illuminated dial - - and finally, the modern timekeeping marvel, the electric clock.

For the early history of the watch, we must go back to the first half of the 16th century, when clocks were more beautiful than accurate. Peter Henlein, a young locksmith of Nuremberg, attacked the problem of reducing the clock to portable dimensions. He succeeded, thus giving to the world the first of the famous Nuremberg eggs.

A short while later, during the time of Shakespeare and Queen Elizabeth, while watchmaking was developing in Europe and watches were rarities afforded only by the wealthy, a watchmaker by the name of Charles Cusin moved to Geneva, Switzerland. Thirteen years later, in 1587, Cusin founded the first Swiss watchmaking guild; out of this guild one of Switzerland's most important industries developed.

By the end of the 17th century, this guild was producing five thousand watches a year - - no small output for three hundred journeymen and one hundred masters, fashioning their watches by hand. Watchmaking was then considered an "art and a mystery", and was passed down from father to son through many generations. These guildsmen protected the guild's good name, and guarded the guild secrets carefully from independent artisans who sought to copy. The guild watches grew famous, and noblemen from every European court cherished them as priceless pieces of craftsmanship.

When a guildsman finished a timepiece, he took it to the master for examination. If it failed to pass the master's scrutiny, it was returned to the maker with a rebuke and perhaps even a fine. So proud were these Swiss watchmakers of their craft and their guild that they signed their watches as Raphael signed his paintings or Cellini his golden vases.

It was a Swiss who invented the fusee, another Swiss who introduced jewels for the reduction of friction, and yet another who first invented the stemwind. It was also a Swiss who eliminated the solid upper plate which covered the works and substituted the system of bridges.

Although the English led the world in the manufacture and sale of watches up to 1840, the Swiss gradually drew ahead until they practically gained control of the world's market for watches. Thus it was that the little country of Switzerland came to be famed for its watches, and the name "SWISS" came to stand as the symbol of a fine watch movement.

The year 1848 marked the beginning of American watchmaking as an industry. The meeting of a young clockmaker and a young watchmaker brought together two men who believed that watches could be made by machinery. They found a man to finance their venture, and in 1850 established a small factory in Roxbury, Massachusetts.

There were serious problems ahead of the young watchmakers. The old guild method of watchmaking used a model which had been fashioned by a master as a pattern, and then distributed its parts among a great many skilled workmen - - experts in forty or fifty trades. Each man copied the model part which he had before him and returned the finished parts to an assembler who put them together.

The young watchmakers' idea, however, was to lay out the entire design of the watch on paper and make each part by machinery. The machine of course would duplicate a part repeatedly, with little or no variation.

That, at least, was the theory. In actual practice it was quite different. To begin with, there were no machines of the desired precision. So before these men could make a single watch, they had to invent the machines, build and install them. And, just as they were beginning to attain real success in their work, the panic of 1857 drove them into bankruptcy. However, a short while later the company was refinanced and today is still in operation.

Since this first company was founded in 1850, other watchmaking organizations have sprung up, building a strong and powerful industry in America. One of the most important of these is The Gruen Watch Company, to which we now turn our attention.

In 1874, the organization which is now known as The Gruen Watch Company, was founded by Dietrich Gruen. Gruen's purpose was to improve the pocket watch, and in the eighties he realized that ambition, producing what is now known as the 16-size pocket watch. For many years this was the popular size man's watch, and today is still the size made by all watch factories for railroad use.

The 16-size, however, did not materially reduce the thickness of the watch, and in 1902 Frederick G. Gruen, Dietrich Gruen's son, evolved the Veri-Thin Wheel Train. It was this idea, in conjunction with other modern improvements, that first made possible an accurate, thin pocket watch.

The Gruen Veri-Thin, improved through the years, is recognized today as America's first accurate thin watch. Through a simple arrangement of the wheels, half the movement space was saved without reducing the size or strength of the watch parts. Today's Veri-Thin watches are wafer-thin, streamlined, beautifully designed versions of the original model.

In addition to the 16-size watch and the Veri-Thin, Gruen has originated many other watchmaking "firsts". It was Gruen who first commercially pioneered the lady's wrist watch in America, and more recently the oblong Cartouche (lady's wristlet) and Quadron (man's wrist watch), rectangular movements which permit greater size and strength of wrist watch parts. It was also Gruen who invented the tiny, gracefully slender Gruen Baguette movement.

Gruen's latest achievement is the exclusive Curvex movement, which is patent protected against imitations until 1959. The Curvex movement, as its name implies, is actually curved to fit the wrist-form case. Its parts are nevertheless rugged and full size, assuring long life and precision accuracy.

Among recognized, reputable watch manufacturers, The Gruen Watch Company holds the unique position of being the only international watch manufacturing organization with factories on both sides of the Atlantic. In picturesque Madre-Biel, Switzerland, where men talk, think and live watches, the Gruen movements are made. In quaint workshops suggestive of the guild halls of old, these men who were trained in the watchmaking knowledge and traditions of the ages produce movements of wonderful accuracy, compactness and durability.

Upon completion, these Gruen movements are shipped to the American Gold Case Factory and Service Workshops at Time Hill in Cincinnati. Here they are fitted into cases which American craftsmen with medieval skill and ideals design and execute. The finished timepieces are the famed Gruen Precision Watches, known throughout the world as "America's Choice Since 1874".

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Time Hill
Cincinnati, Ohio

LESSON I
TOOLS

The proper usage, care and maintenance of tools and equipment, IS VERY IMPORTANT. Tools and other equipment should be kept as near to their original condition as possible by periodic reconditioning, cleaning, and where necessary, oiling to prevent rusting.

Part 1 - Acquiring Skill in the Use of Tools

The File - The shape of the file to be used is determined by the shape of the piece which is to be filed. The various shapes of files ordinarily used are known as flat, square, three-cornered, round, half-round and ratchet.

When filing, maintain perfect balance of both hands, keep the file at all times in a level position. (Fig. 1) Filing is accomplished by the pressure given the file on the forward stroke. The action of a file in this respect is similar to the teeth of a saw. Since the cuts of a file are made on a slant, no cutting can be done on the return stroke, and no pressure is applied. When filing flat, the surface should be tested with a scale, or straight edge, to ascertain if the filed surface is perfectly flat. (Fig. 2)

Draw Filing - Draw filing is drawing a fine-cut file over a piece of work, always moving the file in a right angled direction to the length of the file. The force to move the file is applied principally by the fingers which hold the file right over the place to be cut, rather than by the handle which is used chiefly to help guide the file. (Fig 3)

Pin Filing - For this the blank wire is secured in a pin vise, the extended portion of the wire rests in a groove in a hardwood block held in the bench vise, and the work usually rotated by the left hand while the file is operated by the right hand. (Fig 4-5-6-)

To apply a high polish to certain taper pins, a burnisher is used in the same manner as the file.

The groove in the wood filing block should be notched as shown. (Fig 7)

File Handles - Without handles on large files, power and speed are sacrificed in roughing out work, as we ll as on small files for finishing work. Handles should be in proportion to the size of the files, and must be fitted securely. To fit soft wood handles, a hole should be drilled, large enough to allow about half of the pointed end of the file to enter, then with a mallet drive the handle on until practically the entire end is imbedded in the handle. Hardwood handles should be drilled the same as for soft wood, but the pointed end should be heated red hot and then allowed to burn its way into the handle, far enough so that a final tap with a mallet will tighten it securely. (Fig 8)

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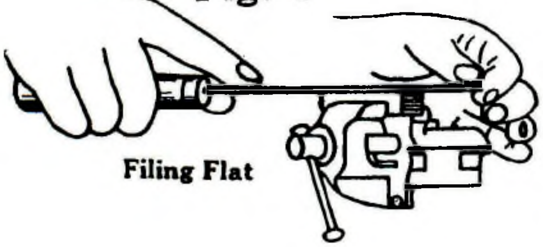

Fig. 1

Filing Flat

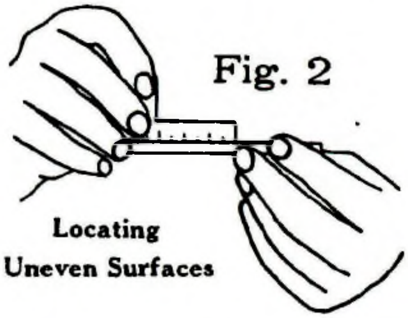

Fig. 2

Locating
Uneven Surfaces

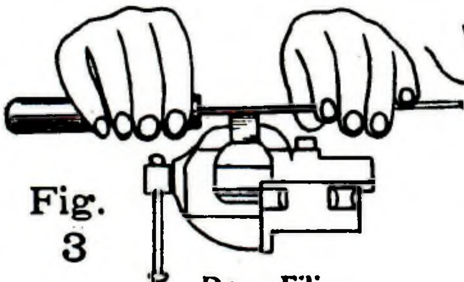

Fig. 3

Draw Filing

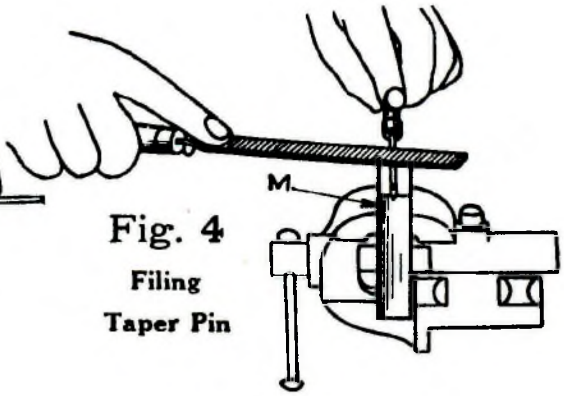

Fig. 4
Filing
Taper Pin

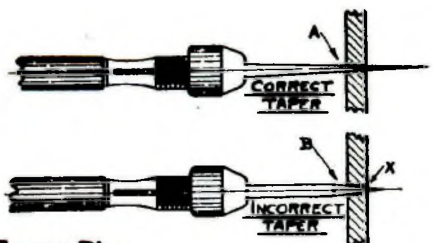

Fig. 5

Taper Pins

Fig. 6

Grooved
Filing Block

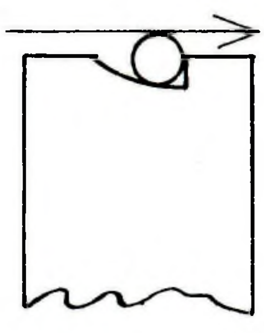

Fig. 7

Fig. 8

Care of Files - A new file should be used first on brass or other soft metals before using it on steel. The teeth on new files are extremely thin at their ends, and may break off if used new on hard metal. Using files first on soft metal, the ends wear very slightly, cut hard metals.

Fasten strips of wood edge up in the bench drawer, with a notch out to hold each file edgewise; then arrange the files grouped systematically as to shapes, sizes and cuts. This will prolong the usefulness of files by preventing their teeth from rubbing together, and will enable the proper file for any use to be quickly found.

A file with teeth clogged by metal particles will not cut any faster than a worn-out file. It is unavoidable that metal filings stick more or less in the teeth of a file while working with it. Tapping the file on the bench clears out some of the filings from the teeth. The best method is to use a file cleaner. (To be made under tools)

Part 2 - Use of Saws

Sawing, like filing, requires full knowledge of working principles and equipment in order to produce work profitable in both quantity and quality.

The equipment should include one of the smallest size hacksaw frames and blades. This is for cutting off rods or bars, or for speedily sawing short straight lines in sheet metal. The height of the blade prevents breakage under the heavy pr essure needed for fast cutting. For sawing curved lines, or for straight lines that change direction as they progress, a jeweler's saw and frame should be used. (Fig 9)

In a hacksaw, the blade cuts better with teeth pointing forward, away from the handle; they should cut while being pushed forward into the work. But in the jeweler's saw frame, the blade should be put in with its teeth pointing towards the handle, because these delicate jeweler's sawblades haven't enough strength to push into the work.

The two kinds of sawing are (a) when the cut begins from the edge of the piece to be sawed; or (b) when the beginning of the cut has to be made inside of the piece; such as a hole drilled in the metal. Fasten a blade in the lower clamp of the saw frame; loosen the thumbscrew at the back of the frame; pass the blade through the drilled hole; fasten it with the upper clamp. Press on the lower end of the frame; this will move the clamps farther apart, sufficiently to give the sawblade the correct tension, when the thumbscrew is turned tight.

When sawing starts from the edge of the piece, the blade may be tightened by clamping its lower end, then laying its upper end between the cheeks of its clamp, pressing the two clamps toward each other by resting the upper one against the edge of the bench and pushing with the handle; then tighten the upper clamp; now the blade will have its tension.

Part 3 - The Lathe and Turning (see illustration of parts of lathe)

Too much time cannot be spent in turning practice. Remember to sharpen the graver as soon as the metal appears rough, due to the graver being dull. Pay particular attention to keep the point sharp. For elementary turning, brass should be used as it is soft and easily turned. Set the T-rest close to the work at a height so the cutting edge of the graver will be in the center or a little above the center of the arbor - never below. Hold the graver, face upward (or downward) between the thumb and forefinger of the right hand, with the handle pressed lightly against the palm with the remaining fingers. (Fig 10) Place the second finger of the left hand on the body of the T-rest and use the first finger as a guide for the graver. Hold the graver so that the cutting will commence near its point, leaving a little clearance between the metal and cutting edge. The shaving will then leave the graver in long spirals and the surface of the work will be smooth.

To Chuck Work for Accurate Turning - If a chuck with a hole a little too large or too small, is used, it will be impossible to turn a true part, and the chuck will be damaged for further accurate work. (Fig 11) A indicates, in cross section, a piece of work in a chuck of a correct fit. At B is shown a chuck with a piece too large forced into it, and at C, the permanent damage done to the chuck by this. At D is shown a chuck with the hole too large for the part; and at E the permanent damage to the chuck. The hole is no longer cylindrical, which makes a chuck untrue, and this cannot be corrected, once it has happened.

Even with a true chuck, of proper size hole, care must be taken to have it and its seat in the lathespindle perfectly clean. Dirt or metal waste at either place may produce the same result as an untrue chuck or one of an incorrect size for the job.

Shapes and Sharpening of Gravers - Gravers are the chief hand tools used in turning. It is a cutting tool formed of a square piece of steel, the cutting end of which is usually made diamond shaped. In truning, the graver should be presented to the work so that the body of the tool lies nearly at a tangent to the work being turned. The two forms most generally used are the "square" (Fig 12) and "diamond" (B). These, together with the right-angle point, C and a rounded point, D will fulfill practically all turning work.

The grinding of gravers should be done with a flat stone, like India oilstone, hard Arkansas, etc. Spread enough oil on the stone to float the waste particles of steel so that they do not clog the grain of the stone. Hold the graver with fingers close to the stone, to keep the work flat on the stone as it is being ground. Use long strokes at first, shorten them as the job approaches completion.

First grind the face of the graver to the angle required. This may be judged "by eye" or with a flat piece of sheet metal with a 45 degree angle filed in it. The graver-face must be made perfectly flat, any rounding of the corners will produce dull cutting edges. Getting a flat surface depends upon keeping a steady finger pressure, and the hand and arm motions sensitive and flexible enough to hold the face of the work flat against the stone at every part of the motion, which will prevent "rocking" the work and rounding the corners. After the graver face is ground, the two under sides that meet at its point must be ground sufficiently to remove the roughness there on the new gravers. Where this is to be done is shown at (F without the angle and F with the angle) the undergrainding slightly exaggerated. Besides smoothing the surfaces, it places a supporting effect under the cutting edges and point of the graver, and lessens the chance to break under the strain of turning. The graver then should be smooth-stoned, on a hard Arkansas stone, so that where the surfaces meet there will be sharp cutting edges. Without well kept gravers, good turning simply cannot be done.

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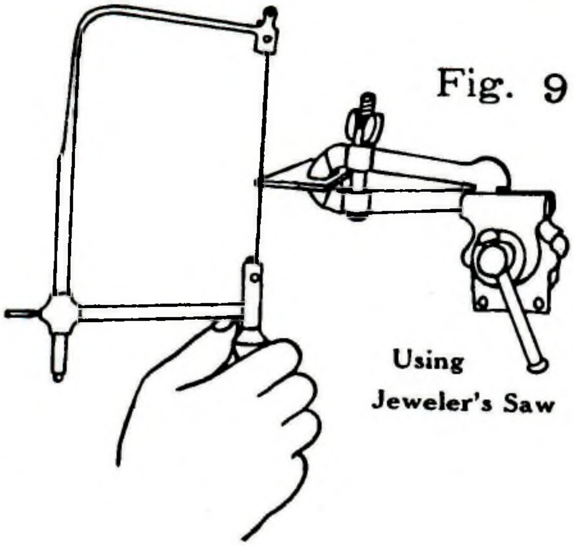

Fig. 9

Using Jeweler's Saw

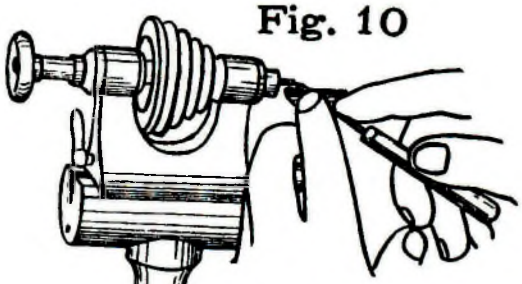

Fig. 10

Holding Graver To Turn

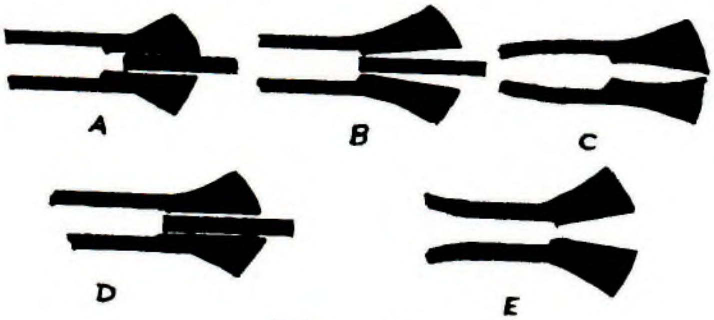

Fig. 11

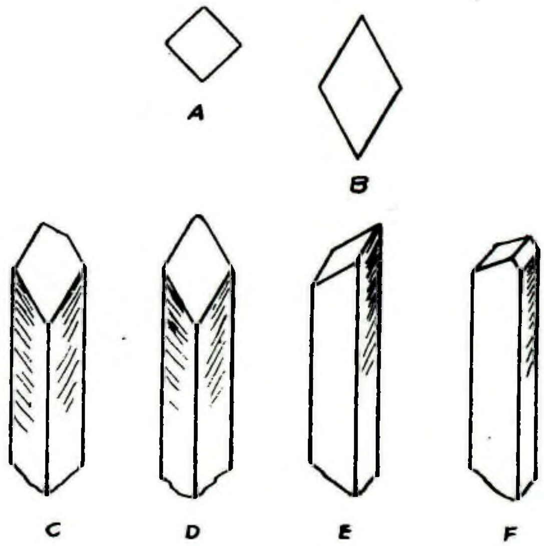

Fig. 12

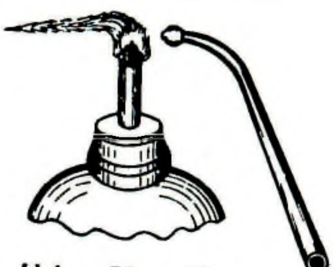

Fig. 13

Using Blow Pipe

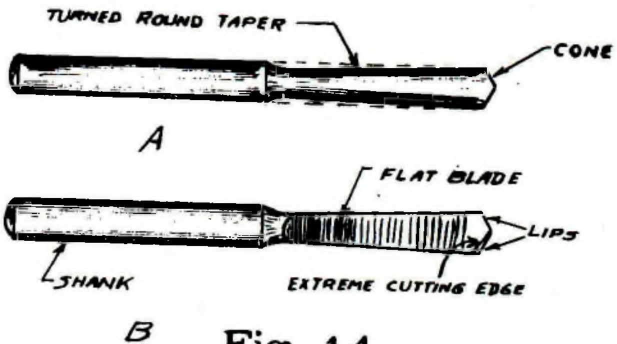

Fig. 14

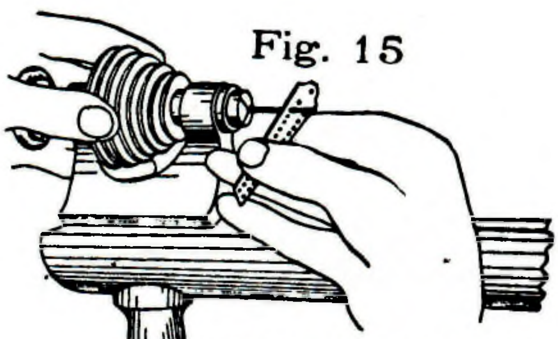

Fig. 15

Cutting Thread In Lathe

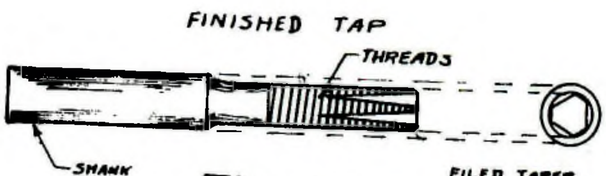

Fig. 16

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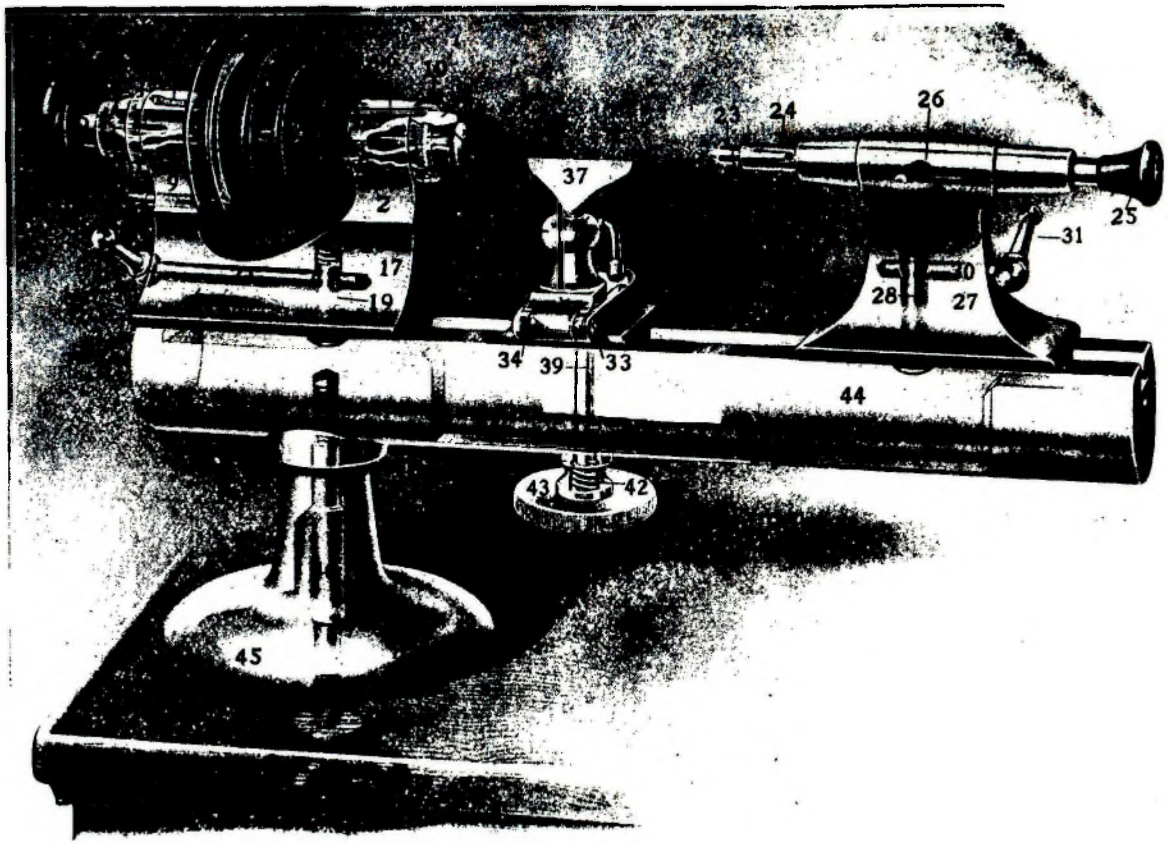

Names of the Parts of a Lathe

Headstock Parts.

1. Headstock Spindle.
2. Throat Pin.
3. Loose Bearing.
4. Loose Bearing Pin.
5. Adjusting Nut.
6. Front Bushing.
7. Rear Bushing.
8. Front Inside Shield.
9. Rear Inside Shield.
10. Front Outside Shield.
11. Rear Outside Shield.
12. Pulley.
13. Pulley Hub.
14. Pulley Screw.
15. Draw-in Spindle.
16. Draw-in Wheel.
17. Frame.
18. Index Pin.
19. Bolt.
20. Spring.
21. Eccentric.
22. Lever.
A. Wire Chuck.

Tailstock Parts.

23. Pointed Center.
24. Spindle.
25. Spindle Button.
26. Spindle Binder.
27. Frame.
28. Bolt.
29. Spring.
30. Eccentric.
31. Lever.

Swing Rest Parts.

32. Slide.
33. Pivot Screw.
34. Pivot Screw.
35. Post.
36. Lever.
37. T Graver Rest.
38. Shoe.
39. Shoe Bolt.
40. Bolt Pin.
41. Bolt Washer.
42. Bolt Spring.
43. Bolt Nut.
44. Bed.
45. Base.
46. Base Bolt.
47. Bolt Washer.
48. Ball Nut.

Part 4 - Hardening and Tempering of Steel

Hardening of Steel - There are many kinds of steel but four general purpose types of tool steel are used widely, carbon or water-hardening, oil-hardening, air-hardening and high speed steel. The watchmaking industry uses mainly the first two, namely, water and oil hardening steels. As we use only steel of the very highest grade in our work, and our tools, etc., are the most delicate, we must be doubly careful about the heating in order to prevent it from burning or warping. Steel, as it comes from the manufacturer, is soft enough to be easily filed, turned or drilled. After shaping the needed part or tool, the next step is hardening the steel by heating it to the required temperature at the proper rate and then cooled in the proper liquid. The steel manufacturer usually indicates on the stock the critical hardening point of the particular type of steel.

The equipment found in most watchmaker's shops is a large alcohol lamp and a mouth blow-pipe. The steel should be held on a charcoal block while being heated. The block should be flat and large enough to support the entire piece. If due to the form of the article to be hardened, it does not touch the block along its entire form, the block may be hollowed or a backing may be made of smaller pieces of charcoal, these will catch heat and hold it around the article and hasten the heating. A large burning flame, is to be directed on the article by a continuous blast from the blowpipe. (Fig 13) Heat until the steel has become a cherry red or the correct temperature. When the piece is of one even red, clip it instantly in cold water or oil that will cool it quickly. After hardening steel will be coated with a black oxide, which is removed by cleaning and polishing.

Tempering of Steel - Due to its extreme brittleness, it is necessary to temper the hardened steel, each piece being tempered or drawn until it is of the proper hardness for the purpose required. There are several methods of judging the diminishing hardness under heat and the one by color is the most convenient, each color denotes a certain hardness. The steel will first turn a very pale straw, straw, dark straw, brown, purple, light purple, dark purple, dark blue, light blue and then green. To obtain an even color, the utmost cleanliness must be observed, even a finger mark being sufficient to prevent a color that otherwise might have been perfect. The finer and brighter the polish before tempering, the better and more even the color will be. The hardened piece should be laid on a metal plate under which heat from any convenient source is maintained. Pale straw and straw is suitable for gravers, cutters, etc. dark straw and brown for dies and taps; purple to dark blue for springs, staffs, screws, stems, and the majority of watch parts. As soon as the desired color is attained, the piece is removed from the heat and allowed to cool gradually at room temperature, but if the color starts getting darker, or the piece is large, it should be quenched in oil.

Part 5 - Demonstration and Instruction in Sawing and Filing

There are certain basic rules to follow in selecting a saw blade. Steel or any thin metal requires a blade with smaller teeth than does brass or thick stock. To select the proper blade, use one that has two or more of the teeth in action against the cut at all times. The teeth of the sawblade should point toward the handle and the blade should be tight enough so that it will not bend backward while sawing; however, to prevent breakage, the tension should not be too great. Apply pressure only on the pulling strokes, while on the reverse strokes, there should be only enough pressure to hold the blade against the cut.

When sawing to a marked line, start away from the line, but gradually approach it. To change direction of the sawing, turn the handle gradually, but keep the blade working against the cut at all times. When sawing around an angle, the handle should be turned slowly, the blade moving without making any forward progress, but continuing the full to and fro motion of the blade. When the blade moves freely in the new direction, the forward progress may be resumed.

Cross filing and draw filing are used to finish the piece. File carefully, stop often to measure with a straight edge on a flat surface or an L-square when filing an angle. The files chosen for this work are smaller and lighter, with finer-cut teeth than those used in preliminary or rough filing. Cross filing is now applied as follows: (1) Cut some strokes diagonally across the surface, by moving the file forward and sidewise at the same time. (2) Repeat at a right angle to the strokes first made and these latter strokes will show where the surface is highest. (3) Continue filing in this manner until the flattened surface enlarges and reaches the edge of the work. If the surface is not large, draw filing may be substituted and the work flattened quickly.

Part 6 - Making Flat Drills

To make a drill, fasten a piece of wire 3 m/m thick and 40 m/m long in the lathe. Let 25 m/m extend from the chuck. With the graver, turn a notch in the wire 20 m/m from the end about 0.5 m/m deep and also a cone on the end of the wire at an angle of 45 degrees to form the cutting edge. The turned blank is a taper from the bottom of the notch to the end of the wire. (Fig 14)

This blank is flattened by filing the two opposite sides to a taper which starts at the turned notch and ends at the cutting edge to a thickness of 0.5 m/m. The larger drills may be left in the lathe for filing, first setting the index pin, filing one side, then resetting a half-turn and filing the other side. The smaller pivot drills are stoned flat after hardening. Next harden and temper the drill to a straw color. The cutting edges of the drill are made by stoning. Lay the flat sides of the blade on an oilstone of medium grain, and rub to and fro until all the file marks are removed, and finish by rubbing on a hard Arkansas oilstone. Fasten the drill in a pin vise and place the lip so as to make a perfect meeting between it and the stone. Tilt the drill sidewise so that the stoning will form a slant to shape a cutting clearance on the lip with the cutting face towards you. The guide for making the lips at the correct angle, and to meet at the exact center is the remaining part of the turned end bevel, each side of which should be stoned off to form the cutting edges.

On the above instructions, measurements were given for length, etc. The only part of a drill where exact measurement is essential is the extreme cutting edges which determine the diameter of the hole the drill will make. The length of a drill is governed by the depth of the hole it is to make and its diameter. The turned taper is made to allow clearance and help prevent chips from filling the hole around the drill, causing it to heat and break,while the filed taper adds strength to the drill.

Part 6 (Continued)

Making Taps - To make the largest tap, select a piece of rod blank, a trifle thicker than the largest hole in the screw plate and fasten it in the lathe. Turn a short taper on the end of the blank to allow it to enter the screw plate easily. Start to cut the thread with a hole in the plate a little larger than the blank and cut a partial thread, to relieve the finishing cut of doing all the work. Thus, the first tap will really be made to fit the second hole in the screw plate. Use oil plentifully while cutting.

When the screw plate is first placed against the blank, it should be at right angle to the length of the blank, so the finished thread will have the proper form. The work should be rotated by the left hand in the lathe pulley and the screwplate held lightly by the fingers in the right hand. (Fig 15) To relieve the strain on the work, turn the blank backward a few turns then forward again. Continue this until the thread is cut the entire length of the tap.

The three flat faces that provide cutting edges on the threads are filed so as to gradually become narrower toward the shank of the tap. (Fig. 16) Now harden and temper to a dark straw color. The file tapers are stoned in the same manner as for drills.

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TOOLS TO BE MADE

1.	Scriber	Fig. 17
2.	File Cleaner	Fig. 18
3.	Center Punch	Fig. 19
4.	Countersink	Sample
5.	Rivet Punch	Sample
6.	Wheel Index	Fig. 21
7.	Bluing Pan	Fig. 20
8.	Bell Metal Polishing Slip	Fig. 22
9.	Iron Grinding Slip	Fig. 22
10.	Jewel Burnisher	Sample
11.	Winding Squares	Fig. 23
12.	Taper Pin	Fig. 5
13.	Movement Rest	Sample
14.	3- Round Holding Arbors	Sample
15.	Hand Removers	Sample
16.	Block for holding small slide rest cutters	Sample
17.	2- Small Slide Rest Cutters	Sample
18.	Slot Cutters	Fig. 26
19.	Hairspring Collet Remover	Sample
20.	Hairspring Collet Holder	Fig. 28
21.	Hairspring Truing Arbor	Fig. 29
22.	Watch Oilers (set)	Fig. 31
23.	Screwdriver Sharpener	Sample
24.	Cannon Pinion Tightener	Sample
25.	Drills	Fig. 14
26.	Taps	Fig. 16
27.	Balance Holder	Sample
28.	Pallet Warmer	Sample
29.	Jewel Graver	Sample
30.	Pin Pusher	Sample

Drills

3	.95	.65	.35
	.90	.60	.30
2.5	.85	.55	.25
2	.80	.50	.20
1.5	.75	.45	.15
1.	.70	.40	.10

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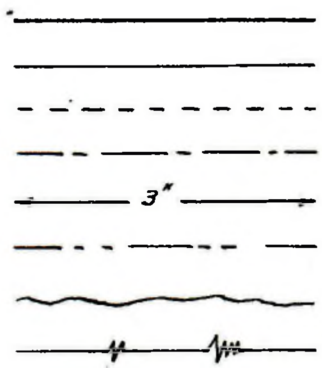
CHARACTERISTICS FOR READING BLUE PRINTS

Blueprints are drawn with various types of lines. Each type symbolizes something pertinent to be observed. In blueprints there are three different thicknesses of lines, heavy, medium and light. The lines drawn below are those recently adopted or retained by the A. S. M. E.



Heavy: Outline of parts seen by the eye.

Light: Section lines.

Medium: Hidden lines or invisible lines.

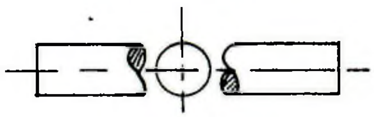
Light: Center lines passing through center of object.

Light: Dimension and extension lines extending from object to show measurements.

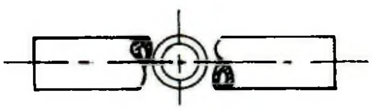
Heavy: Cutting plane or line showing where object is cut to indicate section.

Heavy: Break lines. Indicate remainder of parts are not shown.

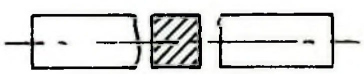
Light: This is also used to place remainder of drawing on same section and to economize on space.



Breaks, illustrating round solid section.

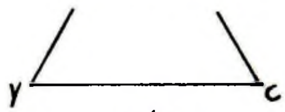


Breaks, illustrating round hollow section.

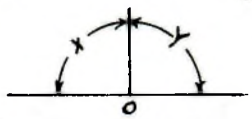


Breaks, rectangular shape.

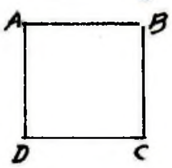
Breaks, wood.



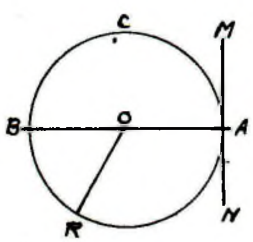
If two lines meet, as at Y, or tend to meet as C, their difference in direction is an angle.



When one line meets another line so that the angles are equal as X and Y they are right angles and the lines are perpendicular to each other as at O.



A B C D shows a square which is formed by four equal lines meeting each other at right angles.



Is a circle, formed by drawing a curved line C, the circumference, the same distance throughout its extent from a point O the center. The diameter is a line passing through the center and meeting the circumference at A and B. The line extending from the center to the circumference as O R is the radius. The line M N is a tangent to the circle which touches the circle at but one point as at A.

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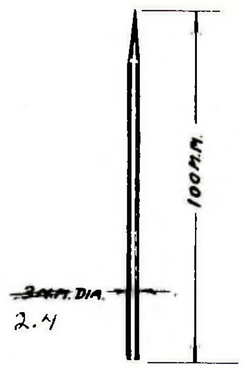
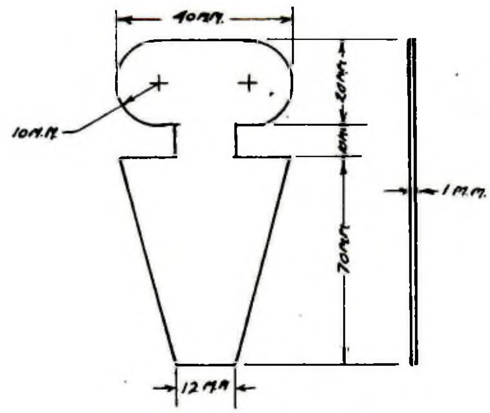


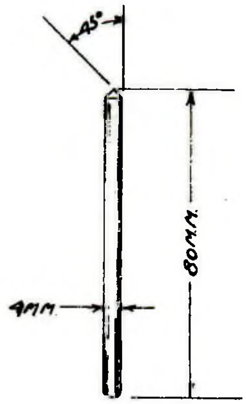
SCRIBER

Fig. 17



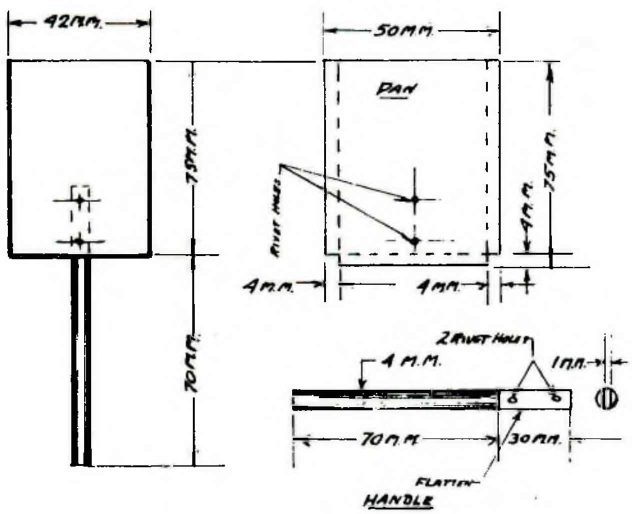
FILE CLEANER (BRASS)

Fig. 18

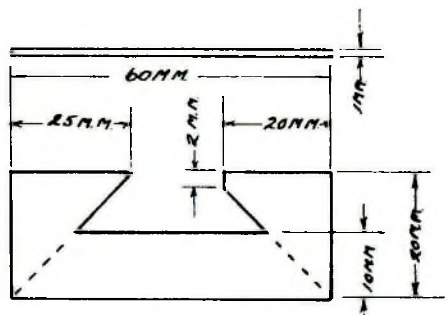


CENTER PUNCH

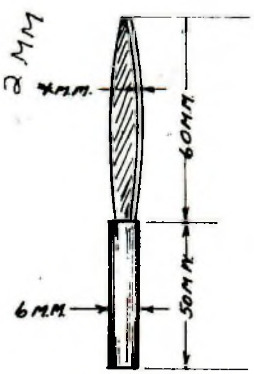
Fig. 19



BLUING PAN Fig 20

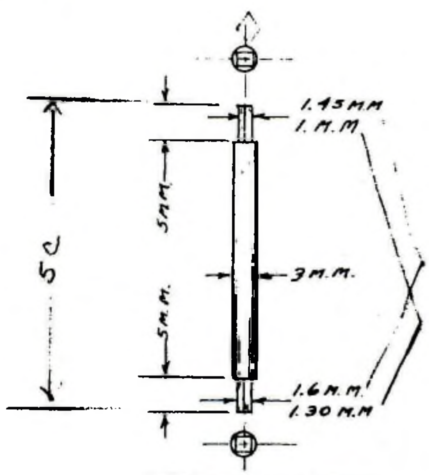


WHEEL INDEX Fig. 21



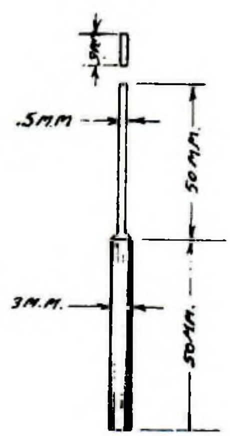
BELL METAL LAP
(SOFT IRON)

Fig. 22



WINDING SQUARES

Fig. 23



GUARD PIN BURNISHER

Fig. 24

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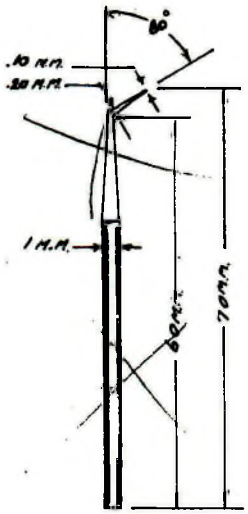
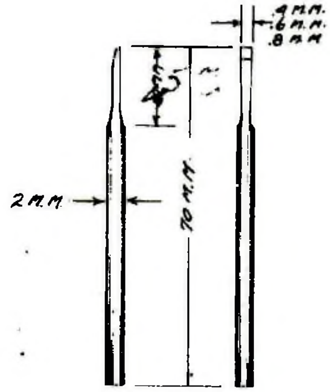


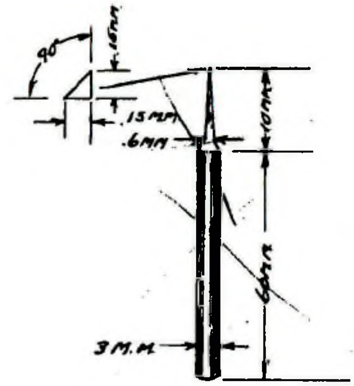
CURB PIN OPENER

Fig. 25



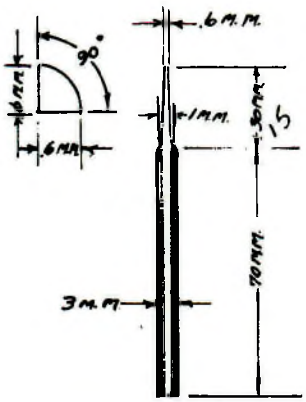
SLOT CUTTER

Fig. 26



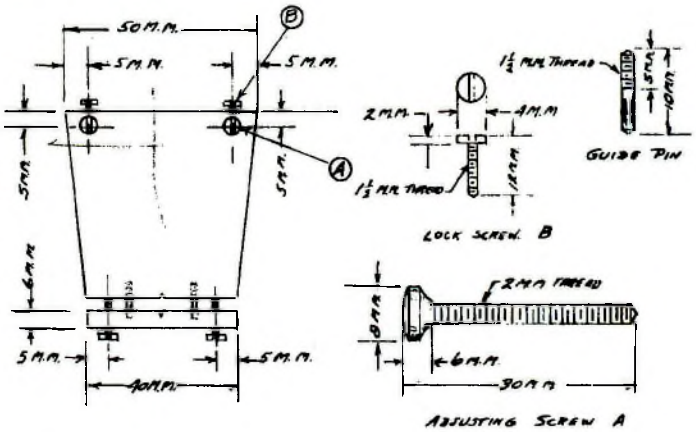
HAIR SPRING COLLET REMOVER

Fig. 27

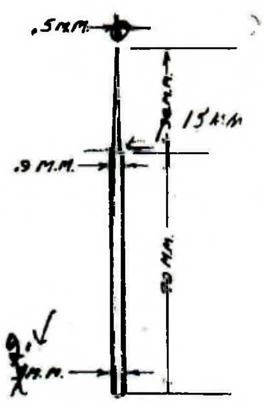


HAIRSPRING COLLET HOLDER

Fig. 28

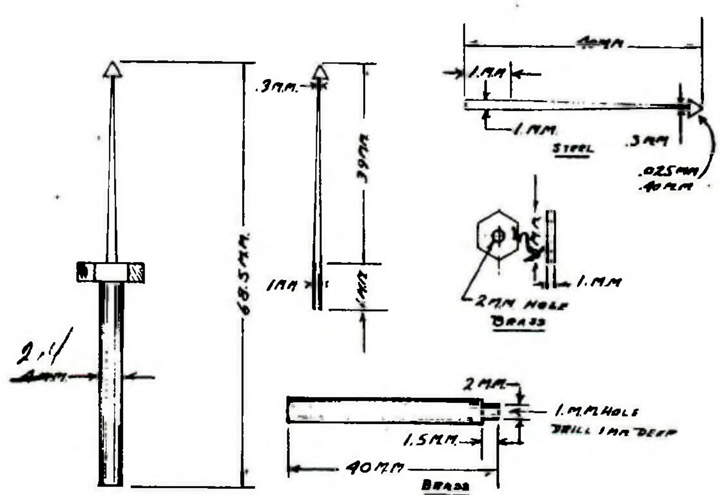


SCREW HEAD LEVELER **Fig. 30**



HAIRSPRING TRUING ARBOR

Fig. 29



OILER **Fig. 31**

✓✓✓14 ✓

Part 1 - Turn and finish square shoulder pivots 2 each .30, .24, .18 and 12 m/m

A. Tighten the rod securely in the lathe so that it runs true.

B. Sharpen the square graver. (See Lesson #1 Part #3 for turning and sharpening the graver)

C. Face off the end of the rod. (Fig. 32-A)

D. Turn a straight shoulder pivot the length of which is three times the diameter of the pivot. Turn the pivot almost ~~to size, but allow .05 m/m for~~ grinding and polishing. (Fig. 32-B) The pivot must be cylindrical and not tapered.

E. In order to assure a clean square shoulder after facing it make a fine cut with a diamond shaped graver in the corner where the shoulder and the pivot meet. (Fig 32-B) After grinding and polishing, the vertical and horizontal faces should meet at the bottom of this cut.

F. Bevel the end of the pivot and the shoulder at a 45° angle (Fig. 32-C)

G. Grind the pivot with the iron lap. A small quantity of oilstone powder and watch oil is mixed with a knife on the polishing block until a thin paste is produced. Spread a thin film of this paste on the lap and place it under the pivot. Run the lathe at medium speed. The form of the pivot can be controlled by observing the blackening of the lap surface.

H. Clean the pivot with a piece of pith dipped in benzine.

I. Polish the pivot with the bellmetal lap charged with diamantine. The diamantine and oil are to be mixed until a thick paste is made, kneading long and hard enough so there are no lumps. Apply the lap, moving it carefully back and forth and watch for the high-polished black coating. The lathe turns at a faster speed for polishing than it does for grinding.

✓ ✓ ✓ ✓

Part 2 - Turn and finish cone shoulder pivots - 2 each .15, .14, .13, .11 and .10 m/m.

Follow the instructions of Lesson #2 - Parts A, B, C and D.

E. Turn a cone shoulder pivot, the length which is twice the diameter. Turn the cylindrical part of the pivot almost to size. Then the cone portion of the pivot is cut with the round-point graver, turning the cone down to meet the cylindrical portion. (Fig 33-A) The finished cone should describe an arc of a circle. (Fig 33-B)

F. Grind the pivot with the iron lap, the rounded corner of which is placed against the cone. Then use the oil stone paste and grind in the same manner as for a square shoulder pivot.

G. Clean the pivot.

H. Polish the pivot with the bellmetal lap.

I. Complete the pivots by flattening the ends with a hard Arkansas slip. Polish with a jasper slip and finish with a hardened steel burnisher, rounding the corners slightly.

Part #3 - Turn Various Balance Staffs to Measurements.

A. Select a piece of steel rod of the proper diameter.

B. Tighten the rod securely in the lathe with a sufficient length of it extending from the face of the chuck to include the full length of the staff plus an additional two or three millimeters.

C. Sharpen the square the diamond shaped and the round - point gravers. The square graver is used for all turning, the diamond shaped graver for under-cutting and the round-point graver for turning the cone on the pivots.

D. Face off the end of the rod.

E. Measure from the end of the rod and mark for the balance seat. Turn the shoulder on which the balance is to fit, allowing .05 m/m for finishing and face the balance seat. (Fig. 34-A)

In Turning collet shoulder undercut - place graver below half way mark for first few cuts

F. Measure from the end of the rod and turn a mark for the hairspring collet seat, and turn this seat (Fig. 34-B)

G. Turn the conical pivot to correct size. (Fig 34-C)

H. With a diamond shaped graver make the undercut on the face of the balance shoulder for riveting. (Fig 34-D)

I. Turn the step between the pivot and the hairspring collet shoulder and bevel this shoulder. (Fig 34-E)

J. Rough out the lower portion for the roller shoulder, making this long enough to include the lower pivot, and thick enough for strength while grinding and polishing the portions so far turned. (Fig 34-D)

K. Complete the shoulders on the upper end of the staff to exact size and grind and polish the pivots.

L. Cut off the staff.

M. Chuck the staff by the hairspring collet shoulder, watching to see that it runs true.

N. Turn lower end of staff measuring from the end up to the roller seat and bring to the correct length. Turn the roller table shoulder to size, with a slight taper.

O. Turn the pivot to correct size.

P. Grind and polish the lower pivot (Fig 35 shows a complete balance staff with the proper dimensions).

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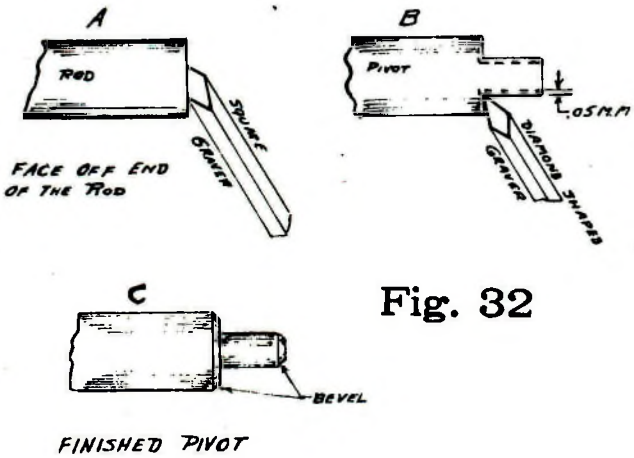

Fig. 32

Fig. 33

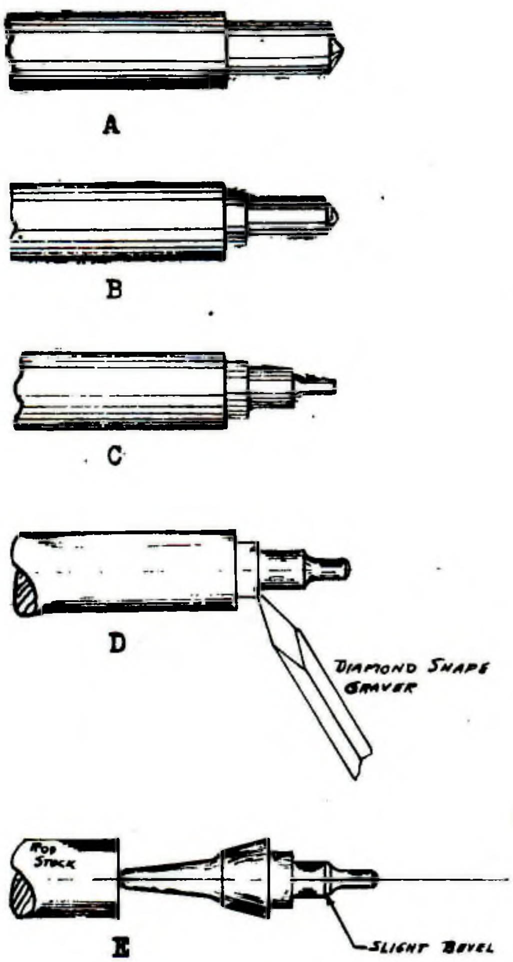

Fig. 34

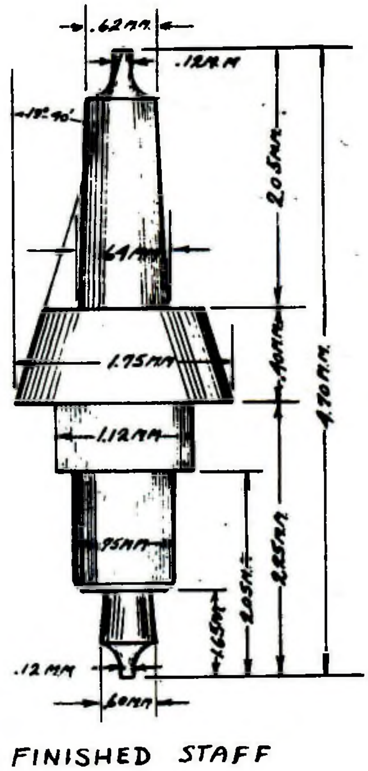

Fig. 35

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LESSON III

Balance - Page 9

Part 1 - What is the Balance Wheel?

The balance is the governing part or regulator of a watch. It was first used about 1600 and was merely a crude wheel of any kind of material. The complete balance wheel assembly is composed of the balance wheel, balance staff, roller table and hairspring. The timekeeping possibilities of a watch depend upon the balance. If its size and weight are not in the correct proportions to the motive force and the rest of the movement, no adjustment can be made that can make it a good timepiece. Therefore, the hairspring and all other parts are always secondary in importance to the balance wheel.

There are two types of balance wheels, the cut bi-metallic and the solid rim or mono-metallic wheels. A brief description of each kind follows:

The cut-rim bi-metallic balance is made of a steel center bar or arm, carrying a circular rim cut into two sections, each of the sections having one free end and the other end attached to the center bar. The circular rim is constructed of brass and steel fused together. The former metal, which is affected most by temperatures, is placed on the outer side of the rim. Holes are drilled and tapped radially through the rim to carry the balance screws. The purpose of the balance screws is to provide a weight that may be shifted to make temperature adjustments. The number of holes exceeds the number of screws in the balance, as allowance must be given for moving the screws in the final temperature adjustments. Then the watch is exposed to higher temperatures, the rim expands, and the watch runs slower. The action of the rim, however, counteracts the slower running because the brass on the outer side, which expands more than the steel inner side, curves the two free rim ends inward, thus bringing the weight towards the center of the balance. When a watch is exposed to lowe r temperatures, the exact opposite occurs. The brass counteracting more than the steel tends to straighten out the rim, and carry its weight outward. It will gain in heat if the screws are too near the center or attached end of the arm, and will lose in cold if the screws are too near the free end of the arm. The size of the balance is governed by the distance between the center of its weight and its axis; therefore the object of the compensation is to keep that distance at its proper point in all temperatures.

The other, the solid rim mono-metallic balance wheel, is the type used in practically all watches today. There are various metals used in its construction, but the alloy of Gruen balance wheels is known as "Elinvar", manufactured under our trade-marked name "CONORUMA". This alloy is a combination of nickel, steel, Chromium, manganese, tungsten and carbon, and creates no thermal error, therefore requiring no compensation in the balance wheel for heat and cold, and also is not affected by magnetism. Further description and advantages of this may be found under the topic of "Hairsprings" in another lesson.

Part 2 - Staking the Balance Wheel to the Balance Staff

A. To remove the roller, the balance staff is held by the collet shoulder in a pinvise. After inserting the roller in a wire chuck, it is removed gradually by turning the lathe pulley with the left hand, while the pinvise, holding the balance staff, is kept steady in the right hand.

B. To remove the old staff from the balance wheel, the staff is chucked by the hairspring collet shoulder. Turning the lathe at slow speed, carefully cut away the hub for the balance seat until a little ring, which is the portion of the staff that drops off at the moment the graver turns the hub away to the edge of the hole in the balance arm.

C. To rivet the balance wheel on the staff, select and center with the centering punch, a hole in the staking tool that will fit the roller shoulder of the staff without binding. Place the balance wheel on the staff and use a snug-fitting round-faced punch which will spread the rivet. (Fig 36) Tap the punch a few light blows with a brass hammer at the same time turning the balance wheel continuously with the little finger of the left hand. Now select the proper flat punch, which is used to flatten the rivet so there are no uneven surfaces.(Fig 37) This flattening operation is done in the same manner as the riveting process.

D. To re-fit the roller, put it on the roller shoulder of the balance staff and the table should drop on to the staff to about the thickness of the upper roller. Place the balance staff over the same hole in the staking tool and push or tap the roller to its final position by using a flat punch.

Part 3 - True Balances

Place the balance in the calipers and set the index. (Fig 38) First true the balance in the flat, starting with the balance arm so that it is flat and not cupped and both arms are level. True one segment at a time, beginning at the arm and working towards the open end. (Fig 39) This should be done as much as possible with the fingers. Next true in the round, also starting at the arm. Any kinks are to be removed with the wrench or a flat plier that is lined with cardboard. After truing the balance in the round, it is necessary to test it again in the flat.

Part 4 - Poise Balances

First clean the poising tool jaws and the staff pivots with pith, and level the poising tool and adjust the jaws. Place the balance in position on the poising tool. (Fig 40) If the balance is out of poise it will start to rotate. When the balance comes to rest the screw that is heaviest will be the lowest point on the balance rim. To subtract weight use the balance holder made for this purpose and remove the heavy screw with a screwdriver. Place the screw in the lathe and under-cut the screwhead slightly. Then replace the screw in the balance, and check the balance for exact poise by stopping it at each quarter. A slight tapping of the poising tool with the tweezer will aid the balance in finding its heaviest point.

The greatest care must be taken when poising a balance wheel so that the weight of the balance is not altered. The slightest addition or subtraction in weight will cause the watch to lose or gain time.

If it is necessary to remove considerable weight, it is advisable to only remove about one-half the amount needed from the heavy screw. Then the final poising is done by adding a timing washer on the screw directly opposite the heavy one. This will maintain the original weight of the balance as nearly as possible.

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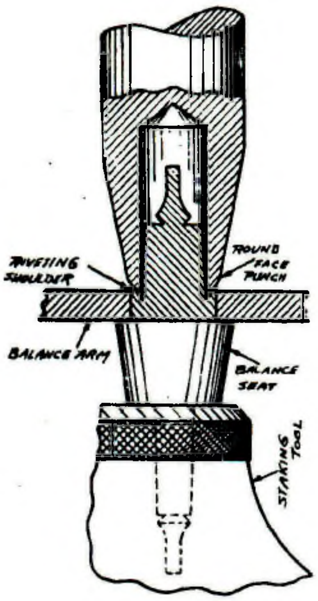
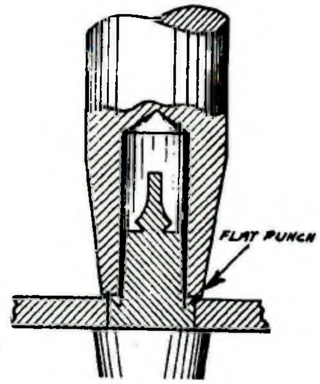


Fig. 36



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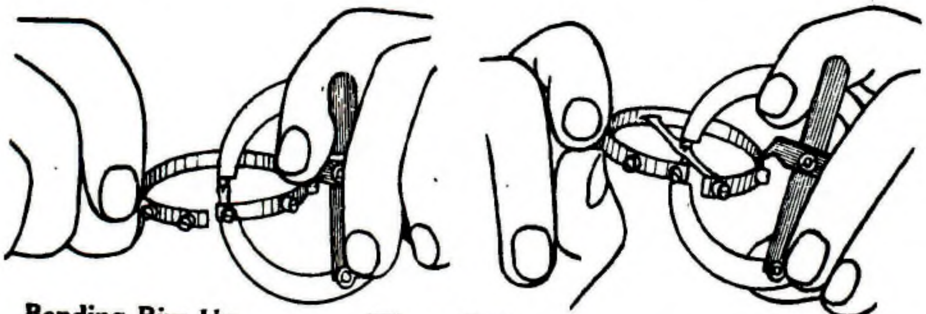
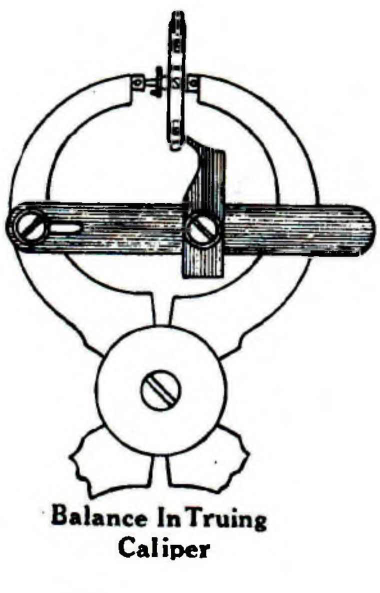


Bending Rim Up

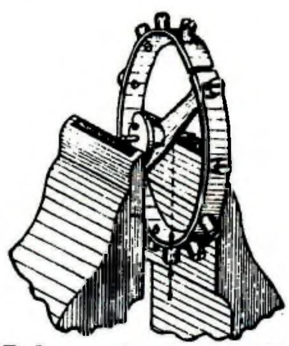
Fig. 39

Bending Rim Down



Balance In Truing Caliper

Fig. 38



Balance On Poising Tool

Fig. 40

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LESSON IV

HAIRSPRINGS Page 11

Part 1 - What is a Hairspring?

A hairspring is a simple, delicate circular spring, whose object is to give a constant, regular, harmonic motion (to and fro; back and forth) to the balance wheel. (Properly speaking, harmonic motion is along a straight line, but it can so well be applied to the circular motion of the balance.)

The harispring was first introduced by Huygens in Paris in 1674. While l'Abbe Hautefeuille of Orleans was experimenting with pig's bristle and Hooks was busy with angular energy, Huygens, with the help of Thurst, was applying the hairspring to the watch. About 1690 it was already in general use. At first, 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 the watches.

Formerly, hairsprings were made primarily of steel, but there were numerous other types made of various metallic composition. CONORUMA is the Gruen trademarked name for this new metal, discovered by Dr. Guilliame, and is of great importance to watchmaking. As an alloy of nickel, steel, chromium, manganese, tungsten and carbon, it produces a hairspring with "invariable elasticity", creating no thermal error -- and requiring no compensation in the balance wheel for heat and cold. The bi-metallic cut-rim balance, therefore, becomes no longer necessary.

As an identification and explanation of the advantages of CONORUMA hairsprings and monometallic, uncut balances, all Gruen movements which carry these features are marked on the balance bridge - CONORUMA, which means

CO - Compensation
NO - No
RU - Rust or
MA - Magnetism

and in addition to the advantages given above, denotes the following:

1 - Hairspring will not vary with temperature
2 - Impervious to rust
3 - Non-magnetic.

The first watches had 3 to 4 coils and now we find 11 to 18. More coils are required when the Breguet is used to allow the proper swing. Some advocate the even number of coils, others mention that the individuality of the watch has to be considered. But a safe rule to remember is that the diameter of the spring be half the diameter of the balance wheel.

Part 2 - Level and Circle Hairsprings

The diameter of the spring, the length of the spring, the exact length of the overcoil and the points of attachment are factors that will not be considered in this lesson. The work conducted here is only to teach the trainee the proper use of his tools and give an idea how the work is accomplished.

The two most common forms of hairsprings are the flat and the breguet. The flat hairspring is the older and most simple form. It is still used in some of the cheaper movements and is the form used in our first experiments. The coils of the hairspring are the same distance apart on all sides and have a flat spiral form. The spring will be bent in several places and the object is to return the spring as nearly as possible to its original form.

Part 3 - Collet and True Hairspring

Colleting is the attaching of the inner coil of the hairspring to the brass collar or collet that fits friction tight on the balance staff. The collet pierced to receive the hairspring which is held fast by inserting a small brass pin. The first step is to break out several inner coils of the hairspring to allow space for fitting the collet and this amount depends upon the size of the collet and the distance between the coils. The distance from the edge of the collet to the first coil is one and one-half the space between any two coils. A practical method to ascertain this distance is to draw two horizontal parallel lines, tangent to the outside diameter of the collet and draw a line perpendicular to the parallel lines. Center the hairspring between these lines, the innermost end of the spring to meet the perpendicular line and where the line crosses at X (Fig 41), the hairspring is to be cut. After the spring is inserted in the collet, the innercoil will have the proper space.

To attach the hairspring to the collet, first form the tongue, which is the portion of the hairspring that enters the collet hole. The length of the tongue should be as long as the collet hole plus the distance to the first coil (Fig 42). The tongue is formed by grasping the spring firmly with the tweezer, at the point where the bend is to be made, and with another tweezer bending it toward the center. The curved portion is then straightened and the tongue leaves the spiral portion of the spring at an angle, which conforms to the hole in the collet. (Fig 43)

Place the collet on the collet holding arbor, with the top of the collet upward and the entering side of the hole toward you. (Fig 44) Take a waste piece of the spring, insert it in the hole and file the taper-pin flat so it and the spring will fill the hole properly. (Fig 45) Push the pin in the hole until it is tight and with a sharp knife nick the pin at the point it is to be cut off, favoring the thicker end of the pins so that the final fastening will be secure. (Fig 46) Remove the pin and the trial piece of spring and insert the tongue in the collet hole. Place the small end of the tapered brass pin in the same end of the collet hole that the spring entered. The pin must enter and leave the collet above the main part of the spring. (Fig 47) Push the pin in tight, break off clean both ends of the pin still projecting from each side of the collet hole, by bending a 90 degrees angle. (Fig 48) A stub-nosed tweezer is used now to push the pin in tight. (Fig 49)

Truing of the hairspring at the collet is necessary to correct the errors caused by the pinning operation.

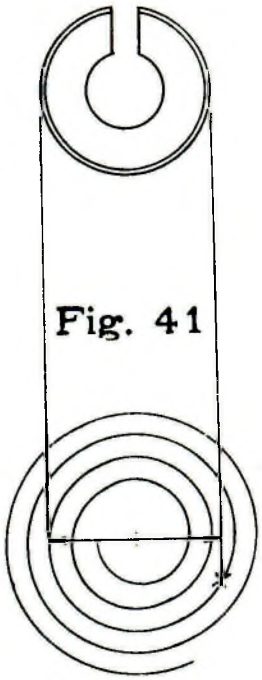
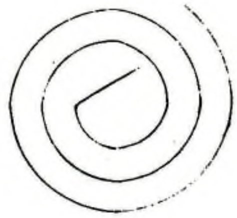


Fig. 41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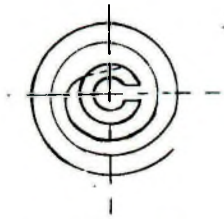
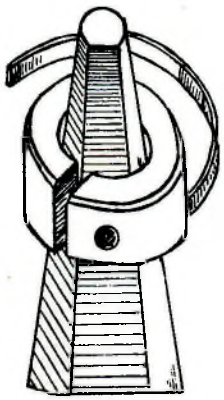


Fig. 43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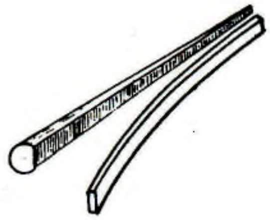
Fig. 45

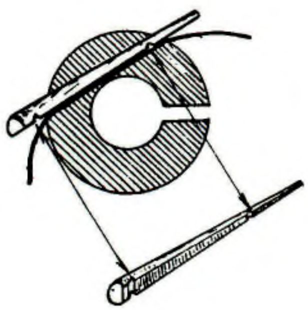
Fig. 46

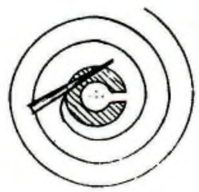
Fig 47


Fig. 48

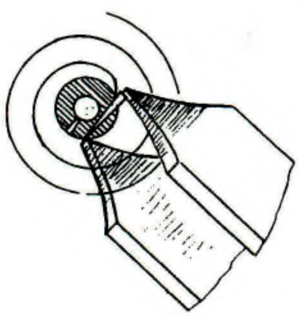
Fig. 49

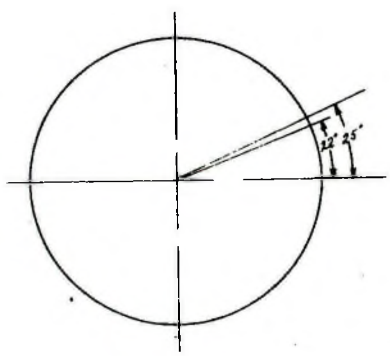
Fig. 50


Fig. 51


Fig. 52

The colleted hairspring is placed on the hairspring truing arbor and to see whether the hairspring is flat and centered, the arbor is turned slowly. If the hairspring is true in round and flat there will be just an even flow of the coils, but if a jerky motion is observed it is then necessary to true the hairspring. Truing the hairspring consists of pushing or twisting the inner coil in the desired direction with the tweezers. When truing in the round it is never necessary to do any work beyond the first quarter of the inner coil; while in the flat, the hairspring is pushed up or down at the points that are low or high.

Part 4 - The Overcoil or Breguet Hairspring

The overcoil is the last coil of a Breguet hairspring which is bent over the body of the hairspring. Before bending the overcoil, draw a circle on the bench paper and divide this circle into four quarters. The overcoil is started from the end of the last coil at the three-quarter point A, which is the first knee. 22 degrees up from A is the second knee, and 3 degrees more or 25 degrees total, is the start of the main body of the overcoil. This drawing is to be used as a guide in making the bends and is self-explanatory (Fig 50)

To form the overcoil, lay the hairspring on the bench paper over the marked circle. Grasp the hairspring tightly with a stout tweezer, about three-fourths from the end of the outer coil, and press into a piece of softwood. This will make an abrupt bend or knee in the spring. (Fig 51) Turn the spring over and grasp the spring 22 degrees from the first bend, press again until the overcoil lies level with the main body of the hairspring. (Fig 5 2) To circle the overcoil use the special hairspring forming tweezer for this purpose (Fig 53).

The overcoil is to be bent to the form of a straight line joined by two quarter circles, the first circle to start about three degrees past the second knee. (Fig 54)

Part 5 - Level, Center and Circle Hairspring in Movement

The actual form of an overcoil is to a certain extent governed by existing conditions. For example, the measurement from the center of the balance hole to the space between the regulator pins is a definite factor and the curve of the spring must be made to comply with it. (Fig 55) The regulator pins are two little pins made of brass riveted parallel to each other in the regulator. The regulator is concentric with the balance jewel hole and the hairspring must be perfectly free between the pins.

Before us we have a lower plate, balance bridge, cap jewels and regulator. The work now to be performed is to make the overcoil formed in Part 4, to conform to the conditions created by these parts. After reshaping the overcoil the hairspring is attached to the stud. Lay the balance bridge on the bench with the regulator downwards, push the overcoil between the regulator pins, then draw the free end of the spring into the hairspring stud and fasten it with a brass pin. Now look down through the collet, and if the center of the balance hole jewel is in the center of the collet hole and if after moving the regulator from slow to fast, the hairspring remains stationary, it is centered properly. (Fig 56) If not, it can be determined where to circle the overcoil to center the hairspring. (Fig 57)

Pinch the spring from the opposite end of the high or low spot in order that spring - overcoil + bridge are parallel.

In centering spring in bridge do all of the adjusting at the "bends" -

Fig. 53

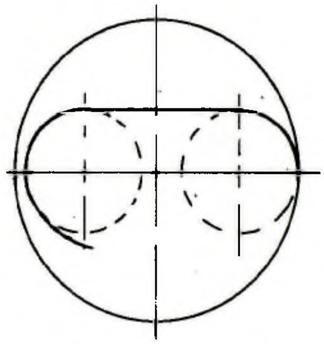

Fig. 54

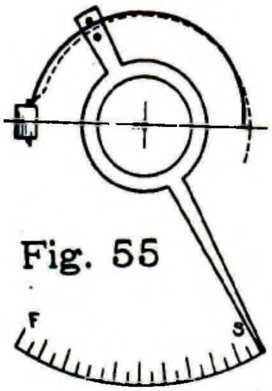

Fig. 55

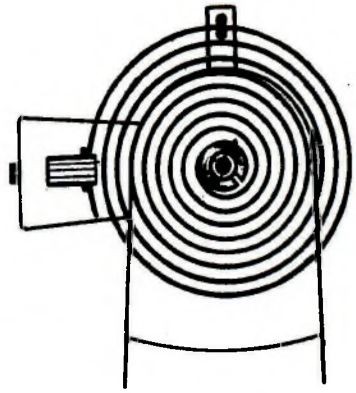

Fig. 56

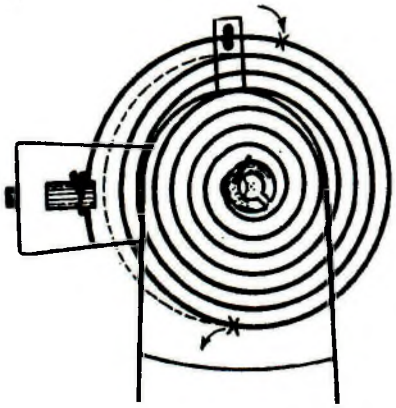

Fig. 57

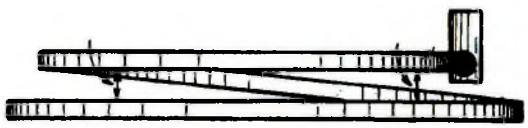

Fig. 58

Fig. 59

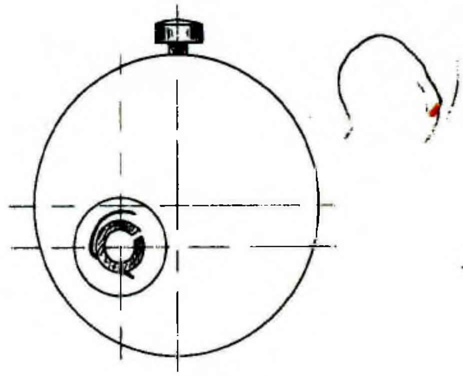

Fig. 60

When the spring is centered properly on the bridge, it is leveled without being removed from the bridge. In forming the overcoil and any alterations that were made afterwards care must be taken to keep the overcoil parallel at all points with the body of the hairspring. (Fig 58) The hairspring must also be level with the balance bridge and any alterations necessary here are due to the pinning operation and must be made as close as possible to the stud. After centering and leveling on the bridge, the hairspring is put on the balance staff. This isdone on the staking tool, using the same hole and the flat punch that were used for staking the roller. The balance is fastened now to the movement and any minor adjustments are made at this point.

Part 6 - Vibrating Hairspring

A. In fitting a hairspring, the first procedure is to determine the number of vibrations of the balance wheel per hour. (This calculation will be found at the end of this lesson) Select a hairspring that has approximately half the diameter of the balance wheel. There are many factors in selecting a hairspring of the proper strength that can only be gained by experience. One method is to suspend the balance wheel and hairspring an inch or two above the bench. If the distance between the point where the spring is held by the tweezer and the run of the balance is one-half inch the hairspring is of the approximate strength. The inner end of the hairspring is temporarily fastened to the collet.

The hairspring is then tried on the hairspring vibrator. (Fig 59) This vibrator has a master balance wheel with hairspring enclosed in a case and on the movable arm are tweezers. The hairspring is held by the tweezers and so placed that the balance wheel arm is parallel with the arm of the master balance wheel and by means of a lever both arms are set in motion. The point that is gripped by the tweezers is moved until the two balances vibrate at the same rate. This is the point that fits between the regulator pins and another quarter coil is allowed for pinning in the stud.

B. The correct pinning point, or point of attachment, of the inner coil, must be observed carefully for this is a means to obtain an equal regulation in the various positions. It has been found that one position of pinning distinguishes itself as best for precision rating. To find the correct pinning point for a particular watch, draw an imaginary line parallel with the crown, through the center of the balance and also a line at right angles to that line, bisecting the center of the balance. The hairspring is to be pinned so that it develops on the last mentioned line. (Fig 60)

C. How do you determine the number of vibrations of hairsprings? Multiply the number of teeth in the center wheel by the number of teeth in the third wheel, the total by the number of teeth in the fourth wheel, the total by the number of teeth in the escape wheel, and the grand total by two. Then multiply the number of third wheel pinion leaves by the number of leaves in the fourth pinion, times the number of leaves in the escape pinion. Divide the total leaves into total teeth for the correct hairspring vibrations per hour. In all cases where there is a second hand, this may be greatly simplified. Then the number of vibrations per minute can be quickly determined by dividing the number of teeth in the fourth wheel by the number of leaves in the escape pinion and multiplying this result by twice the number of teeth in the escape wheel.

Example: $\frac{80 \times 60 \times 70 \times 15 \times 2}{10 \times 8 \times 7} =$ 18,000 vibrations per hour

Part 7 - Miscellaneous Hairspring Data

What is meant by an isochronous hairspring? An isochronous hairspring is achieved by having the hairspring of a certain determined length and the pinned ends of the overcoil of a certain shape. This results in having the balance wheel make every vibration, whether a long arc or a short arc, in the same length of time. Therefore, the watch has approximately the same rate when it is fully wound as when it has been running about 24 hours.

A flat hairspring has several eccentric motions which have a tendency to affect the isochronism, namely: (1) a constant oscillation of the center of gravity; (2) a persistent pushing and pulling effect of the balance pivots; and (3) the effect of torsion, which is a circular impulse taking place at the innermost coil of the hairspring.

A Breguet hairspring, with its scientifically correct overcoil, will produce superior performance in the attainment of isochronism. This is the reason it is used in the better quality watches (together with its higher manufacturing cost) rather than the flat hairspring.

How to untangle a hairspring? To untangle a hairspring merely insert the edge of a piece of paper between the coils under the tangled part, and turn the spring in its outward direction with tweezers. It is not even necessary to remove it from the balance wheel. However, if too badly tangled it may be necessary to unpin it at the stud.

What should be done to prevent hairsprings from catching in regulator pins? The hairspring usually catches when the regulator pins are too long or when there is too much space between them. The pins should be parallel and not extend beyond the width of the hairspring and should vibrate freely without binding between the pins. If the pins are too far apart, it will cause the watch to run slow. The hairspring should expand freely without coming in contact with the balance arms. Sometimes the hairspring will catch on the hairspring stud and then it is necessary to file the sharp corner off the lower portion of the stud.

How do you clean hairsrpings? When a steel hairspring is being cleaned, it should be put in warm sawdust, so that none of the cleaning fluid will cause any rust spots on the hairspring. Those spots already on the spring can be cleaned with diamatine or oitstone powder, but great care must be taken in order not to damage the hairspring. Loose steel hairsrpings are placed in packages and are covered with a fine lime powder, which prevents any discoloration or rust.

How does oil get on hairsprings? This will result in the coils of the hairspring sticking together, thereby making the watch gain very rapidly. Experience has proven that this is usually caused by too much oil on the mainspring, as well as the various train jewels, especially the upper third jewel. The oil from this jewel falls on the center wheel and is carried around to the hairspring, where a slight jar or shock will spray the oil on the hairspring.

What causes magnetism? Watches with steel hairsprings and bi-metallic balance wheels may become heavily magnetized. This is due to the fact that the wearer came in contact with some strong electric current or appliance. A small compass placed on top of the balance bridge over the moving balance wheel, will indicate by a vibrating motion if the balance wheel and/or hairspring is polarized. If it is, the watch complete with case should be put through a demagnetizer to remove all trace of magnetism. (Watches equipped with Conoruma hairsprings and balance wheels are not affected by magnetism.)

Jeweling - Page 16

Part 1 - What is the History of Jewels as Used in Watchmaking?

Before the invention of the watch jewel, the wheel pivots simply ran in the holes of the brass plates of the movement. The art of piercing jewels for use in watches was invented by Nicholas Facio, a Swiss watchmaker, who was living at that time — in 1704 — in London. As can be understood, the introduction of jewels greatly increased the accuracy of watches.

Of what are jewels made? Jewels for watch movements are made of garnet, natural or scientific ruby, natural or scientific sapphire, and sometimes of diamond. Garnet is the softest stone and is not used in high grade movements as it is subject to greater wear and breakage.

What type is used now and what is its construction? Most of the jewels used today are of the scientific, or sometimes called synthetic, ruby variety. This scientifically made jewel is produced of the same chemical elements as the natural ruby, that is, aluminum oxide (Al2 O3) 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 oxhydric furnace at an extremely high temperature into big droplets, called "boules", which are approximately 1½" in length and ½" in diameter.

These "boules" are then cut into slabs of various thickness by means of very thin bronze disc 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.

The next step is the drilling of the holes, which is a very delicate operation, by special steel drills, as the holes are 5 to 6 one-hundredths of a millimeter for balance hole jewels. After this operation, 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 train jewels an oil reservoir is necessary, and a small rotary lap cuts and polishes this cup in the jewel. In balance jewels the holes are further polished to make them "olivated", 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 should be about equal to its diameter. The mean tolerance of the hole is about 0.005 millimeter, or about 10 times smaller than a human hair, so close inspections and measuring devices are necessary. The surface through which the balance pivot extends is rounded or curved, so that when the cap jewel is screwed on, the oil is held in place properly (see explanation of this process under item #11 of cleaning bulletin.)

What are the various kinds and uses of watch jewels?

(a) Balance hole jewel, which is drilled and finished (as described previously), and in which the balance staff pivots turn. (The balance wheel turns 157,680,000 times a year, so it is important to have a perfect hole and cap jewels.)

(b) Train hole jewel, which is drilled and finished (as described previously), and in which the train wheel pivots turn.

5 Kinds of jewels — Balance — Cap — Pallet Stone
Train — Roller

(c) Pallet fork stone, which engages alternately with the teeth of the escape wheel, transforming rotary motion to vibratory motion.

(d) Roller table jewel, which engages in the slot of the pallet fork. There are several shapes of roller jewels — triangular, round, square, oval, and the half moon, which is in use today.

(e) Cap jewel or endstone, which has a flat surface against which the end of a pivot revolves. The cap jewel should be larger in diameter than the hole jewel, with a groove to prevent the oil from spreading, The space between cap and hole jewel should be 0 to 3 hundredths of a millimeter.

A good quality watch should have at least 15 jewels which are: 2 balance hole jewels, 2 balance cap jewels, 1 roller table jewel, 2 pallet stones, 2 pallet arbor hole jewels, 2 escape wheel hole jewels, 2 fourth wheel hole jewels, and 2 third wheel hole jewels. A 17-jewel movement has 2 cap jewels on the escape wheel upper and lower pivots. All jewels should be the frictional bearing type and not as in some low priced watches, merely placed in a movement for advertising purposes.

3 uses of jewels

Part 2 - Fitting of Train Jewels, Balance Jewels and Cap Jewels.

Jewels are used to reduce friction, provide a hard surface for the pivot to act against and to act as oil retainers.

There are three styles of jewels used in the bezel type settings, which are the train or flat jewel, the balance or convex and the endstone or cap jewel. A balance jewel and a cap jewel are used together to support a conical pivot. (Fig 61) The method used for setting all styles are the same. In setting plate jewels the flat side is out and for balance jewels, the convex side is out.

To set a bezel type jewel in an old setting, it is necessary to push out the broken jewel by removing all broken particles from the setting. The setting is then raised with a jewel bezel opener. (Fig 62) This tool has two points for lifting the setting, and is rotated between the finger and thumb, and the points opened by means of a screw. After the setting is opened, a jewel is selected that fits snug in the setting and lies slightly below the surface. Press the point of the burnisher in the groove and gradually rub the setting over the jewel.

To turn a jewel setting, center a piece of brass or nickel wire in the lathe and drill a hole about two-thirds as large as the diameter of the jewel to be used. With the jewel graver enlarge the hole slightly to true it up. The jewel graver (Fig 63) is made from a square steel wire, tapered as (A) slanted at the bottom as (B) For clearance, the bottom surface is made narrower than the top as in (C) and the cutting edge is slanted to the right. Harden, temper and draw to a light straw color.

Turn a seat to fit the jewel and deep enough so that the jewel will lie slightly below the surface of the wire (Fig 64). With a long pointed graver cut a groove or bezel close to the opening for the jewel. Moisten the jewel with a little oil and insert it in the hole. Place the burnisher on the T-rest, press the point in the groove, and turn the lathe at slow speed to force the bezel against the jewel. (Fig 65) When the jewel is perfectly solid, the end of the wire may be faced off until nearby level with the jewel. Turn the setting to fit the watch plate, try the endshake and cut the setting off the wire (Fig 66) It is turned now to the proper the thickness, and stripped with a highly polished graver (Fig 67). Finally, the face is polished by sliding the setting on a burnishing file. (Fig 68)

Part 3 - What is Friction Jewelry?

For over 200 years train and balance jewels were set into holes in the plates and bridges and 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 resulted in an off-centered jewel, and if not of uniform thickness would result in considerable irregularities in the endshake of the pivots. The jewel that is "burnished-in" the plate and the "bridges is shown in (Fig 69-A) while a "burnished-in" jewel, set in a metal bushing, held in place on plate and bridges by screws is shown in (B). Another type of "friction-tight" jewel, is set in a metal bushing, and this bushing also held tight in the plate and bridges. (C) The newest type of jewel, which is very large, and is the same size of the metal setting and jewel combined of the types described previously (D). The following is a detailed discussion on this new type of jewel.

The system of the "friction-tight" jewel was used for the first time in 1920 by a Swiss manufacturer, and now, many years later, it has revolutionized the watchmaking technique. So promising as this process was in the beginning, there still were certain difficulties that had to be overcome. The jewel manufacturers were not in position to guarantee a jewel of exact and regular diameter that would be absolutely concentric to the hole. Thanks to the considerable progress in the jewel manufacture made in the course of the last years, this manufacturing process, which is very remarkable from the technical as well as the repair standpoint, could be carried out quite generally.

However, only mathematical precision, perfect tools and quality can meet the requirements of good manufacturing.

In comparing the method of setting (burnishing) the jewels with that of pressing them in, the following observations can be made:

The burnished-in setting, according to the method used, had two great technical disadvantages:

OFF CENTER

1. Setting jewels, which were not perfectly round or true in diameter, in holes that were too large, unfortunately resulted in noticeable differences in the distances of the centers. (Fig 70-A) shows plate hole too large, resulting in an off-centered jewel.

EXCESSIVE OR NEGATIVE END SHAKE

2. On the other hand, setting jewels of unequal thickness in holes more or less deep, resulted in considerable irregularities in the endshake. (Fig 70-B) shows jewels of irregular thickness and causing variation in height).

The friction-tight jewel removes these irregularities and makes complete interchangeability possible.

By using new machines and dies of great precision, modern technique accomplishes:

1. Jewels that are exact as to diameter, which can be centered in the hole within-one half hundredth of a millimeter.

2. Strictly rectified jewel holes in the plate and bridges.

In addition, a special tool (C & D) presses the jewels in uniformly and at always the same height. This tool presses the jewel to the desired height with a variation of 1 to 1¼ hundredths of a millimeter. The difference in the thickness of the bridges no longer is of any consequence.

Another advantage of these large friction-tight jewels (which are the same size as the bushing of the former type), is that they contain larger cup space (Fig 69-D) for retaining more oil over a longer period of time.

An important and often disputed question is that of the firmness of the jewel in its place. Very thorough experiments with a dynanometer have shown an excellent resistance to pressure by the friction-tight jewel. When it is pressed in, it must resist the lateral and perpendicular tensions and, therefore, it is made more carefully and out of a better quality of ruby than the jewel that is set according to the old method.

To replace a friction jewel, it is necessary to measure the size of the hole in the plate and select a jewel the outside diameter of which is .01 m/m larger than the hole in the plate. The plate or bushing is centered in the lathe and a hole is bored and enlarged with a graver. It is placed next in a friction jeweling tool and the hole reamed to the proper diameter. After removing the burr left by the reamer, the friction type jewel is pushed in to the proper depth.

Part 4 - Bush and Upright Holes.

To bush and upright a bezel-type jewel in a bridge, first clamp the lower plate in a face plate (Fig 71) and true it from the jewel hole. The bridge to be bushed is screwed tightly in place on the lower plate. The hole is cut out slightly tapering it to the edge of the former stripping (Fig 72-A). Remove the bridge from the lower plate and countersink the underside of the hole. Turn a brass wire so it will fit the taper of the bridge, allowing enough stock to extend so it can be burnished over the bridge where it has bean countersunk (Fig 72-B). After burnishing, the brass wire will be solid in the bridge and both will revolve together in the lathe (Fig 72-C). The jewel is set now in the same manner as in the end of a brass wire and the wire is cut off just above the finished part of the bridge. The bridge is screwed again in place on the lower plate, which has not been removed from the face plate and stripped as all parts are centered and turned true, the wheel will be upright.

To bush and upright a jewel setting in a lower plate, first enlarge the hole to the necessary diameter with a broach, the hole to be broached from the inside and countersunk on the outside. Turn a brass piece of wire with the same taper as the broached hole. Gauge the length so that enough will extend for riveting after bring driven in place with a hammer. After riveting, the bridge is screwed in place on the lower plate, clamped in the face plate and trued from the bridge jewel hole. The bridge is removed now and the setting is turned to the required size. The lower plate is reversed next in the face plate and it is centered and stripped.

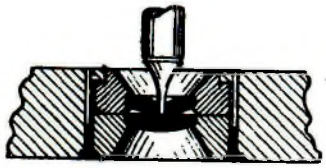

Fig. 61

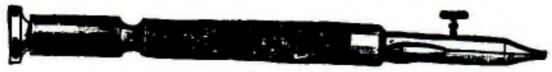

Fig. 62 JEWEL BEZEL OPENER

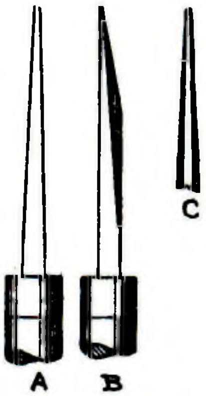

Fig. 63

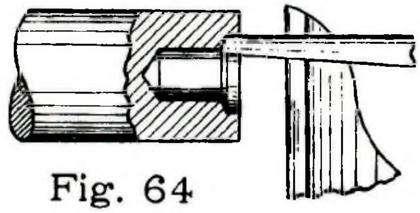

Fig. 64

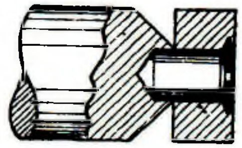

Fig. 66

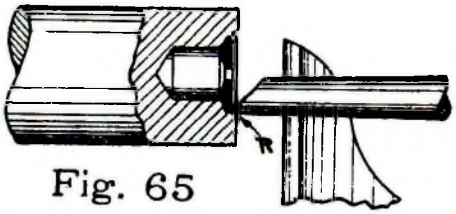

Fig. 65

Fig. 67

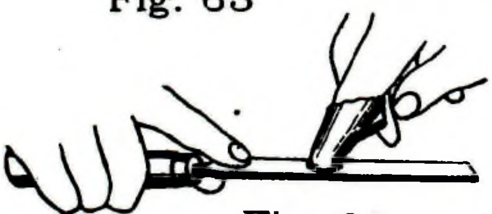

Fig. 68

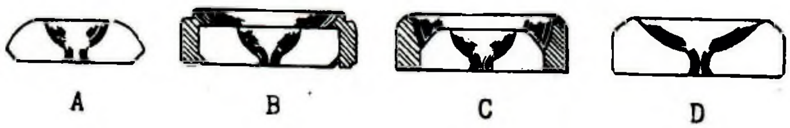

Fig. 69

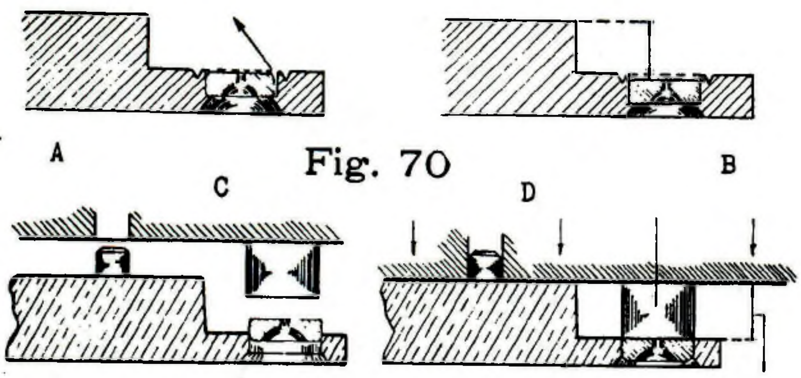

Fig. 70

Fig. 71

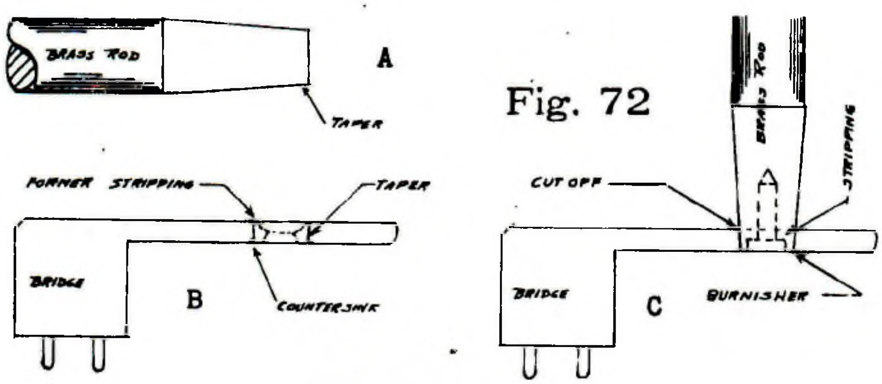

Fig. 72

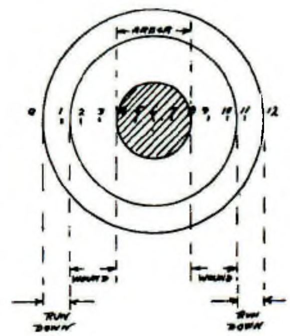

Fig. 73

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LESSON VI

Mainsprings - Page 20

Part 1 - What is the History of the Mainspring?

The motive power of a watch depends upon the mainspring, which is coiled in a circular metal box, or barrel. The barrel has a cover, the barrel cap, and both are mounted on the 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, while in some, the barrel is turned to wind the mainspring.

The mainspring for the first portable watch was hammered out of a band of iron by Peter Henlein of Nuremberg in 1504. The first steel mainspring was made about 1550. Since then the steel used in mainsprings has been improved by various methods, so the mainspring used in high grade watches today is made of the finest steel possible. The following is a brief description of the manufacturing process of a mainspring.

There are several characteristics that the steel used in manufacturing mainsprings should possess: (1) be homogeneous, (2) have proper hardening qualities, (3) stand a high degree of temperature, (4) receive a good finish and clear color.

The basic material is the highest quality pure Swedish iron ore. Processing it in blast furnace produces pig iron of the highest degree of purity and uniformity. (Sulphur and phosphorus in the ore act as strength sappers, while manganese and carbon silicon are strength givers.) The pig iron is melted into ingots in open hearth furnaces or in special high frequency electric furnaces. The steel ingots are next hot rolled into bars and sheets about 1/16" thick and in the cold rolling process the steel is reduced to the thickness desired for mainsprings. Throughout the last process the steel is annealed many times to prevent extreme brittleness and oxidation. Finally, the steel is cut into strips which must be hardened properly in special hardening furnaces. At this point the strips are thoroughly polished and then are cut into the proper width and length by means of very accurate dies and fixtures. The springs are then put into an oil tempering bath, after which the ends of the springs are partly annealed and re-polished, then are given another heat treating process to assure the proper molecular arrangement in the steel. Finally, the tongue ends are riveted, the springs are oiled and are ready for packaging.

During the winding of a mainspring there are several forces at work:

(1) The mainspring is being stretched and its elasticty becomes greate r the more the spring is wound.

(2) The mainspring is being bent around the arbor, which causes the molecules on the inside to be depressed, while those on the outside are stretched.

(3) The mainspring is exerting a pressure or friction against itself and is constantly sliding against this pressure.

(4) During the winding and unwinding of the mainspring there is a continual change of the bending point from one end of it to the other.

Part 2 - Fitting and Selecting Proper Mainsprings

Before fitting or replacing a mainspring, it is necessary to be sure that the barrel is clean, true and free on the arbor. To test the barrel, assemble it without the mainspring and holding the arbor in the pinvise, spin the barrel on the arbor. After the barrel is true, free and any needed correctiins made, mark the outside rim of the barrel where the opening in the cover lies. When reassembling with the mainspring, it is important that the cover be replaced in the same position. Wipe off the mainspring with a piece of tissue paper dipped in oil and work it around the coils, never straighten the mainspring and wind in a mainspring winder, with the proper size hook.

The barrel is divided into 3 parts, 1/3 is for the arbor, 1/2 of the remaining area is taken by the mainspring and the balance is space. The area of both mainspring and space remain equal under all conditions, whether the mainspring is wound completely, partially or let down.

It is very important that the mainspring should have the proper width, strength or thickness and length. The width should be as great as it is possible to use, allowing about .1 m/m clearance between the bottom of the barrel and cap. One method to ascertain the approximate strength or thickness of the mainspring with out resorting to detailed mathematical calculations, is to measure the inside diameter of the barrel and divide by 100. The proper length of the mainspring is when it occupies one-half of the area between the inside rim of the barrel and the periphery of the arbor. A method for gauging the approximate division of the barrel, is to divide the diameter of the barrel into 12 equal parts, allowing the arbor 4 parts, the mainspring 5 parts when wound close to the arbor and the remaining 3 parts when run down. (Fig 73)

Part 3 - Miscellaneous Mainspring Data

Why do mainsprings break? - Just why mainsprings break, or why a new spring is just as apt to break as an old one, is a good deal of a mystery. Science up to date has found no satisfactory answer to the question, nor an absolute and definite cure or preventive 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 mainsprings to break.

A softer spring, which also means a cheaper one, may be more secure against breakage, and can even 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, and must be wound oftener, and, therefore, will not keep the watch running with the necessary precision for good timekeeping.

Gruen mainsprings are made from the finest Swedish steel and are hand-rubbed by skilled workmen. Our mainsprings are accurately gauged as to width, length and thickness. Further, they fit into the barrel without any alterations and are 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.

Each Gruen mainspring is placed in a protective metal container before being enclosed in an individual sealed envelope, stamped with the proper movement model number.

Should a mainspring be removed when cleaning a watch? - It is important to remove the mainspring when cleaning a watch in order to determine whether it is set, distorted, rusted or lacking proper lubrication.

To lubricate properly one should use a good grade clock oil and not vaseline, which is too heavy, or watch oil, which is too light and has a tendency to escape from the barrel.

What are some of the causes of excessive motion? - After a watch has been thoroughly overhauled and a new mainspring placed in the movement, it may have excessive motion or "overbank". This is due to the fact that the steel in one spring may have slightly more elasticity than in another spring of identical length, width and thickness.

Another cause may be that the barrel cover was not put on in the proper place, and this slightly bound the barrel arbor. It is extremely important to replace correctly the barrel cover and lightly oil the pivots of the barrel arbor in order to reduce any friction to a minimum.

Also, if the click and click spring are not properly oiled, this will cause a tension on the ratchet wheel, which in turn tightens up the mainspring, resulting in excessive motion.

Best results are obtained when the motion is a full turn of the balance after winding the mainspring about two turns, and a little more than 1½ turns of the balance when the mainspring is wound fully.

A FEW MAINSPRING DON'TS

Don't expect a mainspring to be flat if it is put into the barrel with the fingers. This method not only is liable to cause rust, which may result in breakage, but it also usually injures the spring, giving it a conical form, thereby increasing the friction in the barrel.

Don't fail to provide yourself with a good mainspring winder. See that the hooks on all the arbors of the winder are no longer than the thickness of the smallest spring, thus avoiding kinking and, therefore, unnecessary breakage.

Don't use a mainspring that is too long, because it fills the barrel and prevents it from making the required number of revolutions.

Don't use a mainspring that is too wide, as it will bind between the bottom of the barrel and the barrel cover, which increases the friction as it uncoils. Such a spring will not give uniform power throughout the daily running of the watch and will, in many cases, cause the watch to stop.

Don't use a mainspring that is too streng, because it will set, thereby increasing the chances of breakage and probable injury to the watch.

Don't expect a watch that needs a thorough overhauling to run satisfactorily by merely putting in a new mainspring.

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LESSON VII

Escapement - Page 23

Part 1 - What is the Escapement?

The escapement consists of a toothed escape wheel, the pallet fork complete with a receiving and discharging stone, a guard pin and a pallet arbor; and the roller table. (Fig 74)

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. Many forget that the complete balance wheel assembly is the actual timekeeping unit of the watch and 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 1/5 of a second by the locking and unlocking of the pallet stones with the locking faces of the escape wheel teeth.

What are some of the earliest Escapements? - The first known one was the verge escapement, invented by the celebrated Peter Henlein of Nuremberg about 1500 Other early types of escapements were the cylinder, the virgule, the duplex, the chronometer or detent. These all gave the power impulse directly from the escape wheel to the balance wheel with no fork, and the impulses were not altogether uniform.

The popular lever escapement was invented by the famed English horologist Thomas Mudge about 1750. 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.

There are two kinds of detached escapements. The equidistant has the locking faces of the pallets and equal distance from the pallet center. The lifting action on this escapement is unequal. (Fig 75) 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 increased locking resistance. (Fig 76) 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 the distance from the pallet centers closer to the locking corners.

Part 2 - Definition of the Various Terms Used in Connection With the Detached Lever Escapement

Banking Pin - 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 known to "overbank" when the roller jewel strikes outside the pallet fork due to excessive motion of the balance wheel.

Club - One of the teeth of a club wheel.

Club Wheel - An escape wheel with impulse faces or planes on the end of its

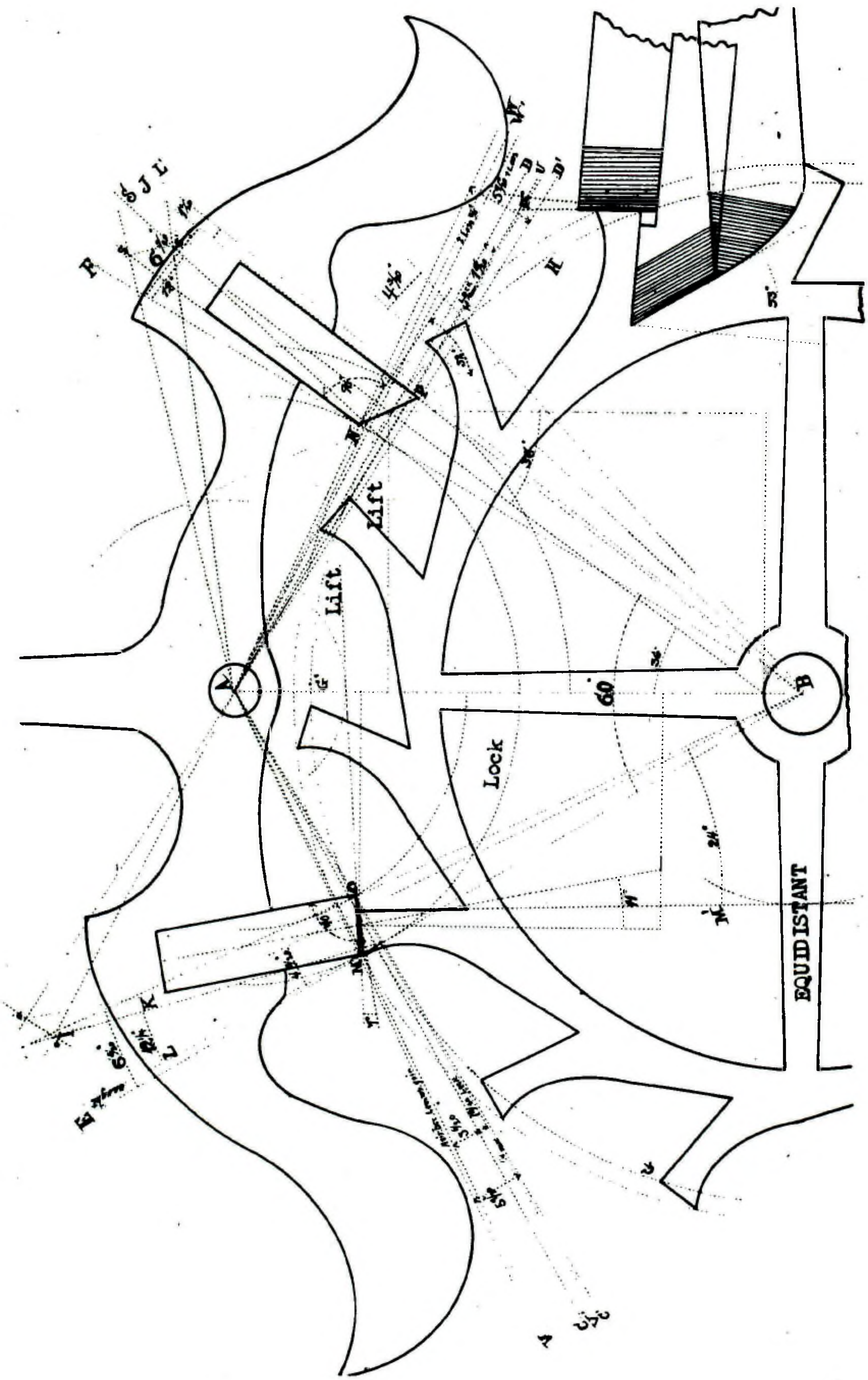

Fig. 75

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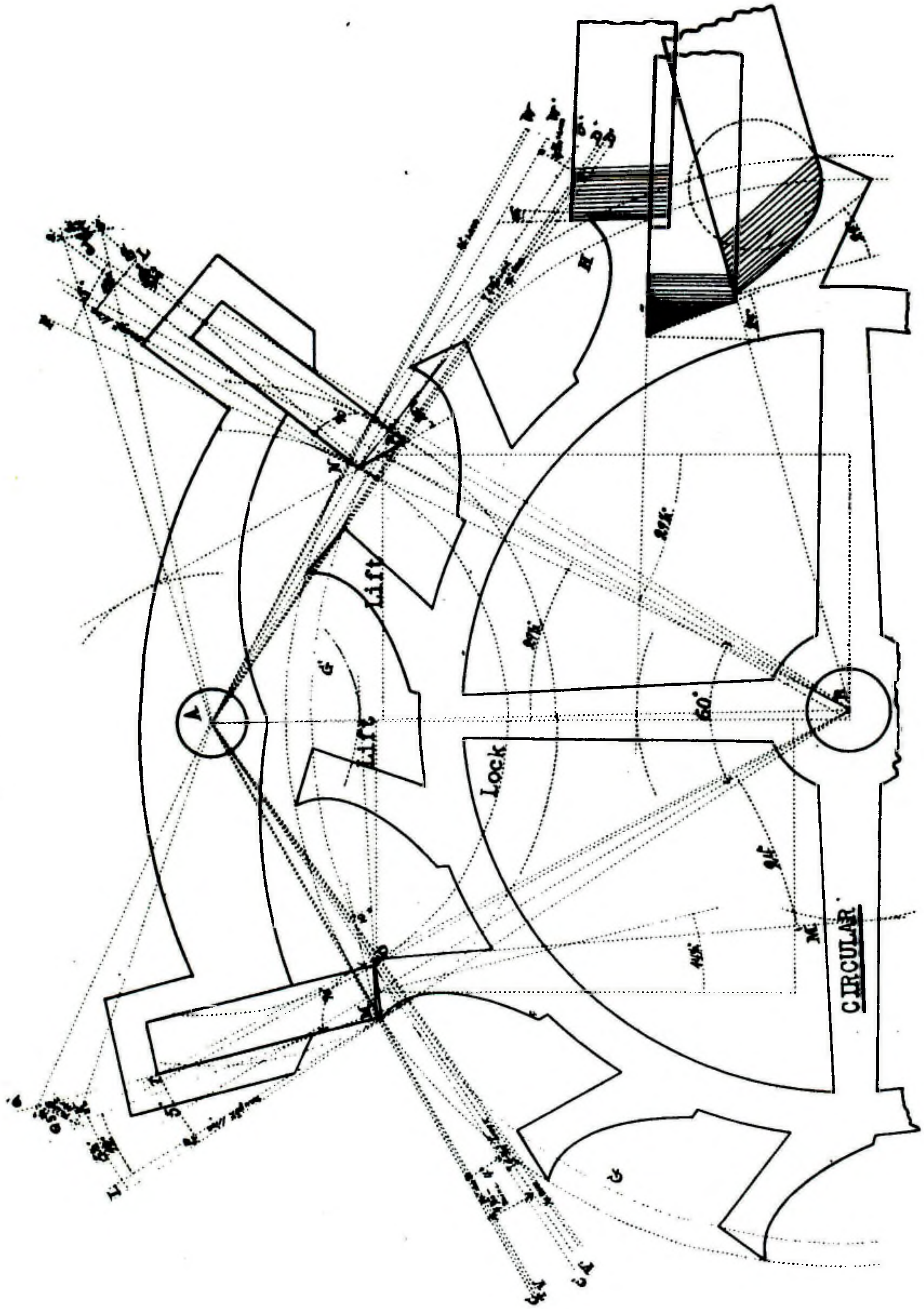


Fig. 76

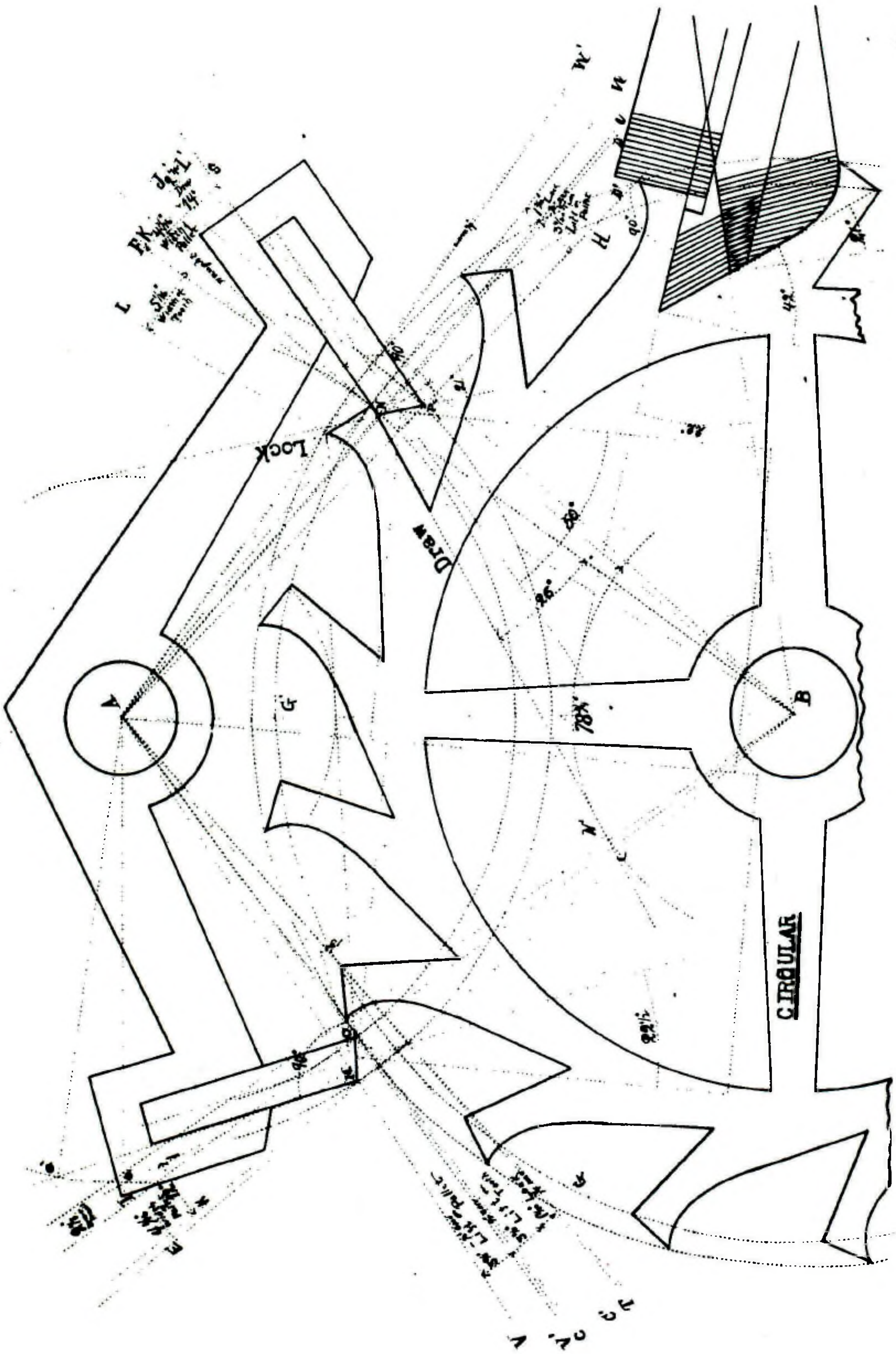


Fig. 77

teeth.

Draw or Draft - The draw of an escapement is the power that draws the fork away from the roller after it has delivered an impulse. (Fig 77) The locking only is not sufficient to insure the safety of its action. Therefore, the locking face of the stone is set at such an angle that the wheel must recoil slightly in unlocking. This angle keeps the fork against the banking pins, and also prevents the guard pin from coming in contact with the roller.

The draw is determined by deviating the locking surface of the pallet from a radial line drawn from the center of the wheel, outside of the circumference of the latter, and in the direction in which the force is exerted, presenting thus, to the tooth of the wheel, an inclined plane down which it may slide. Insufficient draw is a serious error. It is a constant liability, when the watch is given a sudden jar, for the fork to leave a banking pin and strike the edge of the safety roller, thus retarding the motion of the balance. It is impossible to adjust a watch having this fault.

There should be just enough draw to overcome the friction of the tooth on the surface of the pallet stone, and to hold the fork against the banking pins. If the fork is moved away from the pins, but not enough to unlock, there should be sufficient draw to bring back immediately the fork to the banking pin. If the draw is too great, it will take too much to unlock, and such loss of power will reduce the motion of the balance.

To Change Draw - Sometimes can be changed by tilting a pallet stone in its slot. This, however, cannot be done when the stone is closely fitted. When the stone is too closely fitted, the draw may be altered, thus: to increase the draw on the receiving stone, move the discharging stone inward; to reduce it, move the discharging stone outward. To increase the draw on the discharging stone, move the receiving stone outward; to reduce it, move the receiving stone inward.

To test the Draw - Let the mainspring down to the point it reaches at the end of a 24 hour run. Holding the watch vertically, with the fork in opposite horoizontal positions alternately, try the draw, by carefully moving the fork away from each banking, in turn, but not enough to unlock the wheel. If the draft is sufficient, it will draw the fork against the banking at both sides.

Drop - Drop is the space that the escape wheel passes through during the interval between the release of one tooth by a stone and the arrest of another tooth by the opposite stone (Fig 78) When a tooth leaves the receiving stone, another tooth drops on the discharging. Three teeth are then embraced between the releasing corner of the receiving stone, and the locking face of the discharging. There is a certain amount of space between the releasing corner of the receiving and that of the tooth just released, which admits of moving the escape wheel to and fro that amount, and is called "inside drop". When a tooth leaves the discharging stone, the wheel can also be moved to and fro between the locking face of the receiving and is called "outside drop". Both inside drop" and"outside drop"should be equal. If they are not, a watch will sound as though it is out of beat.

Drop may be altered by spreading the stones apart or closing them together. If the outside drop is the greatest, it can be corrected by moving the pallet stones farther apart. If the inside drop is the greatest, it can be corrected by bringing the stones closer together. The stones to be moved only one half as much as is desired to change the drop. If the inside drop is to be decreased and the stones are brought closer together, the inside drop has been decreased that amount, but the outside drop has also been increased the same amount. Therefore, move the

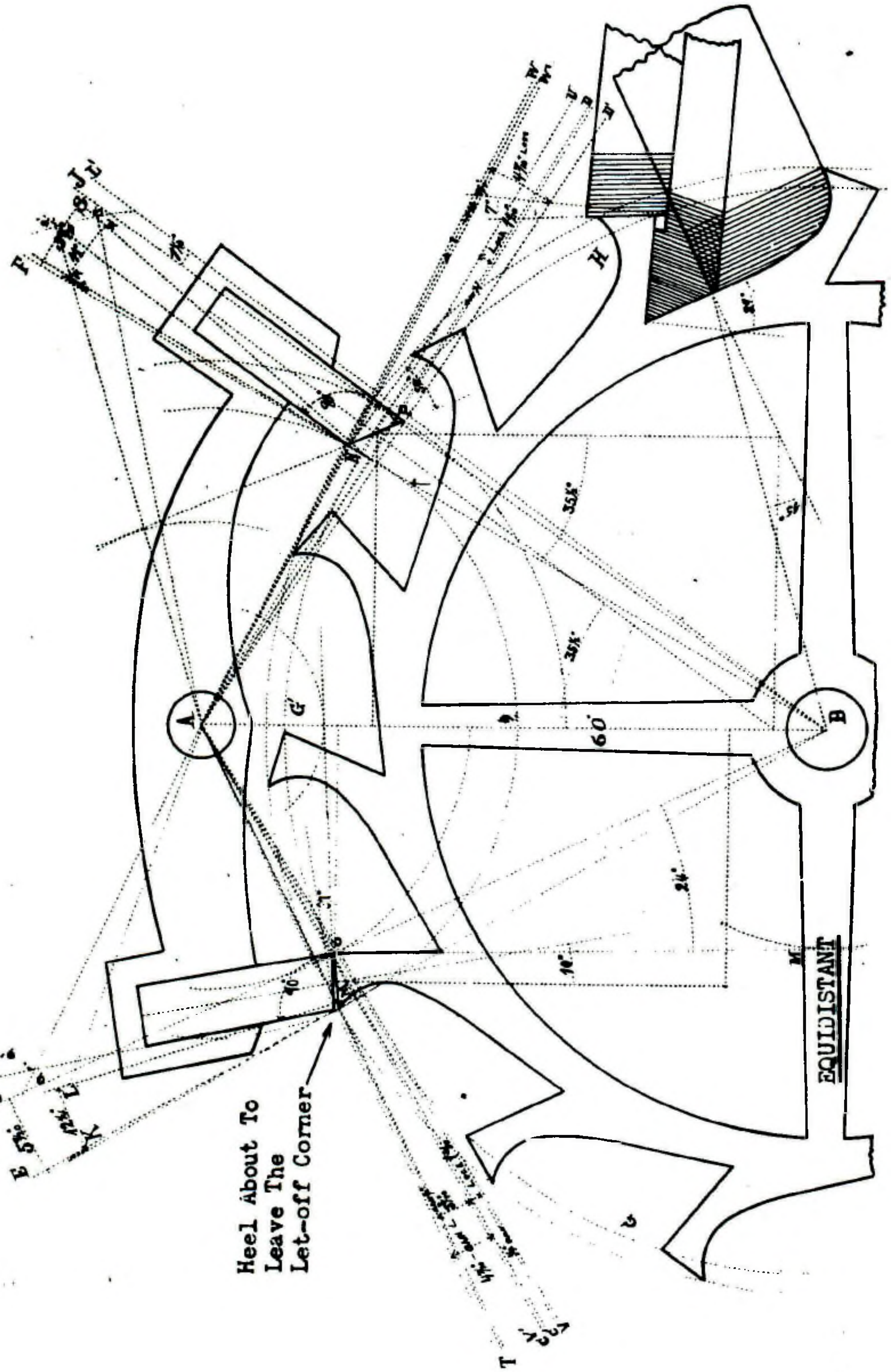

Heel About To Leave The Let-off Corner
EQUIDISTANT
A
B
60°
35½°
24°
10°

Fig. 78

stones one-half as much as is desired to change the drop. There is another way in which the d rop may be altered on either or both stones by moving a pallet stone in or out alters the drop from the stone moved, to the other stone.

Fork Hollow - The two curves — also called "horns" — that extend outwardly from the corners of the fork slot. These are a necessary part of the safety action and prevent the unlocking of the escapement after the guard pin has entered the passing hollow of the roller.

Fork Slot - The rectangular notch in the end of the fork which engages with the roller jewel pin to unlock the escapement and give impulse to the balance wheel.

Guard Pin - The guard pin in a lever escapement is purely a safety device. (Fig 79) If left out, the timekeeping of the watch would not be impaired as long as it is not subject to sudden motion. During the arc of vibration of the balance in the interval between two impulses, the combined action of the guard pin and lower roller edge prevents the fork going out of the position to receive the impulse pin or roller jewel. If it were not for this safety device of the guard pin, any sudden motion given the watch would be liable to cause a condition which is generally termed over-banking.

When the impulse pin leaves the fork slot, the first part of the safety action is secured by the impulses pin and the fork horn. (Fig 80) This is due to the fact that the hollow cuts away a part of the roller edge, and while that cut-away part stands in the path of the guard pin, there can be no safety action on the roller.

The guard pin should always be perfectly central with the fork slot, therefore, never bend or move the guard pin out of center to correct roller shake. The effect of bending the guard pin out of line with the center of the fork slot is, first, to cause the roller impulses to be delivered at unequal distances from the line of centers, and, second and most serious, the escapement is liable to do what is commonly termed "trip". For example, if the guard pin were bent to the left and the escape is locked on the discharging stone, the point of the guard pin is then opposite the hollow of the roller, and if it should be pressed to the left, it may cause the tooth to unlock on the discharging stone. When the guard pin is too far forward, the bankings should not be opened to allow the roller to pass, because this would increase the angle of contact between the impulse pin and the fork, thus lessening the free action of the balance.

Conditions necessary for correct safety action: The guard pin is central with the fork slot; the sides of the fork slot are parallel and of equal length; the inside circles of the fork horns have the proper arc, and both are equal in relation to the fork slot; the impulse pin or roller jewel is square to the front and upright; the edge of the safety roller is polished and concentric on the staff.

To Test the Safety Action - Move the balance around until the tooth escapes and the fork goes to the banking. The guard pin should then be safely free from the roller edge. If it is not, the guard pin is too long and should be shortened. If the guard pin has too much play, it should be lengthened either by pushing it out a little, or fitting a new pin. While the fork is against the banking, press the guard pin against the edge of the safety roller. The tooth should still remain on the locking face of the pallet, when tried with both pallets. If the tooth does not remain there, it must be corrected as stated above. When pressing the fork back, as described, the play is found to be right, and the guard pin wedges against the edge of the safety roller seeming almost to pass to the other side, the fault should be

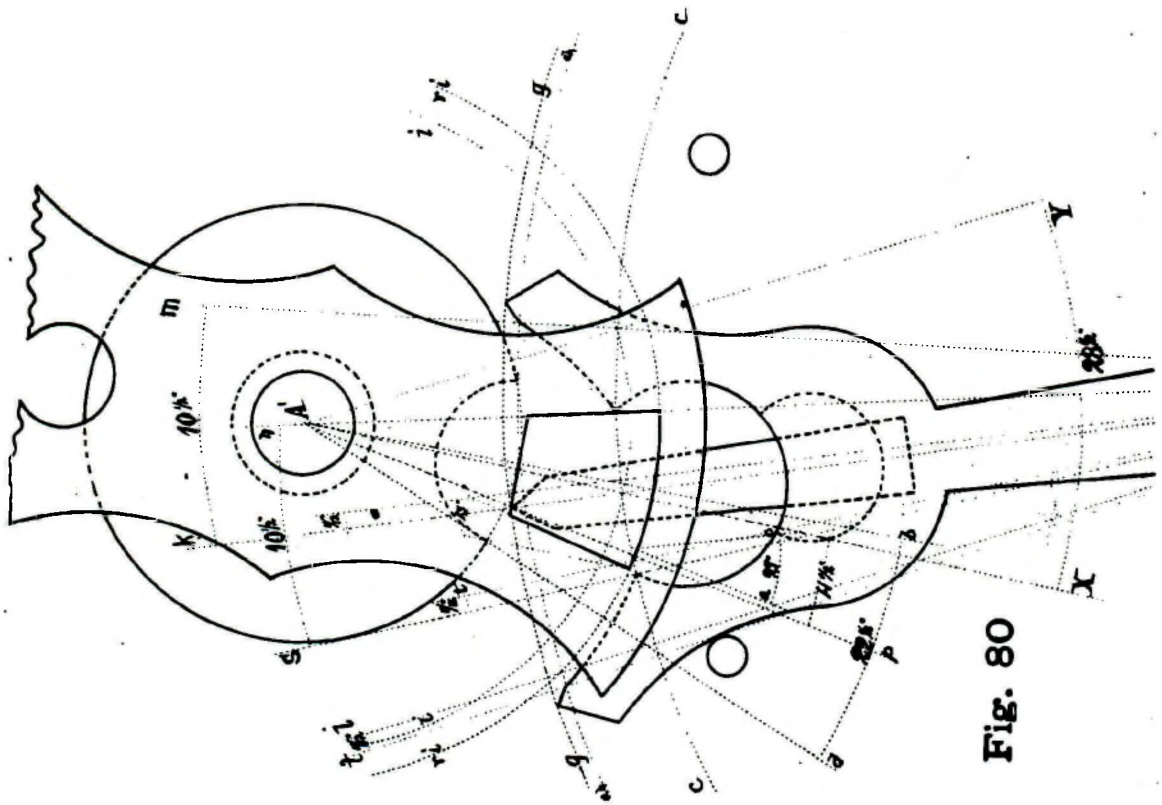


Fig. 80

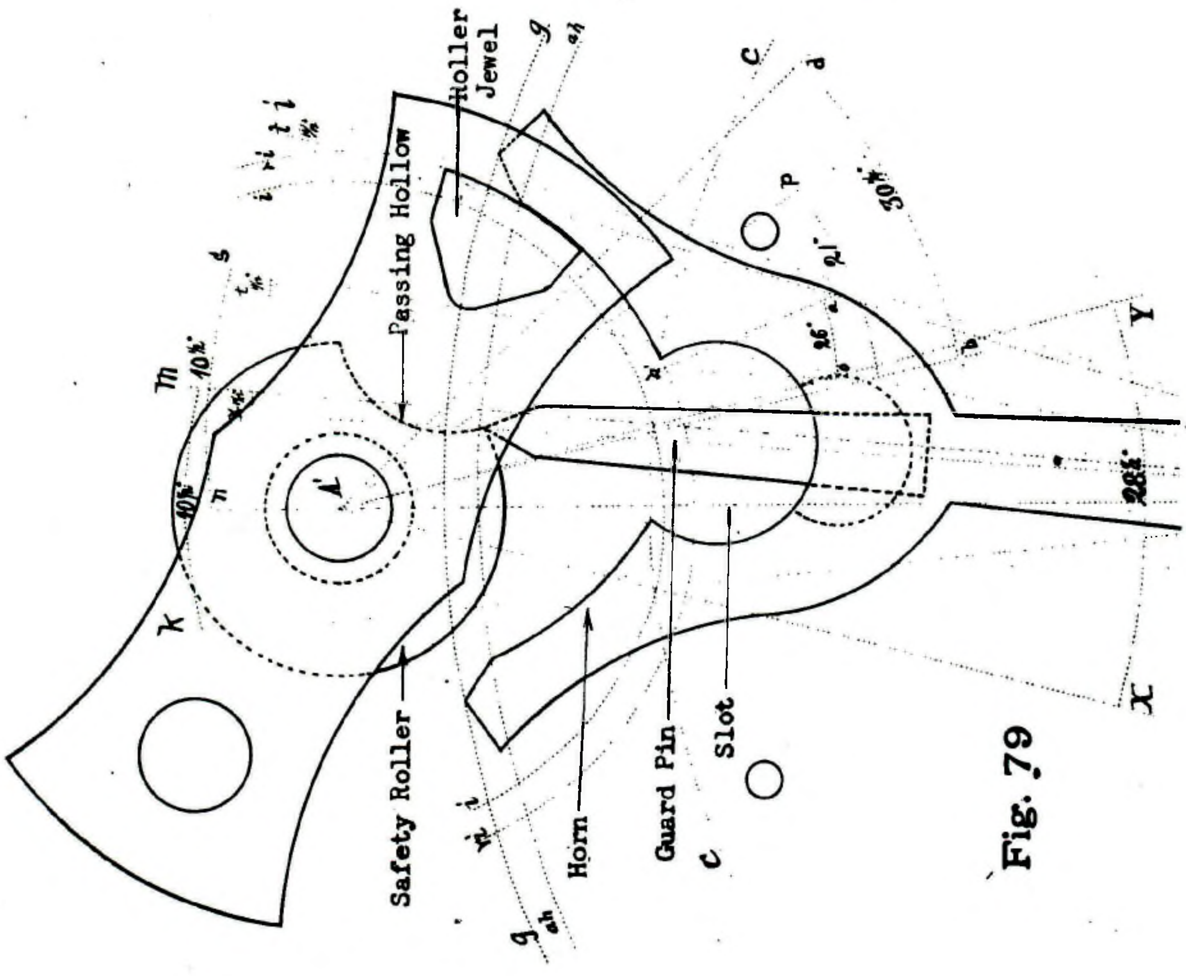

Roller Jewel
Passing Hollow
Safety Roller
Horn
Guard Pin
Slot

Fig. 79

corrected by a smaller safety roller and a longer guard pin. See that the guard pin does not get above or below the safety roller. Test by raising the fork to the highest position its endshake will alow. Care should be taken that the hollow for the passage of the guard pin is wide and deep enough so as to avoid contact with it when passing by.

Impulse and Left - An escape tooth, in delivering impulse to the pallet, moves in an arc of a circle. The circular impulse is measured from the center of the escape wheel and is divided between an escape tooth and a pallet stone. Any alteration made in an escapement by moving a stone in or out changes the impulse action. Another result from moving a pallet stone, is that it changes the extent of the arc of vibration of the pallets called "left". The term "left" is applied to the thrust given to the pallets by an escape tooth. The lift is measured from the pallet center and is also divided between an escape tooth and a pallet stone.

The action between the wheel and the pallets should be that the heel of the toothtooth glides along the impulse plane of the stone (Fig 81) until finally the two impulse faces meet nearly parallel, and then the heel of the tooth passes the let-off corner of the pallets. (Fig 78)

Lock - Lock is the distance from the locking corner of a pallet stone to the point at which the wheel tooth strikes the instant it is arrested by the stone. The distance should be as little as possible, (Fig 77) consistent with allowance that should be made to cover certain unavoidable mechanical errors, such as side-shake in the pivot holes, inaccuracy of the escape wheel in round, variation in spacing of the teeth, etc.

The amount of locking in the pallets is very important for the good performance of a watch. If it is shallow, the teeth are liable to fall upon the impulse face, a very serious defect; if the locking is too deep, then too much power is required in unlocking and the power used is taken from that required for the impulse to the balance. The amount of lock should be from 1/10 to 1/8 the width of the impulse face of the pallet stones.

Moving one pallet stone either outward or inward alters the lock on both stones. When a stone is drawn outward it causes the tooth to drop farther up on the locking face of the opposite stone while moving it inward has the opposite effect. If one pallet stone is set out or toward the wheel or away from it, it will increase or decrease the locking on both stones just as much as either one is moved. If the locking is too light and one stone is set out, it might increase the locking enough. But if the watch was "in line", it would be thrown out of line by moving only one stone, so it is necessary, in order to keep the watch "in line", to move each stone out one-half as much as is required to increase the lock.

To test lock - Move the fork slowly from left to right, and when the tooth drops, it should drop safely on to the locking face, not on the impulse plane. The latter would indicate a shallow depth, and the watch cannot be timed if the tooth drops on the incline or just on the corner. Each tooth should be tried separately on both receiving and discharging pallets. If the teeth are irregular, the fault is in the wheel, which should be replaced as the corners of the pallets may be rounded, or chipped off, causing the tooth to drop on the incline, when the locking is really deep enough. If the tooth drops too far up the locking plane, the safety or the banking action may be at fault. Therefore, never make a correction on an escapement unless the exact cause of the trouble has been found.

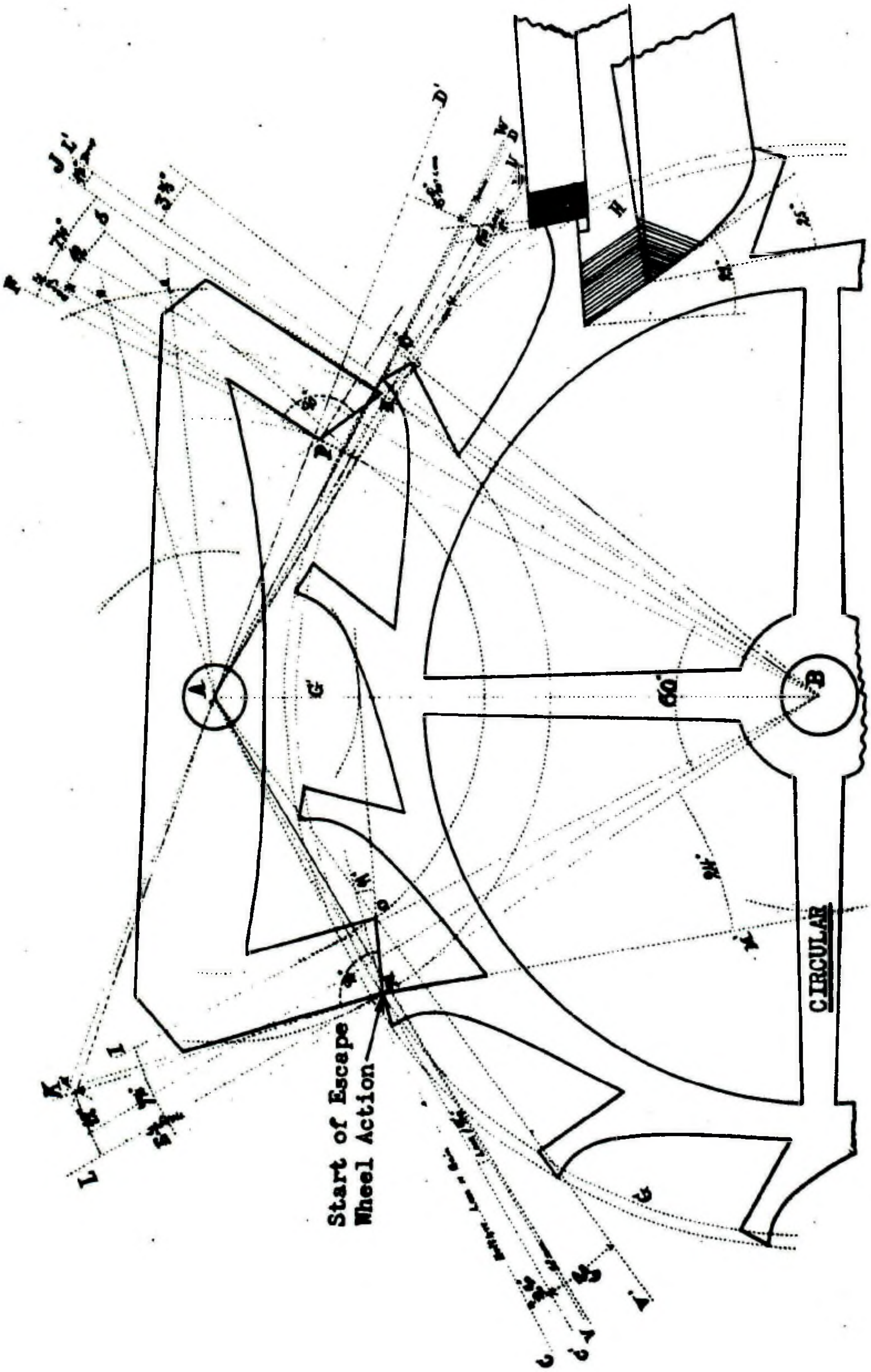


Fig. 81

Pallet, Circular - An escapement in which the centers of its impulse faces are equally distant from the pallet arbor.

Pallet, Equi-Distant - An escapement in which the locking faces are equally distant from the pallet arbor.

Pallet, Discharging - (also called "L" or left stone in American watches) - The last of the two ruby pallet stones to engage with a given tooth of the escape w heel.

Pallet, Receiving - (Also called "R" or right stone) The first of the two ruby pallet stones with which a tooth of the escape wheel comes into engagement.

Pallet Stones - Effect of Moving in the Pallet Fork - Drawing out the "R" stone increases the drop on the inside and increases the draft on the "L" stone.
Drawing out the "L" stone increases the drop on the outside and decreases the draft on the "R" stone.
Drawing out the "R" stone and pushing in the "L" stone increases the draft on both stones.
Dr awing out either stone increases the lock on both stones.
The reverse movement of the stones produces the opposite effect.

Passing Hollow - The crescent-shaped notch in the edge of the roller table which permits the guard pin to pass from one side of the roller to the other.

Rake - This refers to the front side of the escape wheel teeth extending from the locking corner down to the rim of the wheel. The purpose of rake is to prevent the locking side of the pallet stone coming in contact with any part of the escape wheel tooth except the locking corner or bezel.

Roller Jewel - The relation between the fork and roller jewel are divided into two parts: (1) the unlocking of the pallets and (2) the impulse to the balance. The unlocking takes place as a result of power from the balance and hairspring, while the impulse to the balance receives its energy by means of the power derived from the mainspring and transmitted through the train to the escape wheel. The roller jewel should fit the notch in the fork as closely as possible, be free and perpendicular to the roller table. A jewel that is too small will cause the lever to move some distance without giving impulse, resulting in a poor motion to the balance wheel. (Fig 74)

Roller, Safety - The small diameter roller that acts in connection with the guard pin to prevent the accidental unlocking of the escapement. The relation of this roller to the table roller must be such that in looking through its passing hollow at the end of the roller jewel pin, the two corners of the hollow shall appear to be equally distant from the sides of the pin.

Roller Table - The larger roller which carries the jewel pin. A roller table that does not have the safety roller is called a single roller, whereas one that has the added safety roller is known as a double roller table.

Slide - Slide is the distance from the point at which the wheel tooth strikes the locking face of a stone at the instant of drop, to the point it reaches when the motion of the pallet is arrested by the fork coming in contact with the banking. The purpose of the slide is to allow proper freedom for the impulse pin to pass out of the fork slot, and also to allow freedom between the guard pin and the edge of the safety roller. Opening or closing a banking pin changes the slide, but does not change the lock, while moving a pallet stone changes both lock and slide.

The amount of slide should be the least quantity that will insure safety; for the slide combined with the lock and the draw is a resistance to the motion of the balance.

<u>Toe</u> - The part of a club escape wheel tooth which leaves the pallet stone last. The wheel travels from heel to toe.
<u>Heel</u> - The locking corner of the club escape wheel tooth.

<u>Part 3 - What is the New Gruen Escapement Without Banking Pins?</u> - Due to the new technique employed in the manufacture of Gruen watches, the old style banking pins have been eliminated. The walls of the lower plate themselves or the sides of the pallet lever bridge act as the banking pins and the escapement is, therefore, properly adjusted before leaving the factory. It is not necessary to do any further adjusting to it.

Experience has taught us 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 very satisfactory due to the fact, in our opinion, 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 to this type of escapement than the type with the banking pins. In manufacturing the movements, all the escapements are made somewhat light so that if it is ever necessary to change the pallet stones they can be set deeper.

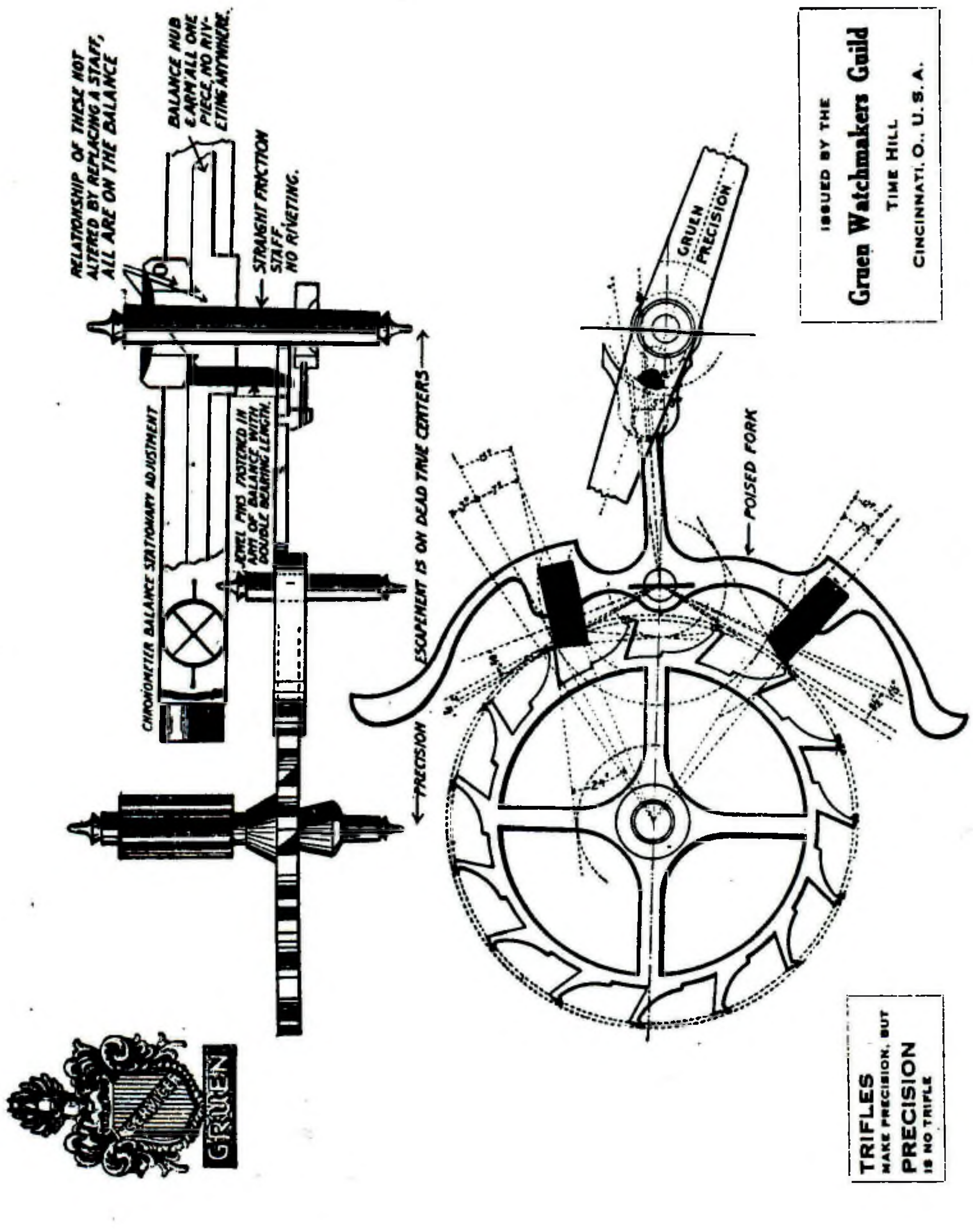

RELATIONSHIP OF THESE NOT ALTERED BY REPLACING A STAFF, ALL ARE ON THE BALANCE
BALANCE HUB & ARM ALL ONE PIECE, NO RIVETING ANYWHERE.
STRAIGHT FRICTION STAFF, NO RIVETING.
CHRONOMETER BALANCE STATIONARY ADJUSTMENT
JEWEL PINS FASTENED IN ARM OF BALANCE WITH DOUBLE BEARING LENGTH.
ESCAPEMENT IS ON DEAD TRUE CENTERS
PRECISION
POISED FORK
GRUEN PRECISION
ISSUED BY THE
Gruen Watchmakers Guild
TIME HILL
CINCINNATI, O., U.S.A.
TRIFLES
MAKE PRECISION, BUT
PRECISION
IS NO TRIFLE
GRUEN

Fig. 74

The Gruen Watch Company
Time Hill
Cincinnati 6, Ohio
Lesson VIII
Trains - Page 29

Part 1 - What is the "Train" of a Watch Movement?

The main train of a watch movement, known as a compound train, consists of a series of wheels and pinions for transmitting the power from the mainspring barrel to the balance wheel. (Figure 82)

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 3rd pinion carrying the 3rd wheel, which in turn engages in the 4th pinion carrying the 4th wheel, which 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 than 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 shows 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.

What is meant by the term "an 18,000 train"?

This indicates that the balance wheel will make 18,000 vibrations in both directions in one hour. If it vibrates more than 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 4th wheel to make a complete revolution in one minute, and as 5 vibrations of the balance wheel are made each second, the second dial will be evenly divided into 60 spaces indicating the seconds.

To determine the number of vibrations a balance wheel will make, it is necessary to multiply the number of teeth in the center wheel by the number in the 3rd wheel, by the number in the 4th wheel, by the number in the escape wheel times 2 (because each tooth of the escape wheel gives two impulses). This sum is divided by multiplying the total of the number of leaves in the 3rd pinion, in the 4th pinion, and in the escape pinion. An illustration is:

$$\frac{80 \times 75 \times 80 \times 15 \times 2}{10 \times 10 \times 8} = \frac{14,400,000}{800} = 18,000$$

It must be understood that all 18,000 trains do not have the same number of teeth in the wheels and leaves in the pinions. The size and construction of the movement determine

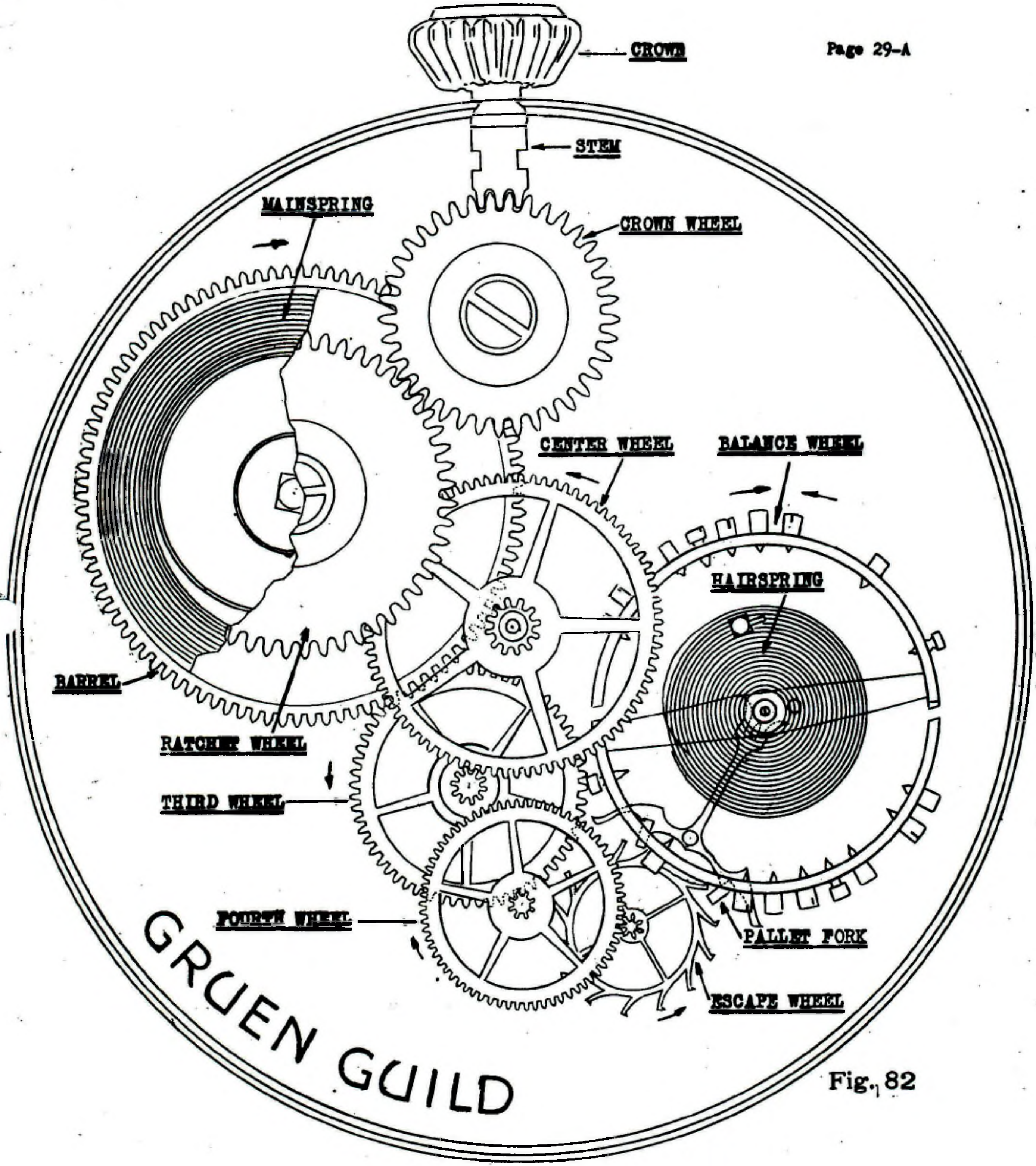

CROWN
STEM
MAINSPRING
CROWN WHEEL
CENTER WHEEL
BALANCE WHEEL
HAIRSPRING
BARREL
RATCHET WHEEL
THIRD WHEEL
FOURTH WHEEL
PALLET FORK
ESCAPE WHEEL
GRUEN GUILD

Fig. 82

this number, as larger movements usually have more wheel teeth than smaller movements.

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. The reason the fast trains were employed was that the balance wheel was given a faster motion, thereby lessening to a certain extent the influence of outside disturbances, such as quick jerking motions of the arm while the watch was worn. However, now with the many technical advances made in watchmaking, such as friction-type jeweling, improved gear cutting technique, modern machines and equipment, the present day movements can be made with the standard train of 18,000 vibrations, that has proven so successful.

Defective gearing of the train (due to faulty design or improper replacement of parts) can cause a movement to run erratically or to stop due to a number of causes. The most common are depthing too deep or too shallow, pinions too large or too small, badly worn teeth and pinions, or incorrect end-shake of the pivots. Therefore, a careful checkup of the train is most essential in order to assure proper timekeeping accuracy.

DEFINITIONS OF THE TECHNICAL TERMS USED IN WATCH TRAINS
(Fig. 83)

WHEEL:- Is any circular piece of metal, usually brass, on the periphery of which teeth may be cut of various forms and numbers, and these teeth mesh into the spaces of the pinions.

PINION:- Is a smaller wheel of steel, with teeth or leaves playing in connection with a larger wheel. The projections on the surface of the pinion are called leaves and work into the spaces between the teeth of the wheel.

PITCH CIRCLE:- Is a circle concentric with the circumference of a toothed wheel, and cutting its teeth at such a distance from their points as to touch the corresponding circle of the pinion and having with that circle a common velocity, as in a rolling contact.

PITCH DIAMETER:- Is the diameter of the pitch circle.

FULL DIAMETER:- Is the diameter measured from point to point of the teeth.

DISTANCE OF CENTERS:- Is the distance measured on a straight line from center to center, between the wheel and pinion. (It should be measured very accurately, as on this measurement depends the entire success of all calculations for train wheels)

LINE OF CENTERS:- Is a line drawn from center to center of any wheel and pinion at which the two acting points should meet.

DIAMETRICAL PITCH:- Is the diameter of the pitch circle, divided into as many spaces as there are teeth on the wheel or leaves in the pinion.

CIRCULAR PITCH:- Is the pitch circle divided into as many spaces as there are teeth on the wheel or leaves in the pinion.

ADDENDUM:- Is the acting portion of the tooth, either on the wheel or pinion, outside of the pitch circle. (Sometimes called the working depth.)

DEDENDUM:- Is the non-acting or inside portion of the tooth, either on the wheel or pinion, from the bottom of the addendum to the base of the tooth.

DRIVER:- Is the wheel or the one that forces the other along.

DRIVEN:- Is the pinion or the one that is being forced.

LEAD:- Is the tooth or leaf of the driver that is in direct contact with the leaf or tooth of the driven.

PROPORTION OF WHEEL TO PINION:- must be, as the number of teeth contained in the wheel and pinion, and size of each, is to the distance of centers, within which they are to run.

NUMBER OF TURNS OF A PINION:- divide the number of teeth in the wheel by the number of leaves in the pinion.

NUMBER OF TURNS OF LAST WHEEL TO THE FIRST:- multiply the teeth in all the wheels (meshing in the pinions) together and divide that product by the total of all the leaves of the pinions, the quotient will be the number of revolutions of the last wheel to the first.

If a wheel is lost, how is the correct number of teeth and leaves determined?

3rd WHEEL:- First, count the number of teeth in the center wheel and the leaves in the 4th pinion. Every 4th pinion in a movement having a second hand must make 60 revolutions to one of the center wheel, therefore, the number of teeth in the wheel and leaves in the pinion must be so calculated as to produce that result. The 3rd pinion must have such number of leaves as will divide the number of teeth in the center wheel without a remainder. The 3rd pinion makes 8 revolutions to one of the center, which makes 8 one of the factors. There must be such number of teeth in the 3rd wheel as to cause the 4th pinion to revolve as many times as is necessary to produce the required result, viz: 60 revolutions of the 4th pinion to one of the center. The other factor is obtained by dividing the number of revolutions the 4th pinion must make, which is 60, by 8, the other factor. Therefore, multiply the number of leaves in the 4th pinion by the last found factor. This equals the number of teeth for the missing wheel. Then use the following rules to obtain the correct diameters for the wheel and the pinion.

The distance of centers times 2 divided by the sum of the teeth in the wheel, plus the leaves in the pinion, equals the diametrical pitch. Then it is necessary to have the addendum, obtained by multiplying the diametrical pitch by 2.5. The pitch diameter of the wheel is as many diametrical pitches as there are teeth on the wheel, therefore, multiply the diametrical pitch by the number of teeth on the wheel. The pitch diameter, plus the addendum, equals the full diameter of the wheel.

3rd PINION:- Obtain the 2 diameters for the pinion in the same manner. This must have as many diametrical pitches as there are leaves in the pinion with the addendum added for full diameter. The diametrical pitch times number of leaves equals the pitch diameter for the pinion. The diametrical pitch times 1.25 equals the addendum. The pitch diameter, plus the addendum equals the full diameter of the pinion. For proof, add the 2 pitch diameters, and divide the sum by 2 to give the distance of centers.

4th WHEEL:- Let "F" indicate the missing 4th wheel:

$$\frac{80 \times 75 \times F \times 15 \times 2}{10 \times 10 \times 8} = 18{,}000$$

$225F = 18{,}000$ $\qquad$ $18{,}000 \div 225 =$ "F" of 80 teeth

4th PINION:- Let "f" indicate the missing 4th pinion

$$\frac{80 \times 75 \times 80 \times 15 \times 2}{10 \times f \times 8} = 18{,}000$$

$\frac{180{,}000}{f} = 18{,}000$ $\qquad$ $180{,}000 \div 18{,}000 =$ "f" of 10 leaves.

4th WHEEL & PINION COMPLETE:- Let "F" indicate the 4th wheel and "f" the 4th pinion.

$$\frac{80 \times 75 \times F \times 15 \times 2}{10 \times f \times 8} = 18{,}000$$

$\frac{2{,}250F}{f} = 18{,}000$ $\qquad$ $\frac{F}{f} = \frac{18{,}000}{2{,}250} =$ ratio of $\frac{8}{1}$

The result shows that the 4th wheel should have 8 times as many teeth as the 4th pinion has leaves. Changing "f" into any of the must used pinion numbers as 6, 7, 8, or 10, the following solutions are obtained, $\frac{48}{6}$, $\frac{56}{7}$, $\frac{64}{8}$, or $\frac{80}{10}$.

Part 2 - Depthings

The train of a watch should be of accurate construction, high finish and the depthing of the wheels and pinions should provide a uniform lead throughout. Due to lack of apparatus by which the depthing of the teeth can be seen, the w watchmaker has to depend upon touch and therefore, the train is one of the most difficult sections of a movement to control Before inserting the wheels in the movement, it is necessary to clean thoroughly all jewel holes, pinions, wheels and pivots.

With the balance and fork removed, test each wheel by pressing a pointed pegwood against the pivot of the pinion into which the wheel engages. (Figure 84) and lead the wheel slowly back and forth. If the wheel cracks or jumps, the depthing is too deep (Figure 85) or the wheel or pinion too large, while if the wheel slips or slides, the depthing is too shallow (Figure 86) or the pinion or wheel too small or too far apart. If no defects were found, wind the mainspring and if the train is free throughout, it will be observed that the moment the mainspring is completely unwound the escape wheel will turn in a contrary direction.

The depthing tool (Figure 87) can be used to see the action of the gears, care must be taken that the distance taken by the wheels in the tool is the same as in the movement. Adjust the points of the depthing tool perpendicular to the movement plate and exactly in the center of the pivot holes. Without changing the distance between the points place the wheel and pinion together between the V centers and lead the wheel back and forth noticing if any defects are present.

In observing the action of a wheel and pinion in a depthing tool, attention should be paid to the outgoing tooth, noting that its point is not used and the incoming tooth takes over without drop (Figure 88). When properly portioned and spaced wheel and pinion engage each other, the contact points will be where their pitch circumference intersect the line of centers, or at the widest part of the leaf and tooth (Fig. 89) The line of centers varies depending on the number of leaves in the pinion, (Figure 90) shows one with 12 leaves, (Fig 91) one with 8 leaves, and (Fig 92) one with 6 leaves in the pinion.

<u>Pinion too small</u>:- If the pinion is too small (Fig 93 the pitch circles do not meet and the face of the tooth engages before the line of centers has its contact on the face of the leaf. This results in a waste of power and much noise and the fitting of a larger pinion is the only satisfactory solution.

<u>Depthing too shallow</u>:- Where the pinion and wheel are placed too far apart,(Figure 86) this can be remedied by a larger wheel or by stretching the wheel and correcting its teeth in the rounding-up tool (Figure 94) to insure that it is perfectly round.

<u>Depthing deep</u>:- Where a pinion and wheel of correct size are too close to each other, the tooth (Figure 85) which is discharging the leaf (A) releases its face before the tooth (Y) comes in contact with the leaf (B) and causes an uneven load.

<u>Stretching a wheel</u>:- When necessary to stretch a wheel, hold it on a staking tool stump in the vise, and with small polished hammer, lightly tap at the base of the flank

without striking the arms. The wheel is made to revolve with the fingers after each tap. (Figure 95) and should be corrected in the rounding-up tool. (Figure 94)

Part 3 - Turning Pinions

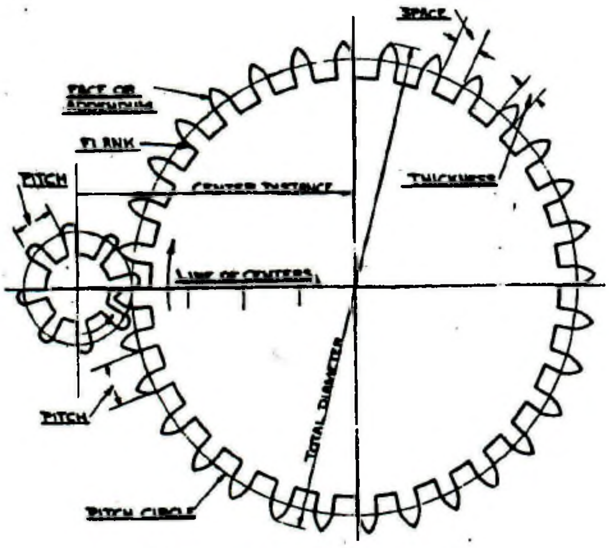
To fit a new pinion to a wheel, first remove the old pinion by turning off the reveting without removing any metal from the wheel. Lay the pinion on the die of the staking-tool and with a suitable punch, tap it out.(All measurements can be taken from the old pinion.) Measure the height of the blank to be turned from the pinion face. Clamp that part of the leaves that is not to be turned in the lathe and cut down the leaves to form a seat for the wheel. When turning pinions use the point of the graver and hold it rigid with the point above the center (Figure 96) and turn until the pinion just begins to enter the wheel.

Care must be taken in fitting a new pinion to a wheel that the leaves fit into the marks made by the old pinion, otherwise trouble may be encountered in securing the wheel. Press the wheel against the seat friction tight and try its truth in round and if the wheel is not true shift its position on the pinion until it runs true. Mark the wheel and a leaf of the pinion so that its position can be found again.

Shorten the leaves allowing just enough to rivet and there should be only a slight intercut to insure a sound rivet. (X Figure 97). Measure the position for the pivot from the pinion face mark, then turn and polish. (P Figure 97).

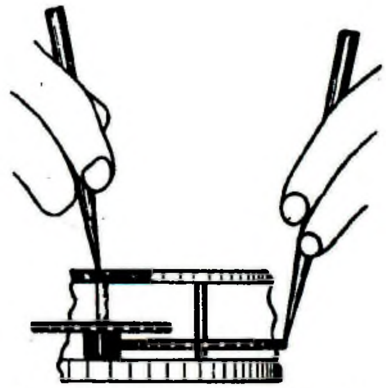
Reverse the pinion, fasten it with the unfinished part projecting from the chuck and turn the opposite pivot with the shoulder to the proper height. (Figure 98). Finally polish the pivot and pinion face.

When the pinion is finished (Figure 99), press a piece of watch paper against the polished face and place it in the staking tool. Select a riveting punch of such size that it will spread the riveting similar to fitting a balance staff. During the riveting operation, care should be taken to shift the wheel every few blows to insure it being true and flat.



Names Of Wheel And Pinion Parts

Fig. 83

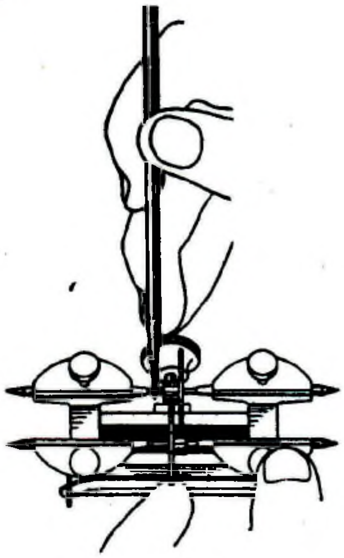


Testing Depthing In Movement

Fig. 84

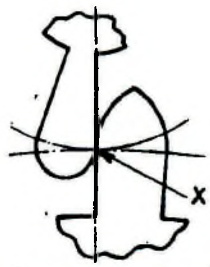
Depthing Too Deep

Fig. 85



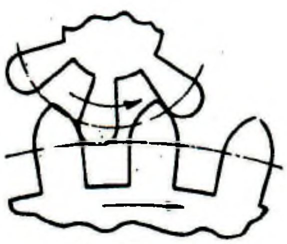
Testing Depthing In Depthing Tool

Fig. 87



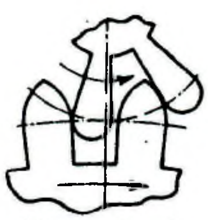
Proper Contact Of Leaf And Tooth

Fig. 89



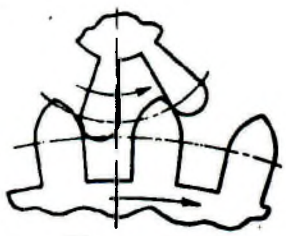
Depthing Too Shallow

Fig. 86



Proper Lead

Fig. 88



Pinion Too Small

Fig. 93

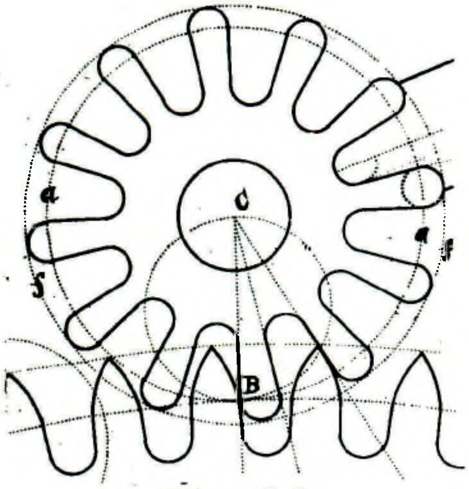


Fig. 90

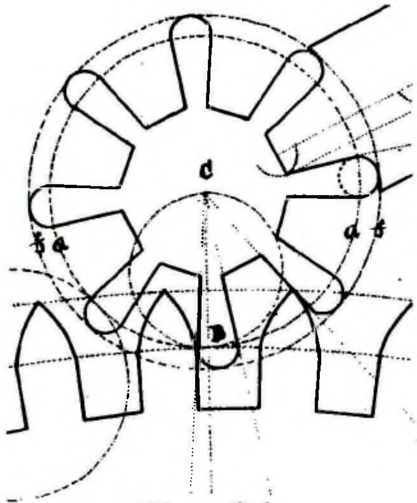


Fig. 91

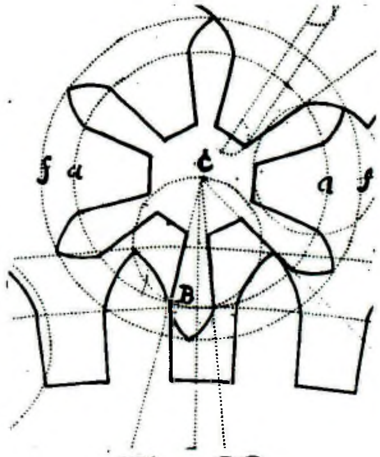
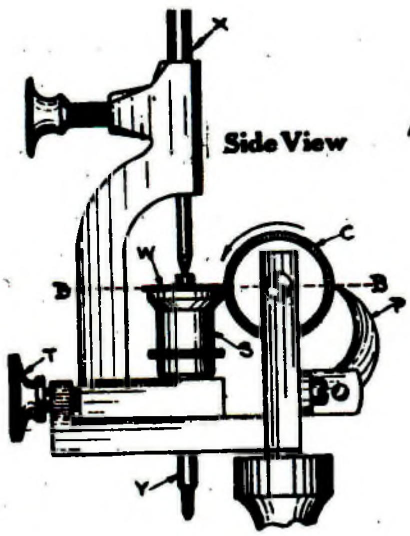
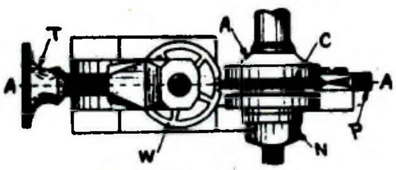


Fig. 92

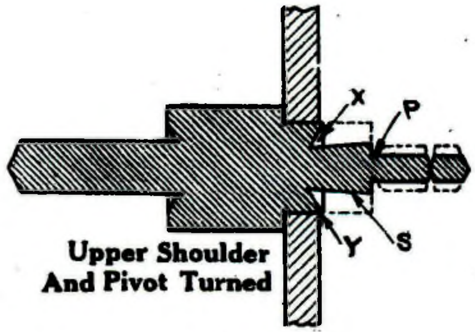


Wheel Adjusted In Rounding Up Tool



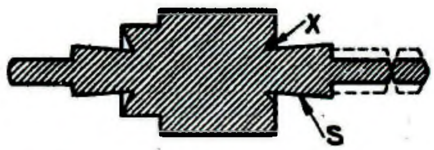
Top View

Fig. 94



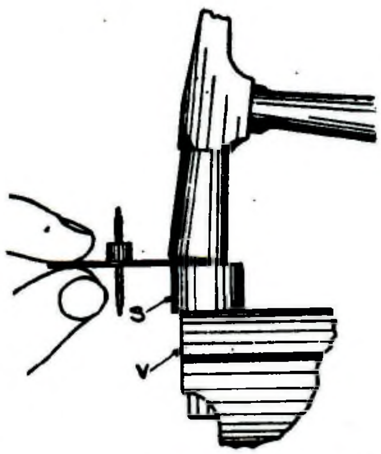
Upper Shoulder And Pivot Turned

Fig. 97



Shoulders And Pivots Turned

Fig. 98



Stretching Wheel

Fig. 95

Turning Pinion For Shoulder

Fig. 96

Finished Pinion

Fig. 99

Part 1 - What is the Dial Train of a Movement

The dial train of a watch movement, as its name implies, is under the dial of the top side of the lower plate. 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 makes one revolution per hour, which in turn meshes with the minute wheel, whose pinion engages the hour wheel carrying the hour hand, which makes one revolution every twelve hours. When the stem is pulled out the clutch pinion engages in the intermediate wheel, which meshes with the minute wheel and other parts of the dial train, as described in the previous sentence, permitting the hour and minute hands to be set either backward or forward.

No of Teeth

In calculating the dial train, the wheels and pinions may be any number of teeth and leaves, so that when the number of teeth in the wheel is divided by the number of leaves in the pinion that runs in connection with it, and the two quotients are multiplied together, the result shall be 12.

The two most common winding and setting arrangements are the stem wind 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 under the dial. A short lever or cam attahced to the lever proper disengages the winding and throws the mechanism into the setting postion. This type is required on all railroad watches.

The stem wind and stem set is operated by pulling out the crown and the setting mechanism under the dial automatically goes into the setting postion 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 attahced. The top and bottom of one winding and setting arrangement using the spring sleeve are shown in (Figures 100 & 101). The spring sleeve screws into the pendant and can be moved in or out as may be required. A one piece stem set is shown in (Figure 102)

The clutch pinion on the square of the winding stem is held against the winding pinion by the clutch lever spring pressing against the clutch lever. When thus held, the turning of the crown causes the winding pinion to engage with the crown wheel, which in turn meshes into the ratchet wheel, winding the mainspring. When the crown is pulled out, the detent pin between the shoulders of the stem is pulled up, carrying with it the detent and clutch lever, forcing the clutch pinion toward the dial train. The lower teeth of the clutch pinion engage with the teeth of the intermediate setting wheel, which in turn engages with the minute wheel and the hands can be then moved when the crown is turned.

Part 2-- Making Various Winding and Setting Parts

Winding stem:- A new stem can be made as easily without the old one as a pattern, as having the sample, as many parts of the winding mechanism are used as gauges for the various dimensions of the stem. Remove all winding parts from the movement.

Turn a piece of steel rod to fit snugly into the stem hole so that it will gauge the same diameter the entire length of the stem. (V Figure 103). The pivot is turned to fit the hole snugly under the intermediate wheel and long enough to reach to the end of the pivot hole. (X Figure 103). While the stem is in the movement, mark the location for the winding pinion and the shoulder then is turned to fit the hole in the pinion which must fit snugly to prevent it from wobbling on the stem. (Z Figure 103).

Reverse the winding pinion on the stem so that the teeth face the chuck. The headstock of the lathe has quarter divisions and sixty divisions on the index of the pulley. With the aid of the quarter division and the filing fixture, file the square to fit the clutch pinion. (Y Figure 103) The stem is reversed in the lathe and the threads are cut to fit the crown. (W Figure 103) The slot of the stem is cut with a special formed graver at the point it normally assumes in the winding position.(Figure 104) The finished stem (Figure 105) is hardened and tempered. The stem is cut now and the end filed flat but with a slight bevel to remove any burrs to fit in the thread of the crown as in (Figure 106)

Clutch lever:- Select a piece of sheet steel a little thicker than the sample and soft solder the old clutch lever onto this piece of steel. Next, saw and then file the outline of the new clutch lever to the outline of the old. When the lever is near to size, draw-file the sides as by this means any irregularity will be revealed. After the lever is made to size, drill any necessary holes. Unsolder the new piece from the old and file to the correct thickness. Harden, temper and polish.

Plate screw:- First turn a blank to equal the full diameter of the threaded part and the correct diameter for the head. Select the proper size die in the screwplate and cut the thread. After this, finish the end of the screw slightly rounded and cut off the blank allowing sufficient stock to form the head. Place the threaded part in a chuck that fits it very closely, turn the head to form and slot it with a screwhead file Harden and temper the screw.

To grind the screw head flat, select a notch in the leveling tool (Figure 107) somewhat smaller than the screw to be held. Fasten in position being careful that the shoulder of the screw rests flat against the tools. Put a small quantity of oil-stone mixed with oil on a flat frosted glass, about 3 or 4 inches square. Place the tool on the glass, and adjust the two vertical screws, until the head of the screw to be ground is level on the glass. Hold the leveling tool so that the

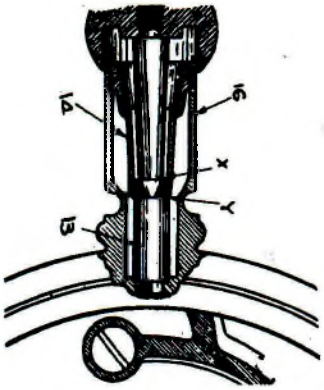


Fig. 100

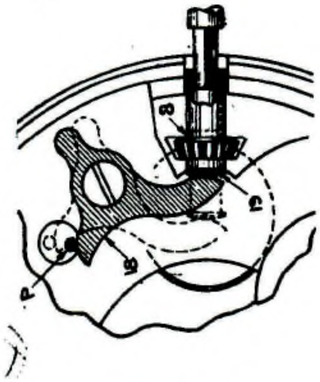


Fig. 101

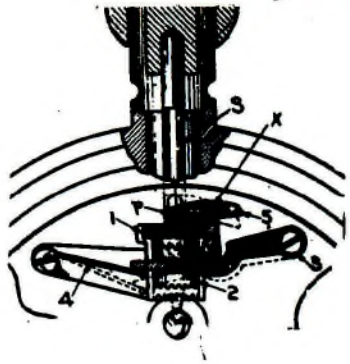


Fig. 102

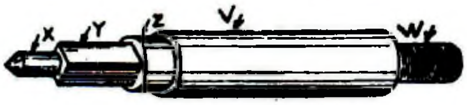


Fig. 103

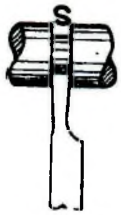


Fig. 104

Fig. 105

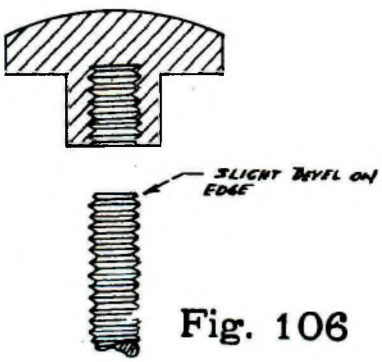


Fig. 106

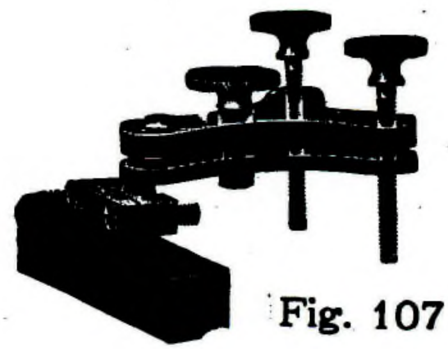


Fig. 107

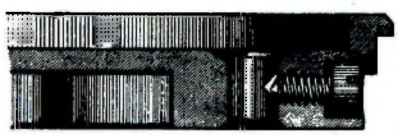
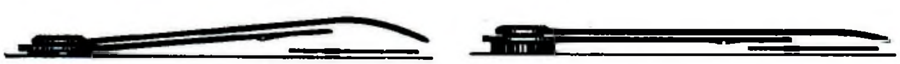


Fig. 108



Incorrectly adjusted hands

Hands after adjusting

Fig. 109

whole face of the screw head touches the glass, and grind with a circular motion. When ground sufficiently, clean thoroughly to remove all the oilstone. The screw is not removed from the tool.

The screwhead can be polished on a very fine frosted glass by putting a drop of oil on the glass and wipe it off with a clean cloth. Take a little diamantine and crush it on the glass, and the moistrue of the oil remaining causes it to adhere to the glass. Blow off the diamantine, which does not adhere and then polish the screw with very short strokes. A zinc block or a combination of 5% tin and lead makes an ideal polishing block.

Part 3 - Fit Dial and Hands

The dial is the graduated plate or disc 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. The feet haveea notch or hollow which is filed at a slightly higher level than the point of the screw. This causes the dial to be drawn downwards when the dial screw is tightened. (Figure 108)

When the dial is put on, the holes must line up with the center post and the 4th 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 should be tested to see that it is free and the endshake and sideshake correct. If the dial is perfectly flat and the hour wheel has too much endshake, check the hour wheel pipe. The top of the pipe should 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 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 with 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 should have a tapered hole to conform to the one of 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 should be 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 should be "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 4th wheel will allow.

The minute hand should be pressed down as far as possible on the cannon pinion and must be tight. This hand also should be straight excepting at the end where it should be curved down to conform to the curvature of the crystal (Figure 109). The hands then should be 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.

Part 4 - Casing

A - What is a watch case?

(a) It is a protective container or housing for a watch movement, and cases are of various sizes and shapes such as round, square, rectangular, barrel shaped, etc.

(b) It consists of (1) the bezel or top portion of the case; (2) the back; (3) a band inserted in the case for the purpose of holding the movement in place; and (4) the crystal.

(c) Cases are made principally of Platinum, solid gold, gold filled, or all stainless steel. The colors of the cases are white, yellow and pink gold. White gold is alloyed with nickel, copper and zinc, while yellow gold is made with copper, silver, and zinc. The pink color is produced by adding to the solid natural gold a greater proportion of copper than is used in yellow, and reducing the amount of silver and zinc content.

The filled gold case, which is the most widely used, is made with a layer of .003 inches of gold on the outside and .001 inch gold on the inside, with a base metal composition -- usually nickel-silver -- between the two layers of gold. The various operations performed in making cases are melting and rolling of the alloy, annealing, blanking out, rolling, soldering, polishing, fitting of crystal, final assembling and inspection.

The making of a crystal is an involved process, consisting briefly of cutting to shape, bending by heating, grinding, edging and polishing.

B - Fitting movement to case

(a) Take 6 movements from box and remove metal shells and place dial down in front of trainee. Never have more than 6 movements exposed at one time, to avoid dust settling into them.

(b) See that none have broken balance staffs or are otherwise damaged. (Return all defective movements to the supervisor immediately.)

(c) Remove the bezels from 6 cases and lay back and bezels in front of each movement. Examine each case to see that it is not scratched or marred in any manner, that the movement band is not bent, the crystal not chipped, and back and bezel free from lint or dust.

(d) Unloosen detent screws and remove stems from all movements.

(e) Determine the approximate length the stem should be and cut all 6 stems.

(f) Place stem in pin-vise and file to proper length (several tries must be made to get exactly right.)

(g) Fasten crown to stem and tighten securely by holding crown in cutting pliers, taking care not to damage the knurl of the crown. (Do this to all 6 stems.)

(h) Place all 6 stems with crowns attached into the movements, then tightly secure all detent screws, checking to see that detent is in stem slot properly.

(i) Re-examine each movement to see if anything is damaged, that it is clean in every respect, removing any fingerprints or spots with a buff stick.

(j) Place each movement carefully into back and press down on ends with buff stick or with finger when covered with tissue paper. Movements should fit in snugly and undue pressure should be avoided as this may bend the movement band or cause other damage.

(k) See that the hands are properly fashioned, so that the minute hand clears the hour hand, and the hour hand clears the second hand on strap and pocket movements. Buff the top of center post and see that there are no fingerprints or spots on the dial.

(l) Brush out the bezel and fit it to the back, observing if the bezel has sufficient snap to it.

(m) Wind the movement, carefully set to correct time and place on tray.

<u>A Few Helpful Suggestions</u>

(1) Keep the screwdrivers in proper condition and always use the correct size of screwdriver blade for the task to be performed. This will prevent broken or damaged screw heads and other marks at the screw hole.

(2) Only a case opener is made to open cases and <u>only a case opener should be used</u>. Never use a screwdriver or other tool which happens to be convenient.

(3) Never blow the breath into a watch. The breath contains moisture in sufficient quantity to cause rust or the spotting of the finish on the bridges. Always use a blower which is made for such purposes.

(4) You will observe a star (*) on the dial side of the lower plate to indicate the position of the balance wheel. When putting a movement into the back, place the end that has the star (*) in first and press down on opposite end. When removing the movement from the back, it is advisable to apply the case opener at the opposite end from the star(*) in order to avoid damage to the balance wheel.

Part 1 - The Proper Cleaning, Oiling and Re-Assembling of a Movement

1 - Remove the dial and hands, using a dial protector to avoid marring the dial.

2 - Remove the balance wheel from the movement and then from the bridge, being careful not to distort the hairspring.

3 - Release the train power by disengaging the click from the ratchet wheel, at the same time keeping pressure on the crown so the mainspring won't release too quickly, as damage can be done by letting it fly back without proper check maintained on the winding assembly.

4 - Remove the cap jewel from the balance bridge, remove the pallet fork, taking care not to damage the pallet stones and pallet arbor pivots.

5 - Remove the escape wheel and other train wheels, using the same precaution, and then the various winding wheels, barrel bridge and the barrel. Finally remove the required parts of the dial train.

6 - Scrub all the plates and wheels in the standard cleaning fluid provided for this purpose (any high grade naptha (commercial name - Textile Spirits) containing no oil or grease). A small brush is used for cleaning the plates and bridges in the cleaning fluid, but if too stiff a brush is used, trouble will be experienced with scratching the high finish. It is also necessary to follow the lines of the finish when brushing the tops of the bridges, for if this is not done, small scratches will invariably show. Dry thoroughly in selvyt cloth, brush plates and wheels, holding them in watch tissue-paper provided for this purpose. If necessary, the edges or tops of bridges are lightly polished with a buff stick, charged with rouge, before putting in the cleaning solution. (If regular cleaning solutions are not available, a simple watch cleaning solution can be made as follows: Mix together 1 ounce Oleic Acid and 2 ounces of Acetone. Then mix together 4 ounces 22% chemically pure ammonia and 25 ounces of distilled water. Now mix the first solution with the second and let stand overnight to "age". The above makes 1 quart or 32 ounces.)

7 - Peg all jewel holes from both sides, also clean jewel countersinks and flat surface of jewels with peg-wood until they are bright and shiny and all traces of gum and oil have disappeared. Next blow off with a hand blower any traces of dust that might appear from pegging; do not brush the plate again as a slight amount of dust and grit accumulated in the brush may find its way or be rubbed into

the jewel holes again. (No matter how clean the brush may be, grit and dirt will accumulate in it from the day's use.)

8 - Examine all jewels for tightness, cracks or chipped holes or flaws, such as oversize holes, unpolished holes and thrust surfaces.

9 - Clean the pinions with pith; be sure there are no defective wheel teeth or pinions and that the pivots are straight and polished and the wheels are true. Clean pinion shoulders with peg-wood.

10 -Assemble the train wheels. (Do not hold wheels by the end of the teeth between the bare fingers after cleaning, for invariably moisture will deposit on the teeth, eventually causing rusty pinions. Always use tweezers or tissue-paper.) See that all wheels drop of their own weight and that endshake is not excessive. The proper way to test the endshake in the train wheels and balance is to let the mainspring down and then hold the movement so as to look between the plates. By raising the wheels from the under-side with a pair of tweezers, the amount of play between the jewels and the shoulder of the pivots is readily seen. Never lift the wheels by grabbing one of the arms with tweezers. Note particularly the endshake of the fourth wheel, an excess of which might allow the socket of the second hand to rub against the countersink of the hole jewel, which may cause the movement to stop by drawing the oil from the jewel, and collecting dirt around itself. Also see that the fourth pivot is not bent, that it is up-right, and that the extreme end of the second hand does not touch the countersink in the dial.

11 -Where the escape wheel has a cap jewel, put a drop of oil in the center of the cap jewel before assembling the bridge then apply the same amount of oil through the hole jewel. All capped pallet and escape jewels as well as the balance jewels should be oiled before the parts are placed in position. Oil is placed in the oil grooves of the jewels and with a pointed gold pin is brought down onto the various upper and lower cap jewels. The latter is very important, as otherwise the oil is absorbed by the conical side of the pivot. The correct oiling of the jewel is assured when the drop of oil on the cap jewels is one-half the size of the radius of the cap jewels, and ifnot oiled in this manner, sometimes the oil does not work through to the cap jewels, and the result is that the pivots run on dry stones, causing a grind and, of course, pitting the cap jewel. For the purpose of retaining the right amount of oil in the pivot holes, we take advantage of a natural phenomenon called capillary attraction. If too much oil is given, the oil will fill the space to the edge of the jewel hole and it would immediately be attracted by the close space between the setting which would pull it away and leave the pivot without a sufficient supply of oil.

12 - When the job requires it, have the mainspring barrel assembled without the mainspring; try the barrel by holding the barrel arbor in a pin-vise -- the barrel must spin on the arbor and have proper end-shake and side-shake be free of bent teeth and harmful burrs, and rotate true. Assemble the mainspring in the barrel, so that the spring is free in the barrel and releases without binding all the way down. Mainsprings should be carefully oiled with a heavier oil. The oil must be placed at the bottom of the mainspring barrel, at the edge of the first coil and only so much as is necessary to slightly moisten all coils. The upper side of the mainspring is covered with just a very thin layer of oil. The arbor pivots should not be overlooked by slightly oiling them to reduce friction to a minimum. The mainsprings of small watches should be oiled sparingly because if too much oil is applied, the oil may travel from the barrel to the center wheel, to the hairspring, where it will cause erratic timekeeping.

13 -Assemble the barrel and bridge to the movement.

14 -Oil the center post and center pivots; then assemble the cannon pinion. (The cannon pinion should have the same amount of friction all around. It should not be so tight as to stop the watch when the hands are turned backwards. Note the center post endshake between the plates, as too much endshake would cause the hour wheel to rub hard against the dial at times and be a source of trouble hard to detect. The hour wheel should fit over the cannon pinion with just enough sideplay to turn freely and with very little endshake.) Oil the lower third pivot; assemble the dial train, winding and setting parts; oil all parts of the winding and setting action. (Winding parts should be oiled with a heavier grade of oil, the clutch and winding pinion teeth should be oiled and all bearing surfaces, including the square of the stem where it runs through the clutch pinion.) See that the detent screw does not work loose and the detent does not rub the lower plate, and test friction of the cannon pinion. Observe the dial train for tight spots, especially the depthing between the hour and intermediate wheels, by winding a few notches and see that the train runs down freely.

15 -Assemble the pallet fork and bridge; put a dot of oil on each impulse surface of pallet stone before the fork is assembled to the watch. It is a good plan to oil the pallet arbor pivots before placing the pallet in position because if there is small end-shake, the shoulders might not receive oil. (Special care must be observed when oiling the upper pivot of the pallet fork, which must be oiled sparingly, otherwise the oil flows under the bridge, the pallet sticks, then the motion is impeded, and regulating is impaired.) See that the fork is free and drops from one banking pin to another of its own weight without power in the train. Then observe that the fork has the proper end-shake and side-shake, that the guard pin is not bent, and the escapement is in proper adjustment. Finally test the escapement by holding the fork toward the escape

wheel while carrying it across between the pins. (An excess of end-shake in the pallet fork arbor would cause the end of the roller jewel to come in contact with the guard pin or the fork rubbing on the roller table. The play between the guard pin and the small roller should not be so great as to allow the escape wheel tooth to leave the locking surface of the pallet jewel. For this test the watch should be partially wound. Slightly bent escape wheel pivots are also a source of trouble hard to detect after the movement has been assembled.)

16 - Assemble the balance cap jewels to the plate and bridge and oil properly (as explained in item 11). Clean the balance wheel, (especially the pivots with pith, so that no foreign matter is brought into the freshly oil jewels), see that the roller jewel is tight, and assemble the balance wheel to the movement. True, level and center the hairspring, test for beat, proper end-shake and side-shake, and see that the roller jewel clears the top of the guard pin and fork horns and that the safety roller action is satisfactory.

17 - Oil the lower train pivots. (The quantity of oil needed for the train wheels is easily determined as the oil containers of the jewels permit a slight control. The center wheel pivots should be oiled before placing the wheel in position, for the pivots need to be well oiled because of their location so close to the source of power. The third wheel should be oiled sparingly, because the surplus oil may find its way to the hairspring. Never oil the pinions or the teeth of any wheels, with the exception of the escape wheel, and that only with a touch of oil on every fifth tooth.)

18 - Assemble the dial and hands, see that the dial is properly centered over the second pivot and center post, that the dial screws are tight and the dial lies flat and fits properly. In turning the hands by the stem one can see if the center post is perfectly upright by observing the distance between the end of the minute hand and the dial. This space should be the same all arougd the dial, provided that the cannon pinion fits well on the center post and the dial is perfectly flat. If not, the end of the minute hand will touch the inside of the crystal when the movement finally is cased.

19 - Make sure all the bridge screws are Tight -- this may prevent a slipping of the winding mechanism. Wipe all fingermarks from the movement, andoil the upper train pivots. Test for motion half wound and finally wind fully and set the hands to correct time.

<u>If the watch is badly tarnished</u> (one that has been in service a considerable time and probably requires repairs) <u>so that the regular cleaning method will not answer, use the following process:</u>

The movement is taken down and any necessary repairs made. Then the parts are strung on wires and cleaned in the cleaning fluid in order to remove any oil or grease. They are next dipped in a cyanide of potassium solution, rinsed in clear water, washed with soap and warm water, dipped in alcohol and finally dried in warm sawdust. Always use sawdust that is thoroughly dried and heated in order to have the work turn out bright and dry. (Be sure that no sawdust particles remain in the plates, wheels, or pinions, which may cause stoppers.)

If the cyanide will not remove the tarnish, a small amount of becarbonate of soda is placed on the brush when the parts are being washed, which brightens them considerably. Care must be taken, however, to see that all parts are thonoughly rinsed in warm water in order to remove all traces of soda, soap and cyanide before placing them in alcohol, otherwise they will tend to spot.

The small springs, steel parts and hairsprings are not dipped in cyanide. These are cleaned in the cleaning fluid and dried with a soft cloth. Of course, all pinions are thoroughly cleaned and all the pivot holes are carefully pegged and the preceding cleaning procedure followed.

It is very important to remember that cyanide is extremely poisonous and must be used with great care, and for this reason the cyanide process is suggested only when it is impossible to remove the tarnish by the regular cleaning fluid.

Part 2 - What Are the Different Types of Watch Oils?

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 through very high temperature and distillation treatments, or, in other words, it is a highly complex molecular process. Such a lubrecant will never evaporate, corrode, leave a gummy residus, or have any of the other disadvantagious characteristics of regular type watch oils.

What are the various properties or characteristics of a good watch oil

(1) <u>Chemical stability</u> - that it retains its body or makeup and will not break down in a short time under normal or adverse conditions.

(2) <u>Non-corrosive</u> - that it should 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) <u>Spreading</u> - that it has a maximum tendency to stay in one place and not spread from pivots and jewels.

(4) <u>Volatility</u> - that it has a minimum evaporation point at various temperatures.

(5) Friction - that it has a maximum friction reducing property. Oil is used in jewel bearings to redнce the friction of the moving parts and the heat caused by this friction.

(6) Viscosity - that is the degree or measure of "stickiness" or adhesiveness, and it should have suitable viscosity properties at both high and low temperatures.

THE CARE OF WATCH OIL-- Stock oil should be tightly corked and kept in a cool and dark place, as light disintegrates the best quality of oil.

RECOMMENDED TYPE OF OIL CUPS-- These should be small agate cups with covers. They should always be cleaned before putting in fresh oil and covered when not in use to prevent contamination by dust and other foreign matter. Containers should be kept scrupulously clean and frequently replenshed with new oil.

OILERS-- A good watch oiler can be made from a pinion broach or thin steel wire, having the tip flat and filed dart-shaped. The point of the oiler should be kept off the bench so it cannot collect dirt (preferably in pith). It is advisable to use various assorted sized oilers for the different types of jewels to prevent excessive oiling of the different parts.

Oiling a watch movement appears to be a simple and quick matter, but really it is one of the most important and delicate operations. For improper oiling, either too much or too little, can nullify all the good work and effort one has put into the movement to have it in first-class mechanical condition.

The jewels, both the hole and cap, must be cleaned carefully, for if any trace of old oil or cleaning solution is left on them, it will cause the oil to disappear eventually leaving a dry pivot, which can cause considerable damage.

Care should be taken not to over-oil any part of the movement, especially the mainspring, barrel arbor pivots, upper third wheel pivot, escape wheel teeth, pallet arbor pivots, and the balance wheel pivots. Too much oil is worse than too little oil.

Tests have proven that oil will last longer and be in a better condition in a movement that is wound periodically, as against one that is not. This is due to the fact that the oil is kept in a "fluid" state and will resist solidification or "gumminess."

Part 1 - What is meant When We Say a Watch is "Adjusted"?

The term "adjusted" or "adjustment" represents a near approach to mechanical perfection and the ideal of timekeeping accuracy.

A good watch usually is said to have the following adjustments: (1) Position, (2) Temperature, (3) Isochronism.

(a) Position Adjustment - A watch is so adjusted when it has approximately the same rate in its various positions, such as dial up, dial down, stem up, stem down, etc.
This adjustment is likewise "built in" by having all the parts fitted precisely so that there is a minimum of friction to overcome excessive loss when the watch is carried or worn in various positions.

(b) Temperature Adjustment - A watch is so adjusted when it has approximately the same rate in both hot and cold as well as normal room temperatures.
This adjustment is "built in" the movement by the use of conoruma, which is an alloy of nickel, steel, chromium and other metals. This produces a balance wheel and hairspring with "invariable elasticity", creating no thermal error, and requiring no compensation in heat or cold. Likewise, it is non-magnetic.

(c) Isochronal Adjustment - A watch is so adjusted when it has approximately the same rate when it is fully wound as when it has been running about 24 hours.
This adjustment is likewise "built in" the movement by having the hairspring of a certain length and the pinned ends of the coil of a certain shape. This results in having the balance wheel make every vibration, whether a long arc or a short acr, in the same length of time.

What are the three categories of watch adjusting?

(1) By timing is meant a movement is brought to time after it has been cleaned and/or repaired. A movement may show a gain or loss timing rate for a number of reasons, the most frequent being: by the fitting of a new hairspring, balance staff, balance hole, jewels, or mainspring. Such errors can be corrected in most instances by the manipulation of the hairspring and other parts or by moving the regulator or by the addition of proper timing washers.

(2) By rating is menat the rate of a movement is determined by the amount of time it gains or loses per day. A perfect rate is one in which the gain or loss is exactly the same perday. Subsequently, a good rate is one in which the gain or loss is approximately the same per day, and a poor rating is indicated by a gain or loss that varies considerably from day to day. The rating of a movement varies with its size and quality; a ladies' movement has a greater variation than a man's strap movement, which, in turn has a

greater variation than a pocket watch movement.

(3) By regulation is meant that a movement, after being cased, should be regulated to the individual wearer, as each owner has different habits, such as degree of activity, type of work, climatic conditions, etc. Precision time-keeping is substantially affected by these things.

Part 2 - Position Adjusting

Adjusting of a watch really starts with the barrel. Close position and isochronal rating cannot be attained unless the main train is in first-class condition. A correct amount of endshake and sideshake is important and all train wheel and balance pivots should be well rounded and polished.

The watch should be tested for magnetism as it is useless to attempt to adjust a watch if it is magnetized. The hairspring must be flat, true on the collet, well centered, the overcoil correctly curved and the watch "in beat".

The arc of motion of the balance wheel, when fully wound should be about 1½ turns or 540 degrees, that is, it will move 3/4 turn or 270 degrees in one direction and then return the same amount in the other direction. The arms of the balance wheel become visible at the moment it completes the arc of motion and starts in the opposite direction on its return vibration. The balance arc should be examined in all positions and if the motion is faulty in certain ones, the necessary corrections should be made before any adjustments to position or isochronism are attempted.

The impulse communicated to the balance wheel, through the escapment, should take place at the moment the hairspring is at its state of rest. An impulse delivered before the point of rest will accelerate the vibrations and one delivered after will retard them. Therefore a carefully adjusted escapment is of the utmost importance in the fine position and isochronal rating of a watch.

One of the most common causes of variation between the positions is a balance wheel that is out of poise. If the light side is uppermost when the balance wheel is at rest, the watch will gain when the arc of motion is greater than 1¼ turns and will lose when it is less. The opposite effect will be had if the heavy side is uppermost.

The hairspring must fit properly the two straight regulator pins, otherwise irregular action of the hairspring can be expected. A slight opening or closing of the pins as the case may require, will aid in bringing the horizontal and vertical postions in closer aggeement. If the regulator pins are closed and the watch gains in the pendant up position, a slower rate is obtained by opening the pins. If the pins are open and the watch loses, a faster rate is obtained by closing the pins. Opening and closing the pins also changes the rate between the long and short arcs. Leaning of the coil against one of the pins will make the short arcs fast, but if the coil is free between the pins that are slightly open, the short arcs will be slow.

Part 3 - Temperature Adjustment

In explaining temperature adjustment, it is necessary only to discuss the compensated type. The purpose of the balance screws is to provide a weight that may be shifted to make temperature adjustment. The number of holes exceeds the number of screws in the balance wheel rim as allowance must be made for moving the screws in the final temperature adjustment.

In adjusting a watch to temperature, it is run 24 hours in heat, dial up position, and then the same length of time in cold. If it gains in cold, as compared with its performance in heat, it is termed "under-compensated." This condition is corrected by shifting some of the screws to holes nearer the free ends of the balance wheel rim.

If the watch gains in heat as compared with its performance in cold, it is termed "over-compensated." It has gained in heat, because the weight is carried too near the center, thus virtually making the balance wheel smaller in diameter. In cold the weight therefore will be carried too are outward, and cause a slowing up. This is corrected by shifting some of the screws away from the holes near the free ends of the rim. As the balance wheel should always be poised before it is placed in the movement, it is of course necessary that the screws be shifted in pairs.

Part 4 - Isochronal Adjustment

Adjustment to isochronism presents other problems and tests, the aim being to obtain a rate as nearly uniform as possible throughout the entire 24 hour run of the watch that usually elapses between winding and rewinding. When completely wound and under full power of the mainspring, the vibrations of the balance wheel are larger than when a number of hours have elapsed. The extent of the balance vibrations is greater when the watch is lying in the dial-up or dial-down position, than when it is hanging or in the pocket of the wearer.

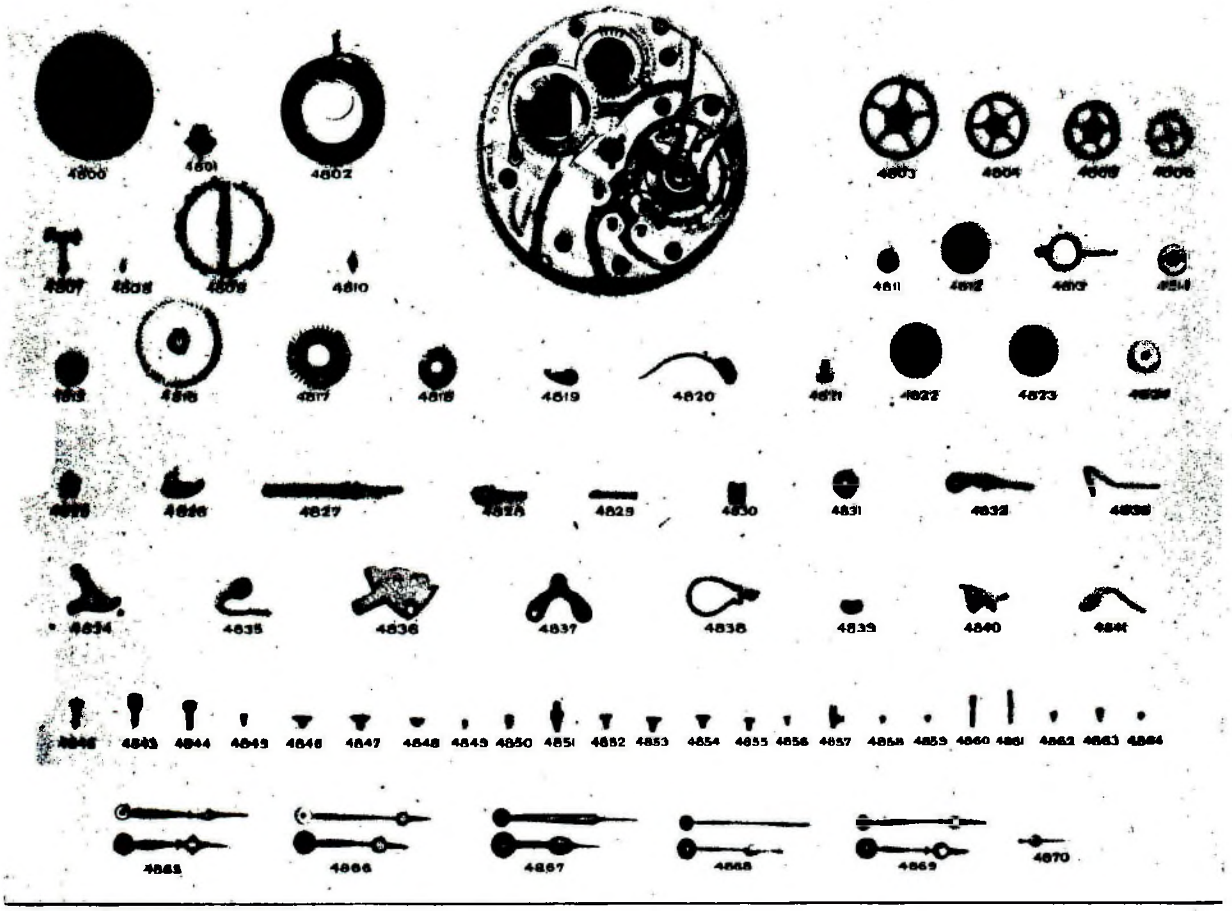
Adding to or reducing the mass of the balance wheel varies the rate of vibrations for the strength of the hairspring does not change. There are three factors upon which the time of the vibrations of the balance wheel depends. They are (1) the weight of the balance wheel, (2) the diameter of the wheel, and (3) the strength of the hairspring. In every hairspring there is a certain length in which the long and short vibrations are practically isochronal. If this length is ascertained and the hairspring is made shorter by whole coils the short arcs will go faster, and if the hairspring is made longer by whole coils, the short arcs will go slower. The shortenting or lengthening is done only by whole coils. The reason for this is if the hairspring is shortened by some portion of a coil and not by whole coils, it may cause the short arcs to produce a losing rate instead of a gaining rate. A hairspring that is practically isochronal as far as the length is concerned, usually consists of about 13 coils.

On a flat hairspring the vibrations wholly on one side and opposite the regulator pins and a similar motion takes place opposite the inner terminal. These eccentric motiongs affect the isochronism because of various conditions. The principal ones are a constant oscillation of the center of gravity, a persistent pushing and pulling at the balance pivots and the effect of torsion which is a circular impulse that takes place at the innermost coils of the hairspring. The result is a retardation or acceleration, depending on the relative positions of the two eccentric motions, as the balance wheel vibrates. The errors thus produced can be varied by altering the length of the hairspring. The rules governing this for a flat hairspring, are as follows:

When the distance between the inner terminal and the regulator pins stands at whole coils, the arcs gain. When the distance is whole coils, plus ½ coil, the short arcs lose and when the distance stands at whole coils plus ¼ or 3/4 of a coil, the short arcs are more nearly isochronal.

The duty of the overcoil is to avoid any side bulging during the expansion and to center all the coils concentrically around the balance staff. Because of the variation in the direction of the forces directed on the balance staff, as a result of the continual motion of the inner pinning point at the collet, and its relation to the outer pinning point at the stud, it is a debatable question whether a theoretically correct form of overcoil has ever been developed. However, the following rules for altering the overcoil may be used. To make the watch run fast in the short arcs, bend the overcoil in towards the balance staff. To make it run slow in the short arcs bend it away from the staff.

To alter or reshape the overcoil, the overcoil forming tweezers are used. Any alterations should be made gradually for in bending the harispring is liable to be weakened and possible broden.



VERITHIN

FIFTEEN AND SEVENTEEN
NINETEEN AND TWENTY-ONE JEWELS

SEVENTEEN LIGNE

Gruen Watch Company "Precision"

4800 Mainspring Barrel
4801 Mainspring Barrel Arbor
4802 Mainspring
4803 Center Wheel and Pinion
4804 Third Wheel and Pinion
4805 Fourth Wheel and Pinion
4806 Escape Wheel and Pinion
4807 Pallet Complete
4807½ Pallet Jewels
4808 Pallet Staff
4809 Balance Wheel with Staff
4810 Balance Staff
4811 Roller Table with Jewel
4811½ Roller Jewels
4812 Hairspring Complete, Vibrated
4813 Regulator
4814 Upper Balance Cap Jewel
4815 Lower Balance Cap Jewel
4816 Ratchet Wheel
4817 Crown Winding Wheel
4818 Crown Winding Wheel Cap
4819 Click
4820 Click Spring
4821 Cannon Pinion
4822 Hour Wheel
4823 Minute Wheel
4824 Intermediate Wheel—Large
4825 Intermediate Wheel—Small
4826 Detent—Solid Stem
4827 Winding Stem
4828 Winding Arbor
4829 Winding Arbor Plunger
4830 Winding Clutch Pinion
4831 Crown Winding Pinion
4832 Clutch Lever
4833 Clutch Lever Spring
4834 Shift Lever
4835 Detent Spring—Solid Stem
4836 Intermediate Wheel Bridge
4837 Pallet Bridge
4838 Regulator Spring
4839 Hairspring Stud Cap
4840 Setting Lever
4841 Setting Lever Spring
4842 Case Screw
4843 Balance Bridge Screw
4844 Plate and Bridge Screw
4845 Pallet Screw
4846 Crown Winding Wheel Screw
4847 Ratchet Wheel Screw
4848 Click Screw
4849 Click Spring Screw
4850 Intermediate Wheel Bridge Screw
4851 Detent Screw
4852 Detent Spring Screw
4853 Clutch Lever Screw
4854 Clutch Lever Spring Screw
4855 Shift Lever Screw
4856 Shift Lever Spring Screw
4857 Setting Release Screw
4858 Upper Balance Cap Jewel Screw
4859 Lower Balance Cap Jewel Screw
4860 Dial Screw
4861 Regulating Screw
4862 Regulator Spring Screw
4863 Banking Pin Screw
4864 Hairspring Stud Screw
4865 Steel Lance Cathedral Hands—Pair
4866 Steel Moon Hands—Pair
4867 Radium Hands—Pair
4868 Whip Spade Hands—Pair
4869 Moon Cathedral Hands—Pair
4869½ Moon Cathedral Hands, Gold—Pair
4870 Second Hands
4871 Balance Hole Jewels
4872 Train Jewels

Fig. 110

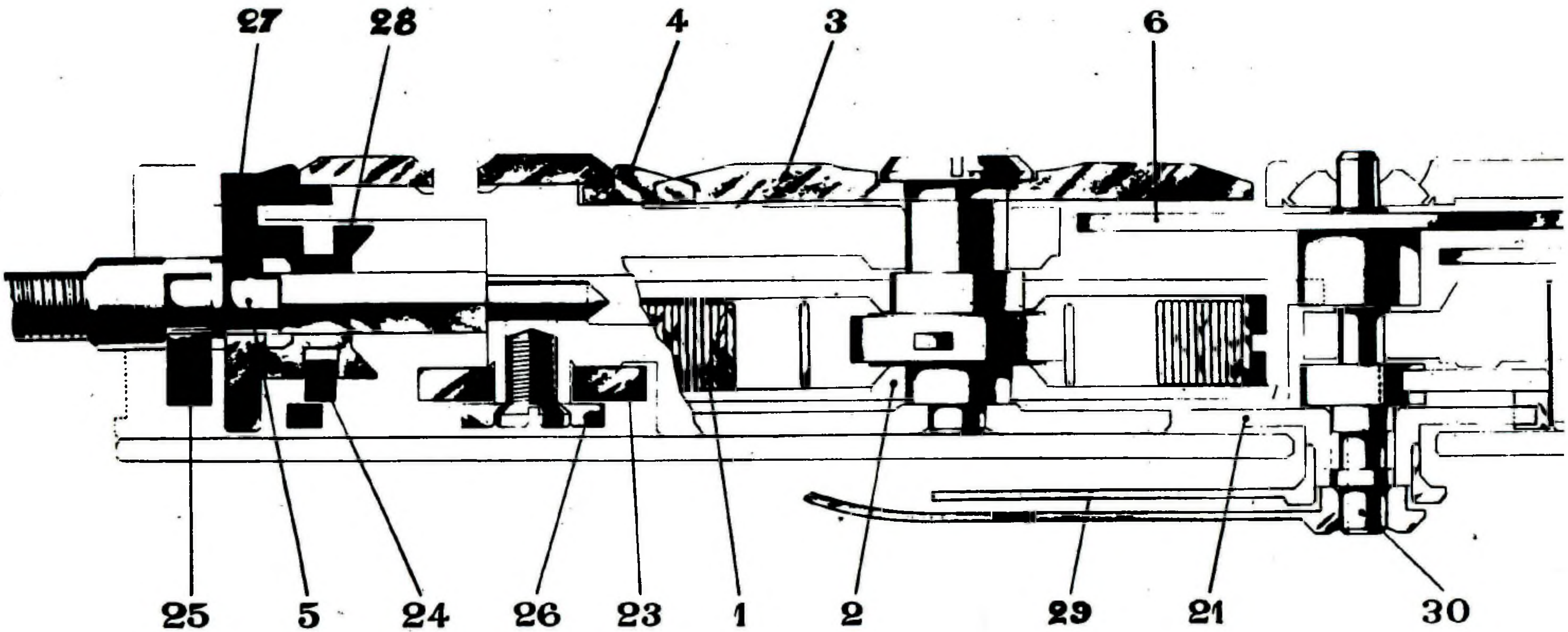
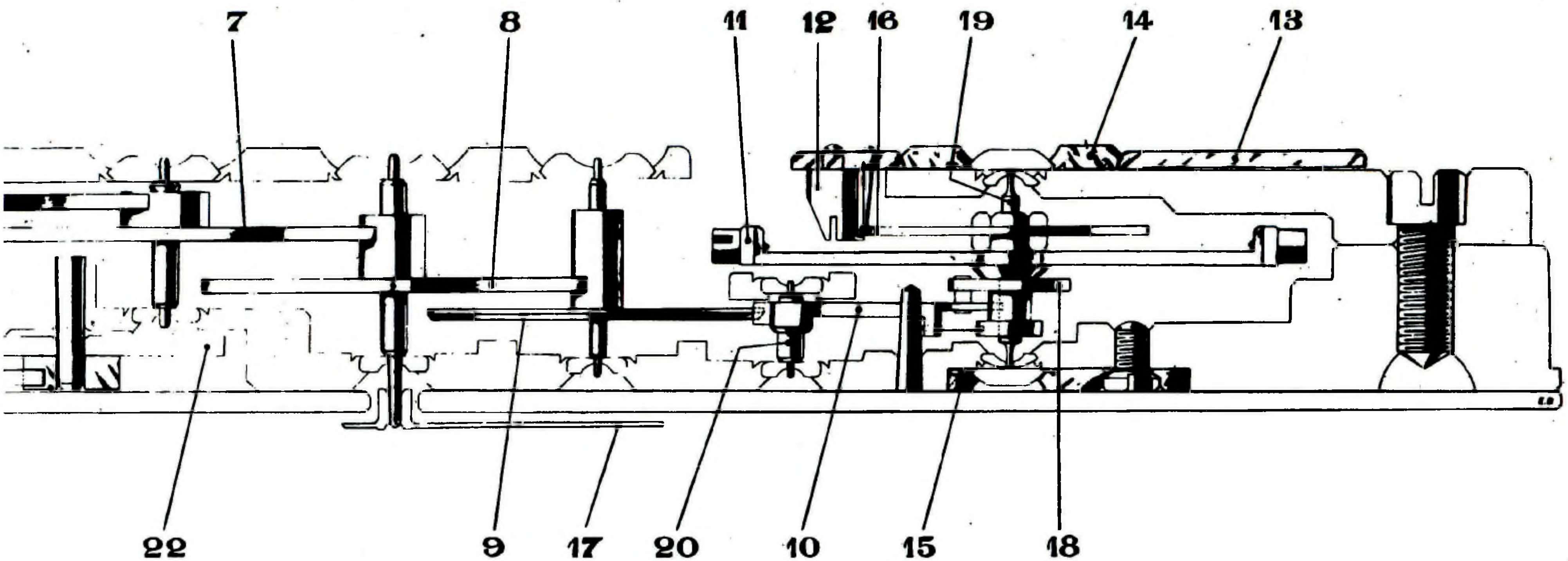


Fig. 111

1. Mainspring
2. Barrel Arbor
3. Ratchet Wheel
4. Crown Wheel
5. Winding Stem
6. Center Wheel and Pinion
7. Third Wheel and Pinion
8. Fourth Wheel and Pinion
9. Escape Wheel and Pinion
10. Pallet Fork
11. Balance Wheel
12. Hairspring Stud
13. Regulator
14. Upper Balance Cap Jewel
15. Lower Balance Cap Jewel
16. Hairspring
17. Second Hand
18. Roller Table
19. Balance Staff
20. Pallet Arbor
21. Hour Wheel
22. Minute Wheel
23. Intermediate Wheel
24. Clutch Shifting Lever
25. Setting Detent
26. Intermediate Bridge
27. Winding Pinion
28. Clutch Pinion
29. Hour and Minute Hands
30. Cannon Pinion



11

The Gruen Watch Company
Time Hill
Cincinnati, 6, Ohio
Lesson XII

Question 1: 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?

Answer: (a) A balance wheel screw that has become loosened and touches some parts of the movement in certain positions.
(b) Some of the bridges touch the case, causing a pressure to reduce the train or balance wheel endshake.
(c) Improperly aligned banking pins.
(d) The teeth of the hour wheel catching in one of the notches in the barrel cover.
(e) The socket of the second hand rubbing on the countersink of the dial.
(f) The inner end of the mainspring binding against the inside of the barrel.

Question 2: What are some of the most common faults that cause a watch to be erratic in its performance?

Answer: (a) Slightly bent or burred balance pivots.
(b) Balance not properly poised.
(c) Hairspring rubbing on balance arm or balance bridge.
(d) Magnetized.
(e) Oil on the hairspring.
(f) Loose roller jewel.
(g) Loose cannon pinion.
(h) Hands rubbing on dial or glass.

Question 3: How are broken screws removed?

Answer: The best and quickest method of removing a broken screw in a plate or any other part, is to mount the part in a lathe. If the screw is in the plate, use a face plate or cement chuck. After centering, proceed to turn off a little of the metal around the broken end, and then go after the screw with a graver as if you were to take a heavy cut -- of course, turning the lathe forward if a left-hand thread and backward if a right-hand thread. It will seldom fail to come out at the first attempt, unless it is rusted, and in that case it may be eaten out with an alum solution. The procedure for this is as follows

Place 3 or 4 lumps of alum in a small porcelain cup, which is about 3/4 full of water. This cup is supported by a small iron stand, while an alcohol lamp is placed under the cup, with the flame about 2 inches from the bottom. As soon as the threads of the broken or rusted screw are eaten out, the screw will fall out. The length of time required depends upon the hardness of the steel. Some screws will be eaten out within a few hours, while others will require as much as 6 to 8 hours, slow heat. Eating out screws by sulphuric acid is a more rapid method, but experience has proven that the acid affects the plating of the bridges and plates.

To Remove a Broken Balance Wheel Screw. To do this without injuring the balance rim, the screw must be drilled out. It is better to drill a hole smaller than the diameter of the threads, as it then may be removed without injuring the threads in the rim and a new screw will be fitted more easily.

To do this, care must be exercised to start the drill exactly in the center of the broken screw. Mounting a sharp pointed drill in a small pin vise and spinning it between the thumb and fingers will probably be found more satisfactory for this than using the lathe. After the hole is made, insert a small square broach in it until it is real tight and turn it to the right, slightly pushing on it at the same time, and the screw will at once begin to turn with it.

Question 4: What is the usual procedure used in tightening loose cannon pinions?

Answer: The cannon pinion is placed on a small broach and then pinched with a pair of pliers or a peering punch of the staking tool set. The notch is usually placed in the center of the cannon pinion, but the notching always depends upon the height of the taper on the center wheel. The notch must be so placed that it will rest just below the highest part of the taper on the center wheel post. If done in this manner, there will be no "crawling up" of the cannon pinion. (To remove cannon pinions without breaking the center post, it is advisable to use a patented Gruen cannon pinion remover.)

Question 5: How should the second hand in model #400 Gruen movement be removed?

Answer: In this movement the second hand is not fastened directly to the fourth pivot as in other models, but there is a separate pinion which carries the second hand. A bushing holds this pinion in place.

The best method to remove this bushing when cleaning the movement is by using two slender, blunt points somewhat in the shape of a heavy sewing needle. These points are inserted from the dial plate side into the holes on the opposite sides of the bushing, and the bushing can be extracted in a manner similar to that of removing hands. Caution must be exercised not to allow the points of the tools to extend too far into the holes, otherwise a tooth in the pinion may be broken.

Question 6: How can a too deep penetration of the clutch pinion in the intermediate wheel be corrected?

Answer: In diminishing slightly the beak of the detent in order to reduce the path of the clutch lever and consequently its penetration.

Question 7: What is the best method of polishing balance pivots?

Answer: A Jacot pivot lathe is unquestionably the best tool to polish balance pivots.

In polishing in a Jacot pivot lathe, one pivot is located and held in a centering arbor, such as is used in a bow lathe or in a tail stock on the bench lathe. The other pivot rests in a groove, cut in a solid hardened steel block. The burnisher rests on this block, which must be perfectly flat, with the groove straight. This should be checked, as the condition of the pivot (whether it will be straight or tapered) depends upon it.

The bow is placed on a pulley that runs on the centering arbor. One or two prongs extend from the pulley to turn the wheel or balance. The lathe is operated in the vise on the right side of the bench and right-handed workmen usually hold the bow in the left hand, and the burnisher in the right. The moving of the left hand in one direction and the right in another direction, represents the most difficult part of mastering the Jacot lathe. Practice will readily overcome this difficulty, however, and skill and speed will soon be acquired.

Question 8: What is Magnetism?
Answer: Magnetism is an ever constant and insidious enemy to horologists. The means by which a watch may be magnetized are so numerous today that it is important that the repairman form the habit of testing every watch for magnetism that comes in for regulation, examination or repair.

Since the subject of magnetism enters into the practice of horology so prominently the workman should possess a thorough knowledge of magnetism. In this connection we suggest the reading of the chapter on magnetism as given in "Elementary Principles of Physics" by Fuller, Brownlee and Baker.

Magnetized Tools and Watches--And what are the horologists' problems relative to magnetism?
First, the workmans' tools are subject to being magnetized. Punches and tweezers especially should be closely watched. Avoid placing such tools in a north south position in or on the bench.
In testing a watch for magnetism place the compass not only over the balance but also over the winding wheels. The mainspring, being subject to magnetization as well as other steel parts, has definite poles at the time the magnetic lines of force passed thru the watch. These poles are split up into countless numbers as the mainspring unwinds. This constant alteration of the relative position of the poles between the mainspring, winding wheels and the balance helps to explain the erratic performance of magnetized watches.

Theory of Demagnetization--An alternating current is that type of electrical current which changes its direction constantly and when such current flows thru the coil of wire composing the demagnetizer the poles also change. The figure shows an alternating current wave and the complete wave is called a cycle. An alternating current of 60 such waves per second is said to have a frequency of 60 cycles.
When a piece of steel rod is inserted in the demagnetizer and the flow of electricity is suddenly cut off the steel rod will be found magnetized, its poles being that of the last half cycle sent thru the wire.
Now, instead of cutting off the current with the steel rod in the demagnetizer, we leave the current on and gradually withdraw the rod, same will be polarized twice for every cycle. Thus the rod is magnetized, demagnetized and remagnetized again in repid succession while the rod is being gradually withdrawn. The result of this is that each successive polarization is weaker than the preceding one. When withdrawn entirely from the field the magnetism has disappeared.
Demagnetizing a Watch--The procedure in demagnetizing a watch is much the same as explained above. Withdraw the watch keeping it central with the opening and giving it a slight twist after leaving the opening. Continue the withdrawal until watch is

about three feet from the demagnetizer. If the first attempt fails to remove all magnetism repeat the operation.

<u>Question 9: What is the proper method to remove broken pallet arbors?</u>
Answer: To remove the broken pallet arbor, put the fork on the staking tool with the top or polished side down, and with a small pointed staking punch, tap on the arbor until loose. Then with a sharp pin, the arbor can be pushed out readily.

To replace the arbor, hold the fork in the left hand and with the new pallet arbor in a small sliding pin vise, the arbor can be inserted with a twisting motion, The final operation is to tap the arbor securely in place with the proper staking tool punch until the conical part of the shoulder is just flush with the fork.