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Watch and Chronometer Jeweling

— THIRD EDITION —

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Horological History

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Chapter 1

Peculiarities of Gems Used in Making Jewels

The whole subject of jeweling is well worthy an article, both in a scientific and mechanical sense, whether we consider the delicacy of the operations or the intractable character of the material operated upon, for there has been no improvement in the horological trade of more importance to accuracy and durability of timekeeping.

The substitution of stone for common brass or gold bearings was prompted by the inevitable wear of the holes from frequent cleaning, and the abrasion of the pivots, produced by the accumulation of dust with viscid oil; the pivot being cut away or the hole opened too large. So long as the verge and cylinder were the prevailing escapements, the necessity for jeweling was not so strongly felt, except in the balance holes. The introduction of the lever escapement brought with it a better watch, capable of more accurate time, but demanding an improved construction.

An Italian, in 1723, first introduced the practice of using stones for bearings. He not only conceived the idea, but was successful as an artisan in making his own jewels. Ingenious and skillful as he was, however, he encountered obstacles almost insurmountable.

The art of cutting gems, it is true, was at that time well understood, but no one had attempted to drill a hole in a hard stone fine enough for a properly sized pivot. The watches at that time that were jeweled could boast of nothing more than the balance holes, and they were not pierced to let the pivots through.

It is a very difficult matter to polish a taper indentation in a stone, even with modern appliances, in consequence of the tendency to create a tit at the bottom, thus throwing the balance staff out of upright. The difficulties in the then state of knowledge retarded the general introduction of stone work for many years. The Swiss, however, seeing the advantages derived, finally struck out the various manipulations with success. Time and experience gave more skill, and at the present time it is impossible to find a Swiss watch, even of the cheapest class, that is not jeweled in at least four holes. The English trade adopted the art later; but even then it did not become general for many years. Within a generation, only fine English watches were jeweled.

The mere substitute of a harder substance was not the only improvement; other conditions necessary to accuracy were insured. The hole could be made *round,* the material of such a character that no chemical action could be effected on the oil used for lubrication, and the vertical section of the hole could be made so as to present the least amount of frictional surface, yet still giving a perfectly polished bearing, thus avoiding the cutting of the pivot. The whole “modus operandi,” from the stone in the rough to the last setting up, is well worth the attention of the watch repairer. Of the materials used, the first and most important is the diamond, used only in the time-piece as an end stone, but all important as the means of making the other jewels. The diamond possesses the requisite susceptibility of polish, combined with great hardness; but this adamantine quality precludes its being pierced with a thorough hole. When chemically considered, the diamond is pure carbon; its different varieties differing only in structure, common charcoal its lowest, plumbago[1] its intermediate grade. Another variety called the “black diamond,” or “diamond carbon” occurs, which is interesting as being a parallel with emery compared with crystalline sapphire. The form of diamond most in use for mechanical purposes, is almost always crystalized; yet it will be seen that the agglomerated form of diamond carbon plays no unimportant part in jeweling. As a jewel, no use is made of the diamond other than as an end-stone. Marine chronometers, in which the balance will weigh from five to nine pennyweights, are almost invariably furnished with a diamond end-stone, set in steel. Yet, hard as the substance is, the pivot will often cut an indentation in its face. The cause of this apparent anomaly is to be found in the structural character of the gem, and its value. The lapidary, saving in weight as possible, does not care in “Rose Diamonds,” to pay attention to the lines of cleavage. If the face of the stone makes a slight angle with the strata of the jewel, there occurs innumerable small angles of extreme thinness. The pivot, coming in contact with any of these thin portions, may fracture it, and the fragment, becoming imbedded in the tempered steel pivot, becomes a drilling tool. In our experience we have had marine chronometers sent for repair that have lost their rate so much as to become utterly unreliable from this cause alone, the pivot having produced an indentation of the stone, creating more friction, and thus destroying the accuracy of the instrument.

As a general rule, the rose diamonds sold for this purpose are sufficiently good for general work. In a very fine watch or chronometer the stone should be selected with reference to its polish on the face, and its parallelism in the lines of cleavage. The diamond, however, gets its importance from being the only agent we can use in working other stones. Without it the whole art of jeweling would be impracticable. The various steps are all connected some way with the diamond in its different shapes. “Bort,” the technical name for another variety, is merely fragments of the stone that have been cleaved off from a gem in process of cutting, or gems that have

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[1] Archaic name for graphite.

been cut, but found too full of flaws to become of use for ornamental purposes. This "bort" is used as turning tools, the larger pieces being selected and "set" in a brass wire and used on the lathe in the same manner and with the same facility as the common graver. For tools, even, the diamond is not of equal value; a pure white and crystalline in structure generally being too brittle (though hard) to endure the work. Among the workmen, the "London smoke," a clouded, brownish stone, is most prized. It possesses the two-fold qualities of toughness and hardness.

Another form of "bort" comes in the shape of a small globule—sometimes the size of a pea. It is crystalline, and when fractured generally gives very small pieces of a needle shape. These are carefully selected, and form the drills with which the hole-maker perforates the jewel. These drills, when found perfect for soundness, form, and size, are very highly prized by the workman, as the choice of another, together with the setting, will often take a vast deal of time and labor.

"Bort" is also used in the making of the laps or mills, with which the jeweler reduces the stones to a condition for the lathe, and subsequent processes. For this purpose such pieces as are not fit for cutting tools, or drills, are selected. A copper disk, having been first surfaced and turned off in the lathe, is placed on a block or small anvil; each piece of stone is then separately placed on the copper, and driven in with a smart blow—care being taken that no place shall occur in the disk that does not present, in revolution, some cutting point. It would seem impossible to retain the diamond fragment, but it must be remembered that the copper, being a very ductile metal, receives the pieces; the first rubbing of a hard stone then burnishes the burred edges of the indentation over every irregular face of the diamond, leaving only a cutting edge to project. The rapidity with which such a lap, well charged, will reduce the hardest stone, is somewhat marvelous. It is the first tool used in jeweling, and so important that a more detailed and explicit description of its make will be given when the process of manufacture is treated upon. Diamond powder is equally as important as "bort," being used in nearly every stage of jewel-making. The coarsest charges the "skives" or saws used for splitting up the stones. These skives are made of soft sheet iron, and act on the same principle as the laps. The finer grades, in bulk, resemble ordinary slate pencil dust very much; indeed, the latter is often used as an adulteration. This powder is not uniform in fineness, and the jewel-maker is under the necessity of separating the different grades. This is effected by a simple process, called "floating off," and is conducted as follows: A certain quantity of powder, say a carat, is put into a pint of pure sweet oil, contained in some such shallow vessel as a saucer. Depending on the fluidity of the oil, the mixture after being thoroughly incorporated, is allowed to stand undisturbed for about an hour or an hour and a half. During this time, owing to their greater gravity, the largest particles are precipitated, leaving held in suspension a powder of nearly uniform fineness. The mixture is now carefully decanted into another similar vessel, leaving the coarse powder at the bottom of the first. This coarse deposit is denominated No. 1, and is used for skives, laps, and other rough purposes. The decanted mixture in the second vessel is allowed to remain quiescent for twelve hours, when the same operation is performed; the third vessel now contains most of the oil, together with the finest particles of powder.

The precipitate from the decantation is the ordinary opening powder; the finest being for polishing both the holes and outside of jewels, and giving the final finish to the faces of pallets, roller pins, locking spring jewels, etc.

The good workman is careful to keep the powder in this condition as free as possible from any extraneous dust, and above all, to preserve the different grades from any intermixture, as a small quantity of a coarser grade would destroy a finer one for all its purposes, and the process of "floating off" would have to be repeated.

The most important stone in jeweling, the diamond, becomes more of an agent of the manufacturer than an object.

Properly, for jeweling, the ruby and sapphire are pre-eminent; inferior only to diamond in hardness, possessing a sufficient degree of toughness, susceptible of an exquisite polish, these stones are the favorites of the Swiss, English and Americans for all high class work. The Swiss, however, use them indiscriminately in all watches.

The ruby proper is of one color, but in its varieties of intensity may change to a very light pink. When still lighter, it is ranked as a sapphire, which comes in almost every possible color and shade, from ruby to a perfect transparent colorless crystal. This stone differs in degrees of hardness and capacity of working. The hardest being a greenish yellow, in the shape of pebbles, with very slightly rounded edges, difficult to work, but forming the strongest and most perfect jewel known.

It must be remembered that this description gives the value of the ruby and sapphire as a material for jeweling only. For ornamental jewelry, the value depends on the color, of the most intense ruby, or blue for sapphire, together with brilliancy and weight. The ruby and sapphire are formed on an aluminum base, the common emery being another form of structural arrangement, but of the same chemical constitution.

These stones possess every quality to make them the base of perfect jeweling; and still the chrysolite[2] is equally in favor with most watch jewelers. It is not quite so hard, but it is more easily worked and cheaper in price, and it would be difficult to see wherein it is inferior to either the ruby or the sapphire. It has a yellowish tinge, verging to the color of the olive. As a stone for jewelry, it is not fashionable, and only in Persia is it valued. There are, however, some very strong objections to its use by the

[2] Archaic term referring to any of several yellow or yellow-green colored gemstones, including: topaz, chrysoberyl, peridot, etc.

workmen; it is not uniform in hardness; in polishing it will drag, that is, the surface is liable to split. Unfortunately the eye is unable to detect the fault before working; it is found only when much preliminary time and trouble has been expended. It is susceptible, when good, of a perfect polish, and is much used in chronometer jeweling. “Aqua Marine” is a brother to the emerald, differing from it only in intensity of color, and compared constituents. These two gems are the only ones in which the rare metal glucinum[3] has been detected.

It is extensively used in the American watches and English watches. The Swiss never use it. It is soft, not much harder than quartz, but comes in large pieces, perfectly transparent, and of a color which is that pure green of sea water, from which it takes its name.

The garnet, in English watches, plays an important part for pallets, also for roller pins; a very soft stone, but very porous. When set in the pallet with a pointed toothed wheel, it is apt to act as a file, its porosity cutting the end of the tooth. This may be detected in any pointed tooth by observing the color of the back of the tooth; “black vomit,” it is sometimes called. Most of the garnets used are Oriental stones, the best quality coming in bead form, the holes having been pierced by the natives. The cost of piercing the stone in Europe, or here, would be far above its value. The Oriental is the best for horological purposes, though Hungary and Bohemia furnish the most highly prized stones used for ornamental purposes; indeed in some German towns the cutting and setting of the garnet is a specialty, giving employment to a large number of people. And, strange to say, the best market for their sale is the United States. This comprises about all the stones used in watch and chronometer jeweling. Yet in clock work, the pallets are generally jeweled in agate, a stone not at all suited to the purpose, it having, even in the best specimens, a decided stratification that prevents a uniform surface being formed by any process. The carnelian form of the agate is not open to this objection, and makes capital bearing for knife edges of fine balances, and compass stones for centers of magnetic needles. For watch or chronometer purposes, the only really useful stones are sapphire, ruby, chrysolite and aqua-marine —all possessing peculiarities that deserve some remarks, as they are of the utmost importance to the hole maker.

The sapphire is the hardest stone, next to the diamond, and yet specimens can be, and are found, so soft as to drag in polishing, Again, if stratified very clearly, they will “fire crack” in opening the hole. The ruby is more uniform in its structure, and is more highly prized on that account; its hardness being all that is necessary, while its susceptibility of receiving a high polish is equal to that of the sapphire. The aqua-marine is always uniform, and may be polished both externally and in the hole with

[3] Archaic term for the chemical element beryllium.

"tripoli," saving something in diamond powder in the process of making. In our estimation, however, the chrysolite is the most valuable of all the stones for jeweling.

These stones form the general stock by and from which jewels are made. The details of the various manufacturing manipulations, the tools used, also the setting in the work, together with other matters of interest, descriptive of the art of jeweling, will be found in the next chapter.

Chapter 2

Requisite Tools, and How to Make Them

In considering the making of the jewels from the various materials enumerated, the reader must bear in mind that much detail, and perhaps repetition, is unavoidable, if the description is to be of use in the practical sense to the artisan, the whole process being made up almost entirely of littles; and any essay on it would be incomplete were we to neglect the little things. With the close of the last chapter we had arrived at the manipulations, which we now propose to consider. In order to give some system to the descriptive part, we will take up the subject of the tools used by the jeweler, which are comprised in the following list: First, and most important of all tools, is his lathe; no very complex affair, comprising simply a headstock, and a mandrel (well-fitted), a common T rest, a driving-wheel, with stand and its band, and a treadle hung on the outer end and connected with the crank by a leather strap. It is not a very formidable tool, nor is it easily deranged; but in very fine and delicate manipulations it is essential that considerable care should be exerted to keep the mandrel in such condition that it is immovable in a vertical line, yet is left perfectly free to revolve with the greatest ease, for one of the greatest requisites is speed. There are three varieties of the jeweling lathe, but not different in principle. In fact, a Moseley lathe can be used to the best advantage, as it combines all the excellences of the English and Swiss jeweling lathes; as a matter of course, the prime necessity in each is rapid motion. To accomplish this, the driving-wheel is usually of large diameter, but light in weight, as it is necessary to control its motions with ease and speed. The alcohol lamp is a most important adjunct to the lathe, it being what the screw wrench is to other lathes.

The tools that pertain to the lathe proper may be summed up as the skive, lap and chucks; the lap was described in the first chapter, and it only remains to treat of the skive and chucks. The skive is nothing more nor less than a circular saw, or nearly a lap; only the thin edge is used in place of the face. It is made from soft sheet iron, planished up true, but slightly dishing, and is clamped on an arbor between two flanges, which are held together by means of a screw and nut on the arbor. The object of the dishing is to render the part left exposed outside the flanges rigid, so as not to "buckle" when the charging process is being done, or by the pressure when the stone is being cut. Except in the factories, the skive is not much used by the jewelers, their lathes being too small to permit an economical use of the instrument. The lapidary uses it extensively, as he has sometimes large stones to slit. The charging of a skive is a simple operation, yet requires some skill to effect a good result.

After having trued up the plate, both as to center and plane of revolution, the arbor is set in motion at full speed; a small quantity of coarse diamond powder in oil is taken up in the hollow of a quill, cut something like a tooth-pick. Having a piece of carnelian in one hand, the operator presses it with a gentle degree of force against the edge, and with the other hand he applies the powder as near the stone as convenient, which becomes attached to the edge of the skive through the viscidity of the oil, and is carried along on the edge until it comes under the piece of carnelian; the pressure of the stone imbeds the particles of the powder in the soft iron. The use of the quill is suggested from the fact that its shape is all that could be desired, while its elasticity could not be equaled in any other way. After two or three revolutions, the skive begins to cut the carnelian used as the burnisher; that is of no importance, for a new spot on the face of the carnelian with a fresh charge of the powder, will generally charge the edge with diamond sufficient to do a large amount of work. The object to slit is held to the edge of the skive by the lapidaries in their fingers, but the small stones used by the jeweler are cemented on the end of stick, and thus can be applied to the cutting edge with facility, the skive being kept well oiled during the operation of slitting. For jewelers' purposes the chucks are nothing more nor less than short pieces of brass with a screw on one end to join it to the mandrel; it is placed in the lathe as true as possible and then turned off with a common steel engraver to any form and dimension.

So much for the lathe and its adjuncts; it would be useless, however, without the two important bench tools—the diamond cutter and the drill; these are made the same way, the only difference being the size and form adapted to their different uses. To make a cutter, the artisan selects a fragment of "Bort" of the size desirable. The form, as a matter of course, being that which presents the best cutting edges and adaptability for being firmly set in the stock, which he proceeds to make in this manner: Taking one of his chucks, he anneals it by heating it red hot and plunges it in cold water, then places it in the nose of the mandrel, turns it off true and drills a hole in the end, large enough to receive the "Bort" and deep enough to enable him to have stock enough to hold the diamond. The outside of the chuck is now turned down with a neck just back of the bottom of the recess, tapering the end of the chuck from the bottom of the neck outward to the end; the piece is now ready to receive the cutter, which is placed in the recess in such a manner that it will be larger in the hole than outside; the operator then, with a pair of pliers, pinches the two sides of the end together on the diamond, the soft-brass yielding and taking the form of the "Bort" in the pinching, the whole form of the end of the chuck is changed; it is elongated on each side of the diamond, and by pinching with a pair of pliers these elongations, it will be obvious that the stone is bound on the edge of the setting almost as if it were a piece of soft wire twisted around the cutter; the rough parts are trimmed off with file, the rest of the chuck turned up to suit the taste of the workman. For additional strength, it is sometimes soldered in with silver solder, which fills up the crevices, and thus forms a solid bed for the diamond. The drill is made precisely the same way, the only difference being in size and delicacy of manipulation.

The miscellaneous articles are such as are generally used on the watch bench, such as pliers, files, gravers, etc. He uses also pieces of iron and copper wire, and of lead in the shape of short cylinders, also glass plate for facing, and boxwood for various uses.

Chapter 3

Shaping and Polishing the Jewel

The watchmaker is well aware that there are two forms of a jewel; one commonly called a plate hole, where the end shake is made by the shoulders of the pivot, another where the shake is effected on the ends; the latter being accomplished by an end stone. As the process is about the same for both, we will take a common plate hole for an illustration of the making, promising that the description will be interrupted frequently by the necessity of explaining some process to which allusion may be made. A piece of stone, say aqua marine, is selected; if large, the jeweler may slit it up by means of the skive, but generally it is broken into fragments; these are sorted for the different sized jewels it is desired to make. The workman fits his lap on the lathe, and taking a fragment he holds it against the face of the lap, the end of the finger being protected by a piece of cloth, which is also useful in wetting the lap, as it must not be allowed to get dry during the operation. In a short time a flat face is produced on the stone; so far but little skill has been exercised, but it is necessary to make another flat parallel to the first; for the object of the whole proceeding is to reduce the broken fragment to a plate of stone, just the thickness of the intended jewel, but this is a nice point in the sense of feeling, as the stone is completely hid by the finger and cloth while being operated on by the lap. Practice alone can enable one to do it with exactness and rapidity; a few hints, however, may lighten the task. The finger may be pressed on any side of the stone being cut; the lap then will cut faster on the side of pressure, and thus a wedging piece may be brought parallel. The experimenter must work very cautiously, not in a hurry, but examining very often the condition of his work and correcting as he goes along. The piece having thus been reduced to a small slab of stone, irregular in form on the edges, it must be rounded as near a circle as the eye can judge and the means allow, which is done by means of a pair of pliers nicking off the projections until a small circular disc is formed. This is now in a condition to go on the lathe to be turned in the shape as seen in Fig. 1 in the plate.

Figure 1

Now commences the first operation on the lathe. A chuck is first turned up in the manner illustrated by Fig. 2; the neck there shown is of essential service, as it allows the end to be heated by a small flame as the conduction backwards toward the lathe is prevented in a great measure; the hollow in the end of the chuck is made in order to insure and get a bearing surface for the object. The chuck having been formed, the operator sits at the lathe in such a position that he can reach his left arm around to the back of the lathe; he now with the lamp, gently moving the end of the chuck, touches it frequently with a piece of gum-shellac, and when warm enough the gum will flow over the face of the chuck; the stone is now held over the flame long enough to warm it, and placed against the face, and the flame delicately applied until the piece is centered to general truth. It must be observed that the less shellac applied the stronger will be the cement, therefore a pressure must be exerted against the flat of the stone while adjusting it to the center.

Figure 2

The work is now left to cool, which it does very quickly, and is then ready for turning off. This is done with a diamond cutter—both the cutter and the stone being kept wet. The outside edge is turned round, and a slight chamfer made with the cutter on the face corner. The stone is now ready to drill half way through from the face side. This drilling requires a few words, as it is a very important part of the performance; the size of the drill, and the truth of the center being the most particular parts in any jewel. While the lathe is running, the operator presses his drill against the exact center of the stone; it is easy to say he does it, but it has required of him much practice and many broken drills to acquire the tact to discern the accurate center and plant his drill so that no eccentric motion of the drill can be observed when the lathe is in motion. Again, much judgment must be exercised to drill the hole just deep enough to meet the one to be drilled from the other side in the center of the stone after the oil cup is turned out. The hole being drilled from the face, the piece must be turned on the chuck; this is done by warming the shellac, taking off the stone, and putting the face side against the chuck, observing the same precautions as before.

A new process of centering now obtains our consideration. Before, we merely observed the general truth; now absolute truth is required. The chuck is warmed until, as before, the stone glides easily over its face; then the rest is fixed near the work, and while the lathe is revolving slowly, a piece of stick or the points of the tweezers are gently brought up to the outside edge of the stone; if it projects from the center on any side, the high side will be rubbed in towards the center, and a few turns (if the operation be conducted gently) will bring the circumference of the work again in the same center as it was before being reversed on the lathe; if it is true, it follows that the hole now out of sight is also in the center, for the hole and the outside were concentric.

There are what are called the convex and the concave; these are now to be made; the convex is generally turned up first, and it is important for success that it should be nearly true, as it may bother a great deal in forming it up for polishing. The oil cup is now to be turned in, which operation is generally done with a smaller diamond cutter; the same precautions given for the large surface must be observed, but there is a greater difficulty in the operation. This difficulty is caused by the tendency of the cutter every once in a while, to run over the center when the bottom of the oil cup is being made, thus creating a tit which is fatal to drilling, as it throws the drill out of center. The drill is now put in until it reaches the corresponding hole from the other side; the form of the hole which is now pierced through, is in section of the form represented in Fig. 3. The jewel, now in a rough state, is in a condition to be brought to a uniform surface on both the convex and concave, for the diamond tool has left rings, and in turning by eye a perfectly true form has not been obtained. This process is effected, first, by a sort of a "former," which consists of a piece of brass wire of a diameter considerably greater than that of the jewel; in the end of this wire a concavity is cut, somewhat larger than the convexity of the jewel; some coarse powder being placed in the concavity, it is applied to the stone on the chuck. It is apparent that if held directly against the stone in the center it would affect only the top of the convex; a lateral motion is given to the former, so that in the course of a few revolutions of the lathe it has acted on every part of the stone, and in a very short time the surface of the convex will become uniform and of true shape. The oil cup is treated in a similar manner, save that the former is convex on the end.

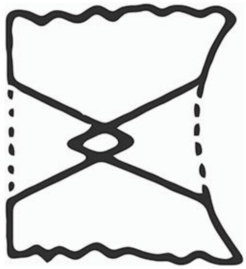

Figure 3

The polishers for all stones as soft as aqua marine are made of lead, used with tripoli and water. This tripoli is a mass of shells, and is exceedingly sharp until it becomes rubbed fine by the friction of the stone on the polisher; then it is capable of producing a very superior polish. The polisher is made of a small piece of lead wire, say an inch and a half long, and of about the same diameter as the jewel, or generally somewhat larger; the end is filed off flat and a concavity formed in it, but as the lead is soft, the workman merely takes the point of a knife or graver and cuts out a conical cavity, as on application to the hard stone the lead will be forced to assume a circular form. The tripoli having been mixed up with water, the polisher is dipped in the mixture and then applied to the surface to be polished. The friction between the stone and the polisher (for the speed must be great), soon heats the stone, and if persisted in, it would soon melt the shellac, and thus take the work off the lathe. To avoid this the polisher is held on but a few seconds at a time, the surface of the stone wiped off and examined as to progress. After a few applications the stone will begin to obtain a semi-polished condition, and at this stage the operation will be accompanied by a very peculiar squeal (it can be called nothing else), the indication that a polished surface is being attained. At this point the water dries very rapidly from the tripoli, and increased care is needed to avoid overheating the work. The object being to obtain a highly polished surface and truth combined, the process must be discontinued as soon as the polish is uniform, for then the stone has a true convex, parallel in all its diameters to the face. The oil-cup or concave is treated precisely like the convex, a reverse polishing tool being used, and the convex end of this is generally filed with a coarse file, being held and rotated in the fingers of the left hand. The file marks are of service, as they receive the tripoli, and thus enable the polisher to more firmly hold it. The hand is kept moving in a backward and forward elliptical direction during the whole time; for if the polisher were to remain quiescent, creases would be formed, and thus render a good polish unattainable. When a very superior job is to be done, a piece of box-wood is used, the grain end having been formed to match the stone, either on the convex or in the oil-cup. The slight chamfer on the face of the jewel is now polished with a slip of lead and tripoli, and the stone is ready to be removed from the lathe, to be topped and faced. The oil-cup meets the convex in a sharp edge, and is generally ragged after the polishing of those two surfaces. The roughness is remedied by facing, a process applied as well to the flat surface. The means employed are various, some jewelers preferring one, and others different methods; but the general principles are alike in all cases. There may be used a flat piece of boxwood, planed on the end of the grain, with the finest variety of diamond powder. This is very effective, and is open only to the objection that the powder is wasted, as it is absorbed into the wood. A plate of a mixture of lead and tin—say half and half—is scratched with a coarse file, and tripoli used as a polishing material.

The jewel is laid flat on the metal and tripoli, and rubbed about with gentle pressure by means of a pointed piece of peg-wood placed in the hole, care being had to keep the jewel revolving and changing its position as much as possible. When the tripoli is about dry on the plate the stone will be found polished, but it must be examined at short intervals during the process. This way of facing seems simple and easy to accomplish, but it will be found to present some few difficulties, the greatest one of which is the liability of the surface to *drag*—that is, small fractures of the face will be torn out, and then the stone has to be faced on the lap again before it can be polished. This is to be deprecated, as the refacing almost invariably throws the jewel out of true with the convex, besides making the finished jewel too thin. The best method for both the ring on the top and the face of the jewel is that in which a glass or stone face, with diamond powder, is used. As the glass or stone faces are of great importance in subsequent metal operations, a very minute description of the mode of preparation will not be out of place, especially when it may be asserted that there is no process so rapid or satisfactory in its results for polishing the flats of steel work. The workman selects three plates of glass—plate is preferred, as it affords a truer surface; but a better choice is to select two pieces of, say the glass plates used for Daguerreotype purposes, and another piece of hard lime glass; the reason for which preference will be seen. Two of the plates are rubbed together with emery, of a grade of about 60 at first, finishing with a grade of 80. The surfaces must be ground until a uniform appearance is obtained. In all cases the grinding plate should be frequently turned around in every direction, and changed from its course at every stroke, as thus only uniformity of surface can be produced with truth. One of the plates is now taken for a grinder of the hard plate; this last must have been ground previously to as near a true plane as possible, which may be effected on a plate of cast iron, with sharp sand, or No. 20 grade emery, with water. Between the hard and soft plate, emery of 90 grade is used, and the grinding process is continued until the hard glass has a perfectly uniform surface, but it will be found that the grain of the lime glass is much finer than the other plate, which, in its turn is coarser than the plate that has been laid aside. Could we obtain glass of three unequal degrees of hardness, a better polishing-plate would be obtained. However, we have now three plates of different degrees of fineness. It may be of advantage to reduce the finest plate still more by the use of another piece of glass with the finest washed emery. The coarsest plate is of no advantage to the jeweler, but may be used by the watch repairer for reducing his flat steel work to a fine gray, with a perfectly true surface, by the use of Arkansas oil-stone dust and oil. After washing the oil-stone dust from the piece of work it may be transferred to a second glass, using sharp or crocus, with oil; this will give the steel a fine face, with a peculiar—apparently pellucid—polish, but of very fine uniformity. Again washing (cleanliness is all important in polishing), it is taken to plate No. 3, which will, provided the surface be perfectly clean, give a polish without any polishing substance; but should an exquisite black polish be desired, well levigated[4] rouge, mixed with alcohol, should be used. The ease with which steel can be polished by this process, and the cheapness of the apparatus, recommends the method to any watch repairer. He must, however, be sure that, before using, the plates are free from dust of any kind; and in order to render the finest plate perfectly clean, it should be well washed with alcohol, and wiped dry with a very soft clean cotton cloth. The stone surfaces are prepared in somewhat the same manner as the glasses. There should be selected two stones—say the carnelian red, such as were some time ago favorite stones for breast pins—and any other agate of another color, no matter what—the only care being that both are uniform, with no striae[5] or lines of cleavage. These stones are very low priced and easily obtained, and are generally so true that but little labor need be expended in facing up. The difference in the color is important only from the fact that the two will almost invariably differ in hardness. These two stones are first to be faced down to a true surface on a piece of cast iron, with No. 20 grade emery, with water, then the two may be ground together with a very fine grade of emery until they touch in every part of the two surfaces; they are then finished with No. 2 diamond powder and oil. One of these stones may be used for facing and topping jewels; the other, for polishing brass settings, as will be described when we come to the metal department of jeweling.

In topping, the stone is laid on the finest glass, with a small quantity of the finest diamond powder, and held by a pointed piece of peg-wood in the hole. The wood must not touch the plate, and must not enter the hole so but that it can have perfect freedom of motion. A few circular strokes, combined with straight lines, will develop finely defined circular flat on the top of the stone, having a polish superior to the rest of the surface. The jewel is now turned on the same plate, and the face polished in the same manner. It need not be stated in lengthy terms that the higher polish the face of the jewel gets, the more brilliant is its appearance when set in the watch-plate.

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[4] Reduced to a fine powder or smooth paste.

[5] Linear marks, ridges, or grooves on a surface, often accompanied by multiple parallel lines.

Chapter 4

Opening the Jewel

The jewel has now received all the work necessary to its external form and polish; the hole, however, is as it was left by the diamond drill, with a sharp corner in the center that must be taken out, the sides of the hole finished and the corners chamfered off and polished. This operation is called opening, and on it depends the real working value of the finished jewel. The jewel may be first set, or opened before; in either way the process is the same. In opening by hand the only tools used are some pieces of wire, say an inch and a quarter long; these are filed to a long, taper point—the longer the taper the less risk there will be of breaking the stone in opening. The jewel, whether set or unset, is put upon a chuck which has been drilled to a good depth from the end, to allow the opener to pass through the hole, and yet be perfectly free at the point. This opener, generally of copper wire, is dipped in No. 2 diamond powder; then, the lathe being set in motion at its highest speed, the end is introduced into the hole, and the powder begins to cut the stone—being held by the copper wire, which is held lightly in the fingers, and pressed against the side of the hole; for if it were introduced in a straight line with the mandrel, the powder would grind the opener in very much like a screw, and it being taper, the jewel would be split. It will readily be seen that the form of the hole may be made to suit the requirements of the maker—either perfectly straight, taper, or rounded in the vertical sides. The opener is moved backwards and forwards through the hole while the operation is going on, and occasionally rotated in the fingers, the reverse of the motion of lathe spindle; and again it must be held in an angular position to the line of the mandrel. This operation is continued with No. 2 powder until the sides of the hole are of the desired form in vertical section, and of a uniform surface. The jewel is now cleaned of the accumulated diamond, stone dust and oil, the peg-wood being used for the hole. To clean the surface, the best article is soft new bread, which not only takes off the powder, but effectually takes up the oil, so that the effect of any process may be observed. It is used also by the pinion makers, and all other steel polishing, on account of its detersive quality and the ease with which it may be used. No. 3 powder is now to be used to obtain a polish. In the soft stones tripoli may take its place, used on a copper opener; but the powder is most economical in time. A piece of tortoise-shell, such as a comb-tooth, filed up to a long taper, may be used; or a piece of peg-wood answers every purpose, provided the speed is increased. This last process generally leaves the hole of the requisite polish and form. The only thing remaining is, to take off the corners of the hole. This is done by a rounded conical point, charged with fine powder. The corner on the oil-cup side requires but little consideration, but the face side must be chamfered the slightest possible amount, or the bevel may admit the shoulder of the pivot, thus causing a defective end-shake and an increased friction, which might be very detrimental if it occurred in the fourth or scape holes. The jewel is now supposed to be ready to be put in its place in the watch, provided it has been opened to a proper size for the side-shake.

The opening of jewel holes is done by the jewel makers in the American watch factories in an entirely different way, as the opener is not held in the hand, and the speed is increased two-fold. The advantages gained are speed and a *round* hole. It is almost impossible to get a round hole by the hand process, especially in an English drilled jewel. The elasticity of the opener allowing it to follow the shape of the opening made by the meeting of the diamond drill, in some cases the hole will be angular, but with the corners rounded off; in others, of an oval form; this last being highly objectionable, as, if the proper side shake is taken from one diameter, the pivot will be too large or else too small. To remedy these defects and still lessen the cost, the jewel was chucked as usual; only the spring chuck was used, and the jewel placed in a setting which was thus in a condition to be held true both in center and in plane. On the bed of the lathe is placed another head stock facing the other, but set at a very slight angle, which is but little more than that of one half the taper of the wire; this head stock has a hollow mandrel with a spindle inside that rotates with it, but this spindle is capable of motion longitudinally. The wire opener is held by the inside spindle, and the power is applied in such a manner that the spindle, together with the wire, revolves with the same rapidity in a contrary way to the mandrel holding the jewel. One consequence of this arrangement is, that double speed is achieved; another, that, owing to that duplicated speed, the opener cuts away the inside of the hole before it has time to leave its own place, and therefore the hole is round. A common round Swiss pivot broach may be made a good test of the circular truth, for the broach is not round, and were it to be introduced into an angular or oval hole, the high sides of the broach would fill the low sides of the hole, so that rotation of the broach would be impossible: but in a round hole it would make no difference, were the broach five-sided, oval, or of any irregular section; another advantage is, that No. 2 powder is used for opening and, polishing at one operation; but the saving of time is the greatest element of value where large quantities of work are to be dispatched. By the old process the jeweler could open about thirty pairs per day; by the new, a girl can open from 125 to 150 pairs in the same time, the work done being of as good quality as that performed by the skilled workman.

In the description of jewel-making we have taken a soft stone, aqua marine, as the material, and a common plate hole as the form; but there are some slight modifications when ruby or chrysolite is used, and the polishing is invariably done by the use of fine powder. The form of a jewel to which an end stone is to be fitted differs very materially from a plate hole—one side is convex, the other has a plain face and two concaves, the end stone fitting to the convex side. On the whole, however, the process is alike for all kinds of stones, and therefore we need not particularize, but may mention that the jewels for end stones are generally much better made than plate holes, as in chronometers the quality of the work cannot be too good. We might add some paragraphs on the making of roller jewels, pallets, duplex rollers, etc.; but it is hardly of much importance, for the processes differ only in the shape to be formed—the milling, grinding and polishing being identical. The English roller pin has generally a flat side, produced very simply, by placing a number of the round pins on a fine-surfaced plate of glass with a little facing powder; a common cork is now placed on the whole of the pins, and a few strokes of the hand will make the flat surface. End stones are merely turned up on the convex and polished in the same style as the jewel.

We have now followed the stone from the rough up to the finished state, and it is ready to be placed in its seat in the watch or chronometer. This department of jeweling is of more importance to the general watch repairer than the maker, for he frequently has jobs in which a jewel is to be replaced by reason of fracture, or, as it sometimes happens, from its being rough and so cutting the pivot. In such a case, if the pivot is repolished it will have too much side-shake. Among some whose pride of workmanship is of very low grade, it is the custom when the jewel is broken to replace it with a brass bushing. A knowledge of jeweling would break up such a pernicious habit from motives of economy, for in nine cases out of ten a jewel can be replaced in one-half the time, and the result will be a good job. Two styles of jeweling are used in the trade; in one, the jewels are set directly in the metal of the plate or cock, the Swiss watch being nearly always jeweled in this manner, even in first-class work, and in the majority of English watches the lower holes are thus set in the bar and plate. In the other and best style, the jewels are set in settings, which having been trued on the outside with the hole, are let in the plate and retained by jewel screws.

In repairing, the Swiss style gives much less trouble than the English screwed jewel-setting, for if the watchmaker has a fair stock of holes he can hardly fail to find one of the number of very nearly the size of the original; such a one having been selected with reference to the size of the hole as well as to the seat, the workman, having removed all the fragments from the jewel seat, carefully rubs back the burnished side of the seat; he now places the stone in the seat, being very careful to have it have an even bearing; then he burnishes the edge back again over the face of the jewel. This operation can be performed in half the time it would take to fit in a bushing, lay off the depth, drill the hole and free off the face to get a proper end-shake. The same thing, it is needless to say, can be done in English work, but there is a difficulty, as the setting is generally stripped very close to the stone; this renders the size deceitful, for if the jewel is very thick in the convex, it will apparently fit, when in fact it may be too small. In cases where a jewel is to be replaced in a screwed seat, it is best to make a new setting; as in that way the workman may true up the hole perfectly—a matter of no small consideration, for many of the holes purchased of the material dealers are very considerably out of truth.

Chapter 5

Setting the Jewel

The first step in jewel setting is to select the jewels in reference to the size of the holes and pivots; this is generally done by trial, or the workman may open hole to the right size, should he have none that are right. Opinions as to the proper degree of side shake are somewhat diversified; and again the same degree would not be advantageous, as applied to the whole train; and again, in English watches, wheels and pinions are very frequently seen out of upright, which condition would render a larger degree necessary, or the pivot would bind on opposite corners of the hole. As a matter of course, no wheel should be out of upright; but this fact is discovered in a large proportional number of English levers. This want of truth is sometimes a great annoyance to the workman, especially in repairing; for he must cut out the holes in the plate to receive the jewel settings from the center of the pivot hole in each plate; were they true he could upright the frame, and cut the holes by taking but one center and without removing the pillar plate until the job is finished. In sizing the holes for the pivots, unless the workman has had considerable experience, mistakes will very often occur, even with brass holes. A gauge can be made that will give the sizes with great accuracy, providing a good split gauge is at hand; it will require some little trouble to make it perfectly true, but sufficient truth may be obtained by any one accustomed to the use of the file and split gauge. A piece of good steel wire, about three and one-half inches long is filed as nearly as possible to a regular taper, ending in a fine point. This may be rendered a true taper if the workman will get a machinist to plane a groove with a diamond shaped tool in a block or bar of steel; he can get the requisite taper by elevating one end of the bar when in the plane; this steel should be hardened to the highest point. The needle now may be filed up in the taper groove thus planed; the sides of the taper will be straight lines, and the truer the face of the block the truer the lines. The large end of the needle is now inserted in a small block that is fitted to a bar of brass, and the small end projected through a small nozzle at the end of the bar; it will be understood that the block and needle are free to move on the bar. If, now, we make the nozzle a stand-point we may with the split-gauge, place the needle, and consequently the block, at any degree marked on the gauge which rests against the nozzle; the degree may be marked off on the longitudinal bar, and thus a mark corresponding to every degree on the gauge may be made on the needle bar. The longer the taper the more delicate the instrument will be.

This mode of measurement for the side-shake has an additional value, inasmuch that it habituates the workman to use known quantities, rather than trust to the rule of thumb. The split-gauge that is the basis of measurement is easily obtained in a form that combines the whole range of watch sizes, from the finest pivot to the largest watch-glass. We now refer to Dennison's combined gauge, an article indispensable to every watchmaker, who may, by its use, size wire or plate to all the sizes indicated by any Stubbs' gauge, also the diameter of wheels and pinions, most perfectly. The prices is very moderate, when the wide range of sizes is considered.

Figure 4 — Cutter

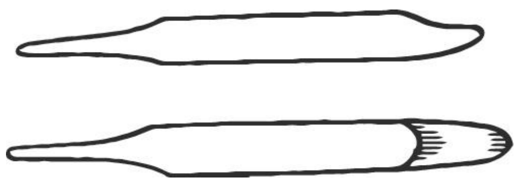

Figure 5 — Burnisher

The side-shake having been determined, the first step is the setting. There are a few small tools used in the operation that are worthy of an illustration. Figs. 4 and 5 are respectively a cutter and burnisher. As a matter of course, the sizes are arbitrary, in order to suit all kinds of work. Fig. 4 is the general form of the cutter for centering, made of flat steel, and ground in the form shown. To make a proper concave seat for the jewel, the corner should be slightly rounded. Fig. 5 is the burnishers, not only for jewel setting, but extremely useful in a variety of the ordinary watch repairs—made of common Stubbs' round wire, the end being first turned up round, and a flat filed on one side. The corners are rounded off, and a tang forged on the other end. The acting end is now hardened, and then drawn soft from the tang to about an eighth of an inch from the point. The rubbing surface is now to be made uniform with oil-stone powder, and then finished with rouge, until a high polish is effected. While using, a piece of sole leather is found valuable to preserve the necessary surface. It, like the cutter, is put in a good handle, and forms, as said before, a handy tool on many occasions, such as setting stones in jewelry, etc. These tools having been provided, if the operator has no spring chuck, he screws a piece of brass wire in the lathe mandrel, and drills a hole in it, first centering it with the sharp cornered tool, Fig. 4. The hole of course is smaller than the external diameter of the jewel to be set, and the shoulder turned in is to be of the exact size, leaving it with a bevel for the convex of the jewel to rest on. It will be obvious that, if the jewel is not true on the convex, the plane of the face will not come true when rubbed in; if it does run out the burnisher is liable to slip off and break the stone. The shoulder having been cut, the jewel is now introduced and, in order to make it stay, is slightly wetted. The setting is turned off at a slight bevel with the true face, and by means of the burnisher the edge of his bevel is rubbed down on the slight chamfer and face of the stone; the burnished edge is polished by means of a piece of cork, dipped in rouge, and applied during a few revolutions of the lathe.

In this operation nothing but a hand tool has been supposed to have been used. If however, a large number of jewels have to be set, it would become tedious as well as unprofitable to set them by hand. This was more especially the case in the inception of the watch manufacture in the United States. A large number to be set and but few to do the work, it became a very perplexing problem to do the required quantity in the old style. Mr. E. Howard comprehended the difficulty, and set his active mechanical brain at work to devise some way by which the jewel might be set true without skilled labor.

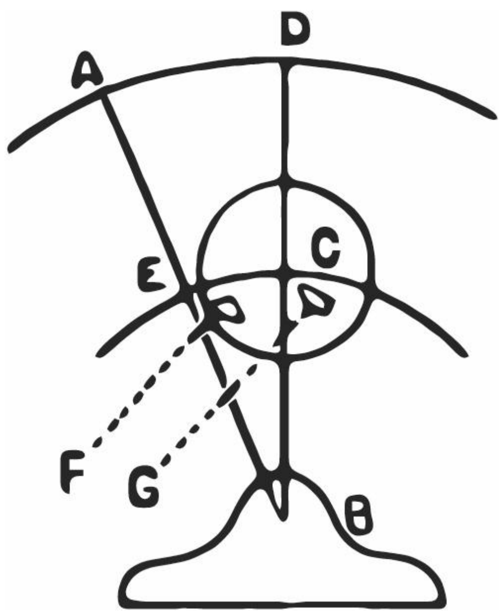

Figure 6

Mr. Howard invented the swing rest, and as the principle is founded on true geometrical premises we will try to give an outline of its general construction—premising that the point of departure is in every case the absolute geometrical center of revolution of the lathe, and also that in this case the spring chuck is used in connection. As handy as the shellac may be, it is expensive when the operations are repeated an infinite number of times. The setting is a piece of punched brass, a little larger than the size required when finished, and is held in the jaws of the spring-chuck as any other piece of work, by the external circumference. A hole is drilled in the blank first, and then a cutter represented at F and G, is used for getting the true size of the jewel. Let C represent the center of the lathe mandrel and the circle a hole we wish cut in the metal held in the chuck. Now, if we make a rest to carry the cutter, hanging on a center at a point below C, say B, with the cutter at E, it is evident that the point or cutting edge of the cutter, will preserve its relation to the circle, however far we may swing it from the center, C; but in all cases C and E are equally distant from the point B; if, now, we continue the lines B C to D, and B E to A, the arc between the two points A and is twice the arc E and C; but when one side of the circle, of which C is the center, is cut away, the diameter of the hole will be increased by twice the amount of the cut; therefore, if B A should be moved towards D until it coincides with B D, and the edge of the cutter point F coincides with C, the whole axis of rotation would be in the same straight line with the cutter. Now, D being stationary and A movable, if an object, say a jewel, is laid on the arc A D, it will measure its own diameter in the cut at the arc E C. As a matter of course it will strike the reader that the distance B C, or B E, must be exactly equal to C D, or E A. The line D B represents a solid part of the rest, while A B is a frame pivoted to the rest at B, and is movable forward, that is, toward the workman; the tool is held by means of a spindle moving through the frame at E. The rest is not confined alone to jeweling, for it can be adapted to every variety of watch repairing, pivoting, polishing, or facing, and might be applied to any existing lathe with the most gratifying results.

It must be remembered that the jewel thus set is in the piece of brass wire that forms the chuck; it will therefore be necessary to cut the wire off, in order to obtain the required depth of setting for the thickness of the plate. This is accordingly done, and the jewel, with its setting, is reversed on another chuck, whose face is smaller than the face of the stone; therefore, when the stone is trued up by its own center, the outside of the setting may be turned off to the size of the largest diameter of the hole in the plate, and the face of the setting may be made parallel to the face of the jewel. The jewel and setting, thus far finished, are now ready to be put in the plate. The lower holes have already been set in the bar and pillar plate, so we must sink the upper hole in just far enough to allow the pinion a sensible motion endwise, which motion is called the end-shake. To get the proper end-shake the jeweler now reverses the setting and jewel on a chuck face, a trifle larger than the setting; thus he has the jewel with the face out, as when he set it. He now turns a shoulder on the setting that just fits the smallest diameter of the hole in the plate and tries the setting in. If he has set the lower holes with reference to the level of the face of the upper holes to the lower side of the potence plate, he may leave the face of the jewel just level, take it from the chuck by a sudden jerk of the plate while the setting is in its place, and try his pinion in by putting it in place and placing the two plates in their true positions. If, now, he has in his judgment too much shake, he chucks up the jewel again and takes a slight chip off the shoulder, and continues this tedious operation until he has succeeded. But suppose he gets, by accident, no shake at all, he will burnish the edge or corner of the shoulder down, and thus raise the face of the jewel in the plate. This pernicious and very unprofessional way is not to be commended; the setting should be made anew, for the hole requires a good square face to rest on—not the sharp edge of a burnished rim of brass. The getting of a proper degree of end-shake is a very delicate matter. When we add to the difficulties already described the fact that the plates hardly ever go together alike in the separate trials, for it would be too much to screw together the plates every time he tries the shake, therefore he will judge by the pressure of his finger and thumb, and still find himself mistaken when the watch is finally put together. In nine cases out of ten in such a condition of affairs, the workman will "bump" the plate, in order to remedy the defect. Even in some high grades of English levers, the watchmaker may detect that the finisher has "bumped" the plate to get the proper degree of end-shake, rather than take a small amount off the pinion shoulder in case the shake was too large, or reset the jewel where the shake was too close. While this style of jeweling may not affect the owner of a watch, it is perplexing to the repairer, who, on taking down and putting up the movement, finds that he has again to adjust, by *bumping,* the mistake of the watchmaker.

The ordinary course of jeweling in England renders it almost impossible to make correct shakes without subsequent adjustments, for the watches are jeweled in the gray, or before gilding, and in the process of gilding the plates are annealed, thus warping them out of truth, or position in reference to which the jewels were set. Now, the only true plan on which any screwed jeweling should be done is to jewel after gilding. The watch may be all set up and put in running order before a jewel (except the cock and foot holes), is put in; then it may be taken down and gilded; then the jeweling may be done with a certainty of the parts coming together with the same regularity as a well-made steam engine. Again, in brushing the plates for gilding, the sides, or at least one edge of the hole in the plate, will necessarily become burred up, and the jewel, when replaced, will be found not to go to its place truly, in consequence. True, it is much more trouble to jewel after gilding, as the plates are liable to be scratched or even tarnished by frequent handling; but it should be understood that watchwork in all cases requires care, and no excuse can be had for any scratching by any one who professes to jewel a watch.

In the English mode of watch finishing and jeweling, the end-shakes are invariably attempted to be made in relation to the level of the plates. The whole process as there carried on, is one of unmixed stupidity; not so much as to the quality of the work when done, as in the mode of doing. The general operation is for the frame maker to send the frame to the finisher in the following described condition. The plates are put together and pinned or screwed; the train with barrel and fuzee and motion work, together with the potence and cock, are in readiness for the finisher. The pinions and arbors are left long, and, in order to put the frame together holes are drilled in the plates for them to pass through. These holes are not planted with any reference to accuracy in the matter of depth, and are as large as the largest parts of the respective pinion staffs and arbors. The first thing for the finisher's consideration is to get the length between shoulders in relation to position. These having been marked, his next step is to bush up all the holes, stone off the plate, and then proceed to lay off his depths. After having turned up and finished all the shoulders and pivots, according to the marks made on the train, the new holes having been drilled in the bushings and the escapement put in, the watch is inspected; and if the depths are correct, the plates and train to be jeweled are sent to the jeweler. He turns out *the plugs* that had been put in by the finisher and replaces them with jewels; but it sometimes happens that the frame maker has made the hole so far off from depth that the true hole for the pivot will fall outside the bushing; in this case the jeweler has no other choice than to cut out the plate to the full diameter of this eccentric bushing. It will be seen at once that all this work on the bushing is not only utterly lost, but a positive injury.

The jeweler having set the faces of his jewels level with the surface of the plate, the end-shakes are supposed to come right, the frame is now sent to be gilded, and, as said before, this process is almost fatal to the preservation of the correct shake.

In the American companies the shoulders are all finished to gauge, and at one time the jewels were set in the pillar plate in the Swiss style, with their faces level, the shake being got by the greater or less sinking of the potence plate jewels in the plate. As the distance between shoulders was intended and supposed to be equal, there would have been but little difficulty, provided the conditions were fulfilled; such, however, was not the case. The height of the pillars, the warping of the plates in gilding, and the difference that is inseparable in the dimensions of a number of pinions, conspired to prevent, by the accumulation of the errors, the result that otherwise might reasonably have been anticipated.

Where so many watches were to be jeweled per day, it became a very important matter to diminish the repetitions of manipulations that so seriously retarded the work. The only method that could be devised was to make the work self-measuring; that is, cut the shoulders on the jewel settings by the lengths of the pinions, when they absolutely gauge the depth of the shoulder. The principle of self-measurement in work was never better shown than in the end-shake tool now in use in all the factories. A brief description, in words alone, will answer to enable the reader to comprehend the tool, and the principle on which it is founded.

If a cutter were made to cut the shoulder, and at the same time a stop that rested on the face of the jewel, it is certain that the shoulder would always be of the same depth. Now, if the stop were made variable in relation to the cutter, it is equally evident that the shoulders could be varied at will. The next step in the process of reasoning was to devise some means by which that stop was varied in exact proportion to the length of the pinions. But here was another difficulty—the pillars cannot be exactly equal in gauge, and the shoulders cut in the plates were widely astray from equality. Whatever care might be exercised in the use, even of the best appliances, an error would always creep in. Here, then, were four measurements to be effected by one tool, which at the same time was intended to cut the work exactly to those measurements. The difficulties will be the more readily understood when the fact is considered that the measurement is so small—being in most of the trains not over one and a half degree, where the degree is only one-twenty-five-hundredths of an inch; and that the mere fact of a few degrees of difference in temperature applied to the instrument would invariably either take up the allowed amount or double the shake.

No one can fail to appreciate the difficulties that must be encountered to avoid so many causes of error. The simplest form will be conceived if we should take a hollow arbor, terminating at one end in an adjustable cutter with a square corner, the other end being furnished with a small hollow nipple, just the size of the largest shoulder cut in the plate. Running in this arbor are two small spindles, meeting just in the center where the ends of the inside spindles correspond to the exact length of the outside arbor. Now, if any size was placed between the two center ends, the inside spindle would be increased in length by just the size added. The upper plate is first jeweled with the faces of the stones just level with it under surface; as a matter of course, the depth of the shoulder in the plate is of no importance. The lower plate is now cut out from the dial side for the jewel setting, with a shoulder for the reception of the jewel. The plates are now screwed together, and the two arbors are applied to it—one on the outside, with its tit or nipple resting on the shoulder in the hole of the pillar plate, the other passing through and resting on the face of the jewel in the upper plate. A pinion, the one designed for the place, is now put in between the center ends of the inside spindles, and the stop pushed back in relation to the corner of the cutter. It is evident that the inside spindle, lengthened as it is by the distance between the shoulders of the pinion, must now be a measure of difference between the stop and the corner of the cutter; and therefore, if the cutter, with its stop fastened to it securely, be brought up to a jewel in its setting while it is revolving in the lathe, a shoulder will be cut on the setting just deep enough to allow it to enter the lower plate sufficiently to make the distance between the faces of the two jewels exactly equal to the gauge between the shoulders of the pinion. The end-shake can now be definitely made by increasing the length of the stop portion of the inside spindle, as it would lessen the depth of the shoulder on the setting. The object of the above description has been to give a general idea of the principle. In practice, the tool was found capable of doing the work of a dozen men, with accuracy never attained by hand. Great care is required in its use, as the slightest pressure or change of temperature will alter the result.

Chapter 6

The End-Shake Tool

The principle on which the end-shake tool is founded is capable of too extensive application to the ordinary repair shop to be passed over with a merely verbal description. We have, therefore, considered the subject worthy of a more extended description, and illustrated by diagram, and we do this the more willingly as the idea may be very much enlarged in its application to small tools. The following facts warrant us in our assertion:

The principle of self-measurement was carried out in topping off the settings level with the plate, and also in countersinking the jewel screws. The use of the principle enabled the movement to be jeweled after gilding with as much ease as it had been done in the old style. We have, for the sake of further illustration, given the two diagrams that show the whole philosophy of the tool. It must be remembered, however, that the diagrams are not intended as working drawings and many parts are left out that are important in the real instrument. Enough is shown, though, to enable any one to comprehend the reasoning on which the tool is founded.

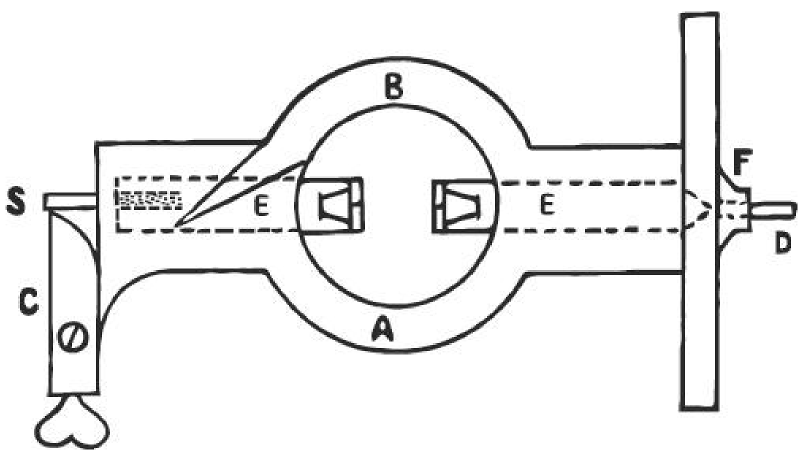

Figure 7

On reference to the last chapter, the reader will find that two spindles are mentioned —in fact, three; for the inside spindle is made of two pieces, meeting in the center of the hollow space cut out from the center of the outside spindle. Let A represent the hollow arbor at the center B; it is expanded so as to leave room for the largest wheel intended to be used. The two inside spindles are indicated by E, the ends S and D being reduced to gain room; the end S is let into E by means of a fine screw that enables the operator to lengthen or shorten the absolute lengths of the two. C is the cutter, adjustable for diameter. On the center ends of the spindles, E, the plate is fastened, with a V cut in the upper edge, and the spindle ends are slotted, in order to furnish room for the pivots. It will be obvious that the shoulder must rest solidly against the end of E. By looking at the drawings, the reader will see that if the two Es are close together in the center at B, the ends S and D would be exactly equal to the whole distance C and D, plus the amount of the end shake to the left. The screw serves to adjust the cutter to the right diameter of the shoulder on the jewel setting. There can be no mode of measurement more accurate, for it is evident that the distance between the two ends of the Es will be the exact length of any pinion put between the Vs, and thus the full distance between the shoulders is self-measured. In letting in the screws the heads are self measured, and let in flush with the plate, without a burr, and with sufficient bite on the setting to prevent any looseness. While the counter-sinking was being done, the settings were prevented from turning by an ingenious system of clamps that enable the stops to reach the plate and yet hold the jewel firmly.

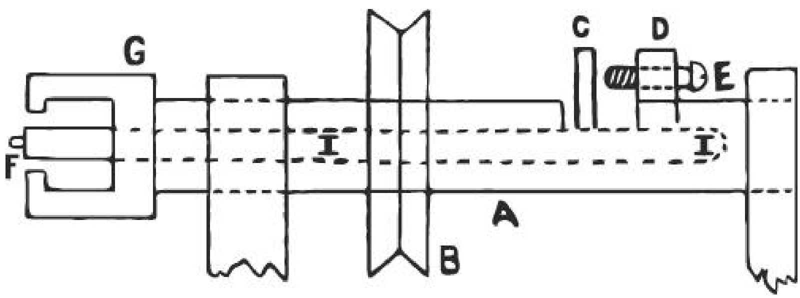

Figure 8

The following diagram gives an idea of how the automatic system may be applied to tools on the bench, to enable the repairer to perform his work without trial. If we suppose A to be the outside spindle, running in two standards, I, I, and to be driven by the pulley, B, we have a good external view on the end of A; at G is a frame let on to the end of the mandrel, free to rotate, but perfectly solid so far as an end motion is concerned, and thus it happens that the mandrel, A, will revolve inside the collar, G. While the whole frame connected with G will remain motionless, as the mandrel, A, has an end long motion at will, and G is permanently fixed, G will move with the mandrel, A endwise. The mandrel, A, is hollow, and one side has a slot cut, through which piece, C, projects, that is firmly fastened to the inside I. Screwed into the outside spindle is the leg, D, through which an adjusting screw is tapped, in order to make the contact perfect with the cutting lip, F, is exactly level with the spot face of C; if, then, anything to be measured were placed in the space between the point of the adjusting screw, E, and the inside face of C, the cutting lip of F would project from the stop face of G by just the thickness of the article to be measured, or, rather, that is intended to measure itself. In some of the common polishing and facing tools that are on the watch bench, this principle might be introduced to advantage, the more so, as any repairer could make a tool for use either with the ordinary lathe or bow. There is one thing that renders the principle of advantage, and that is its certainty. We have supposed the jewel set in the plate with the proper end shake; the next step is to counterbore for the jewel screw heads. As the screw holes are drilled a slight distance from the hole in the plate, and the countersink cuts with but one lip at a time on the jewel setting it will be seen that the countersink has a tendency to turn the setting around in the plate, as if it were a toothed wheel, and the cutter a pinion of one leaf; to avoid this in the gray work, the settings are cemented in by means of shellac—some using it in solution of alcohol, and others by heat—the same as in cementing up the work on the chuck. We would condemn this last, as the heat has too much tendency to warp the plates, and thus destroy the very work the jeweler has been so long engaged in perfecting. It is absolutely necessary, however, that the settings should be firmly set in the plate, and held while the countersinking is going on, as the leverage between the tit of the tool and the outside corner of the cutting edge is so great that the setting is almost sure to be rotated unless very firmly fixed. Where the movements are jeweled in the gray the whole plate, with the settings, screws, and all, are first filed down to a level and then stoned, the screws and settings taken out, and while the plates are sent to the gilder, the jeweler proceeds to give that exquisite polish generally observed on the jewel setting, both on the top and in the chamfer cut down to the convex of the stone. It would be a mistake, however, to apply the word polish to the chamfer, for there is not the first process of polishing applied to effect the result. The whole point consists in the condition of the cutting edges of the tools used in cutting away the superfluous metal from the setting. There have been many devices for the shapes and many more to render polishing possible, but it will be found to be the only really practical process where the graver point or cutting edge is brought up to a grade of polish equal to the polish sought to be obtained in the setting.

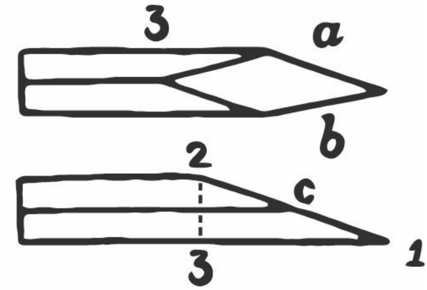

Figure 9

We will suppose that we take the common steel graver, "Stubbs," and on grinding off the point at the angle 1, 2, 3, say 30°, being careful to leave the plane represented between A and B perfectly level, we may proceed to finish the two edges, A and B, up to a point that shall be equal to the finish we desire to produce in the cut of the setting. At this point we must diverge from jeweling to a somewhat different branch of watchwork, but which, in its turn, demands the very same conditions. We refer to the engine turned work on the ordinary case, as well as the best class of work offered to the public.

We would premise that in this case we are speaking of how the polish on the barleycorn is effected. It is done entirely by the cutting edge of the cutting-tool, held in the slide rest. The value of the tool depends on equal angles and perfectly polished cutting edges. Another point is to be considered, and that is that the brilliancy of the polish would be much affected by difference in the angles at which the light is reflected, and thus, on the best class of watch-cases, the cutting edges of the tools are made at an angle of 30° on each side, or what the machinist might call a diamond point, but the angle made from the bottom should be 60°. Hollzapffel constructed a tool called the Goniometer that was intended to furnish the workman with a positive mode of getting the proper angles with certainty. This instrument is founded on the same principle that is employed in determining the angles of crystals. The whole science of cutting a gem depends entirely on the angle in proportion to the refractive power of the material, and just the same with the brilliancy of the barley-corning on the watch-case. Other things being equal, the angle of the cutter that gives the best reflection of light will be the best for brilliant effect. Now, in what is technically called "stripping," the angle at which the bevel is cut has much to do with not only its own brilliancy, but adds largely, when well done, to the luster of the stone. The graver, as generally used by the jeweler, is of more importance, as he has to judge of the effect from personal experience.

We wish, then, to make an edge on the graver that shall be able with careful manipulation to make a clean, polished cut. If any of our readers have been in a machine shop and observed the operator in the act of turning off a shaving from a piece of wrought iron, with the aid of water, he will comprehend our meaning of a polish cut. The jeweler, after having ground the point of the graver to the angle we have indicated, 30°, proceeds to put on this face between A and B, as fine a polish as can be effected on any piece of steel. No pains are spared to make it perfect; and as it is important, not only to the jeweler, but the general artisan, we will give a minute description of the process.

Depending somewhat on the habitat of the workman, he may use emery, oil-stone powder, or, what is much better, sapphire pulverized and floated off to get the various degrees of fineness, as is done with diamond powder. As the oil-stone powder is within the reach of every watch repairer, we shall take that as the modulus of operation. We will then suppose that the workman has the glass plates, of which we have in a former chapter given so minute a description; if he has not these, he may use with advantage a piece of the ordinary bell metal that has been brought up to a surface by grinding on a cast-iron face with sand and water. After a fair surface has been obtained, the face is roughened up with a sharp file, in order to hold the finishing powder in the grooves made by the teeth of the file. It will be seen what importance may be attached to this form of surface, when we come to treat of setting the diamond-end stone, so much used in the best class of watches and chronometers. At all events the bell metal surface must be so prepared that the polishing material may in every case be retained by the vacant spaces. Great care must be exercised in grinding the face of the graver, if the true bevel is to be retained. Assuming that the grinding plate has been well prepared, the first material used after the grindstone, will be the oil-stone powder, in oil. It requires a steady stroke and hand to keep the graver at exactly the same angle, and if it is not so done, the subsequent polishing necessary will be impossible. After the face of the graver on the angle has been effected it remains to finish the two other sides that constitute the cutting edges. In this consists the real difficulty, for if the smallest deflection takes place in regard to a *perfect plane* meeting the angle of the plane side, the edge will not be perfect for cutting purposes. In such cases, the graver is laid flat on the face of one of the sides and ground down until the edges meet; but the surface of the two sides where they meet the edges of the angle, should be a *perfect dead-level.* In fact, the finishing of the graver will require some considerable practice. After the edge has been rendered perfectly uniform, it is polished up with first sharp, and then by means of a boxwood slip, used with the Vienna lime. If, after the boxwood and lime, you find the edges of the graver give a sensation of roughness to the finger nail, it will be necessary to again grind the graver, and again go through the same process of finishing. There can never be certainty of a good edge on any new graver only after the temper has been ascertained.

When the temper has been found right, the graver used for a stripping tool should be used solely for that purpose, as by its use for other objects the very fine edge so necessary is completely destroyed. This tool is not alone used for stripping the jewel setting, but the dirt cups on the barrel arbor and center staff also owe their exquisite polish to the finish of the cutting tool. The jewel screws are, as before stated, counterbored and set, when, on stoning off, the plate, including the top of the settings and the screw, is removed; the jewels, with their settings, taken out of their seats, and the tops, after the stripping, are ready for polishing. Nothing in watchwork can excel in beauty the fine finish that is given to these tops. The method of effecting it is so applicable to wheels and any other small brass work in the watch, that we shall not apologize for the minuteness of the following description: A homogeneous agate or carnelian stone surface is the best; it is necessary to have two stones in order to get the required surface, which may be attained by the use of emery, but the result will not be so good as it would if diamond powder were used. The nature of the polish produced by means of the abrading surfaces is somewhat, if not exactly, like that produced by the action of the burnish file on steel, only the polish is much more exquisite, and can be done with a great deal more expedition. The polishing surfaces having been prepared according to the method explained heretofore, they should be wiped very clean with a cotton cloth and alcohol, in order to remove every trace of oil that may by accident have got on the face from contact with the fingers during the manipulations required in the preparation. The jewel setting, or other small brass work, after having been stoned down to a level on a piece of fine Scotch or blue stone, is placed on the polisher, with the stoned surface in contact; it being premised that any traces of the stone dust have been previously washed off. Now, with a piece of clean cotton cloth covering the end of the finger, the work is moved with considerable pressure over the surface of the polisher. The work must be examined after every four or five motions, to ascertain whether it is polished; for if the process is continued too long the brass will be found to clog up the fine grain of the polisher, and a new cleaning will be requisite. We may mention here that where the stone or glass plate has become unserviceable by reason of the brass adhering to it, it may be cleaned very rapidly by means of a drop or two of nitric acid, then washed in water, and afterward thoroughly dried. As a matter of course, this plan cannot be adopted when the jewel or end stone projects above the top of the setting. When this is found to be the case, the workman may be sure either that the stone is too thick or that the end shake is too great.

In most of the first-class watches, and always in marine chronometers, the cock is jeweled with a diamond end stone, the setting of which requires great skill if a perfect job of work is desired. The first and most important point to be looked after (the face of the stone being all right), is to set the diamond in the steel perfectly level. As the setting is of steel and the diamond generally irregular in its form, the burnisher is of no advantage, and the workman is compelled to use other means.

Fitting a piece of soft steel wire to his lathe mandrel, he drills a hole in it endwise, just large enough to take in the stone, whatever may be the differences in its different diameters. This hole is rather a concave cavity, against the walls of which the convex surface of the stone rests. This end of the steel chuck is cut off at a suitable distance, to give the correct thickness after finishing. The cavity having been cut a little deeper than the whole thickness of the stone, the face will fall below the steel, which is placed on any block of metal, and the diamond introduced, and with a small steel punch and hammer the workman closes the steel gently over the edges of the diamond's face. In this operation the utmost care has to be taken to keep the face perfectly level with the face of the setting.

After the stone has been fastened in by means of the riveting process, the workman proceeds to flow, by means of fusion, brass around the diamond, in order to fill up the vacant spaces not touched by the stone, by reason of its irregular shape and the fact of its being cut in facets. The soldering being completed, the face of the setting, solder and all, is filed with great care down to a level with the face of the stone. It may be ground on a glass plate with oil-stone powder, but the grinding must be done with the greatest caution, or the whole will be out of flat. The stone, with its setting, is now chucked up on the lathe by means of cement (shellac), with the face side on the chuck, and the workman trues it up by means of the outside, as by reason of the brass filling the cavity, he is unable to get it true by the center. The next step is to turn out, in the form of a bevel, all the superfluous brass and steel down to the diamond, and the novice will find it a very difficult matter to do this apparently easy job.

The difficulties arise from the very irregular shapes in which the diamonds occur, and the hardness of the stone, the corners of the facets taking off the point of the graver almost as fast as it can be sharpened. The brass must be picked out of the irregular faces of the stone, and a great effort is to remove every visible portion of the brass from the cavity, and at the same time bring a true bevel from the edge of the setting down to every part of the diamond, regardless of its great irregularities; this bevel circular surface must be true, and, in order to achieve the subsequent polishing, the angle of the bevel should be a perfect straight line, though in some diamond covers we have seen the surface rounded, polished and then blued. With a very large diamond this mode produces a fine effect. The usual course of polishing, after a true surface has been attained, is to use a small copper grinder with oil-stone powder;

the subsequent surface is got with the usual polishing materials, such as sharp and rouge. We have seen a much more exquisite polish obtained by means of fine diamond powder, the tool being nothing more than a common piece of soft iron—say an old horse-nail. The outside of the setting will have its shape determined by the circumstances of the case, and is polished while in the lathe in the same manner as all other steel work; but as the steel setting is soft, there cannot be obtained the fine deep black polish generally found on the steel work of the best class of watches, and particularly of marine chronometers.

The necessity of having the surface so truly level will be seen readily if the reader will for a moment reflect on the mutual relations that exist between the pivot, jewel hole and face of the end stone. Thus, if we suppose the face to be inclined at any angle, the tendency of the pressure of the pivot will be to crowd it to one side of the hole constantly; in fact, it would have all the effect on the action that a close hole would, and that, too without any compensating advantages.

The small steel collet seen around the fuzee arbor, is polished in the same manner, though, from the absence of any obstructions in the center, a rounded polisher can be used that acts exactly the same as the one used for the oil cup of the ordinary jewel, and, as the steel can be hardened and tempered, the degree of finish is limited only by considerations of cost and the requirements of the class of work to which it is to be attached. These collets are generally screwed on with the heads of the screws holding the piece down by means of a small flange that is turned on the outside of the piece; sometimes the steel is set, countersunk in the plate. The screws in this case are rarely countersunk, the steel being so very hard in proportion to the brass, that the countersink tool is almost always broken; the conditions of a uniformity of metal being absolutely requisite for truth.

This brings us, before we take up the subject of jewel screws, to consider the drilling, countersinking, and tapping of the jewel screw holes. The American plan, the plates all being alike, is to drill the holes by the aid of a templet, and where the work is jeweled before gilding, of tapping the holes. This practice is not, in the eyes of a good mechanic, the best that could be adopted, for it will readily strike the reasoner that, in countersinking, the tit of the countersink must necessarily injure the integrity of the thread; and of all the screws in the watch, the jewel screws are the most liable to strip. The English, having no determinate size, are compelled to lay off the jewel screw holes according to the circumstances; and, no doubt, some of our readers have been struck with the dissimilar positions laid out in watches of the same manufacturer. Thus he will find in one three screws to one setting, while in another he finds three screws holding down two settings. It is, perhaps, of no account as far as the general public are concerned, but the watchmaker suffers when he comes to repair; for if the screws have not equal bearings, it will very likely tilt one or the other of the holes, thus make a bad side shake.

There can be no doubt that the best way to lay off the holes would be to make the settings, if possible, the same size, and then fit in a steel plug having a very wide flange; through the flange a series of holes at regular intervals are to be drilled, and this may be used as a templet. The holes should be drilled small enough to allow the tap to give a full thread, as, when the countersink is made, but little stock remains to hold the screw. Again, the slight burr, caused by the drill in passing through the plate on the other side, should be taken off as nearly even as possible, with the object of leaving as much stock as possible for the thread.

The jewel screw holes having been drilled, and the settings in their place, the next step is to countersink for the jewel screws. If the work is gilded, great caution must be used in order to avoid any burr around the edges of the countersink. We have seen workmen who set the whole plate together with the jewel and setting upon the lathe chuck, and with a cutter used on the rest, made the recess—the center being obtained from the hole to be operated on; but the same object may be attained by using a counterbore, made in the best style, and run at a very high speed. The most ordinary mechanical mind will comprehend that the counter-boring should be done previous to tapping, and therefore we shall assume that position understood. To make the tool for letting in the screw heads, it is necessary to put up in the lathe a piece of steel wire, and turn down the end with a "tit" of just the size of the hole in which it is intended to be entered. The shoulder, as a matter of course, should be perfectly true and square, and the outside turned off to the accurate size of the head of the screw that is to be put in; the workman, in every case, endeavoring to get the size of the heads the same. The really best form of a counter-bore for gilded work to be used with high speed, is illustrated in the drawing. The spiral form given to the clearing portion of the tool will enable the chip to roll out of the hole without marring the edges. This tool may be made in the form of a twist drill; that is, the cutting lips may be formed in the same manner, and this gives, provided the groove is slightly undercut, a means by which the chip may come out without touching the edge of the countersink, the form compressing the waste material to the center.

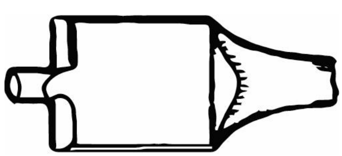

Figure 10

Chapter 7

General Hints to the Repairer

In this, the last chapter, the idea will be to give, in a discursive way, some hints that may be of advantage to the watch repairer. The subject of screws used in the work is of great importance; it is true that when materials are so ready at hand, as they are nowadays, the repairer has but little call, except occasionally, to make a screw. Now, it must be observed that even a jewel screw, for good service, requires truth; that is a perfectly equal diameter from the point to the shoulder under the head.

This is a matter of vital importance, for if the screw is taper it will so open the hole when it is forced down, that on removal and replacement the screw will not hold. Again, the head should be turned up parallel, with a perfectly square shoulder, as the bearing on the setting is so small that a slight taper towards the shoulder might leave no hold on the setting, while it may be screwed down solid; if the head be much taper, and slightly large for the counter-sink, the screw will force the setting out of its place, as the bearing in the plate is so much greater than that in the setting. In the nickel plates the holes will not take so good and full a thread as the brass, and consequently, if the watch repairer is obliged to replace a screw, he will be compelled to make the hole slightly larger than if the material was brass.

Accompanying the screws, imported ones especially, there are taps, left soft purposely; and the repairer will generally, if not always, find the body of the tap turned up to a square shoulder. Now, it may be a very trivial thing to write about, but many a repairer would have been saved hours and hours of vexatious trouble had he taken the precaution to turn or file off that shoulder to a curve before hardening, as shown in Fig. 11. In fact, a square corner in any piece of steel is the very weakest part when the article is exposed to the action of fire and water. These taps may be fitted to the lathe, and if there is a tail stock a die may easily be made that may be preserved for future use.

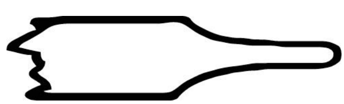

Figure 11

As these dies, thus made, are altogether superior to the ordinary plate, a particular description will not be amiss. Let us suppose the back mandrel to be fitted up with a taper hole; the repairer can then proceed as follows, and he will find that after a short time he can have an assortment of dies from which he can make new taps at any time, and with very little trouble. It is to be assumed that the operator will make the blank taps of the form shown in Fig. 11. The dies are made, or should be, of good steel wire, turned up with a taper to fit the back mandrel of the lathe; the blank need not have a very large bearing on the taper hole, but should be bored through with a hole much larger than the intended screw. After having been fitted, and the face turned true, a dovetail is made directly across the face, and two thin pieces of steel fitted in the dovetail in such a manner that the ends do not exactly meet in the center; the broach is now used to make a round hole, excepting the space left by the separation of the ends of the two pieces of steel; the hole is now tapped, the tap being held in the lathe; after hardening and tempering it will be found that a good cutting die has been made, superior to any jamb plate.

There can be no doubt of the superiority of this form of tool; and as the dies can be used for making screws, they become doubly valuable. The same process can be applied to the construction of pointing and milling tools for getting accurate uniformity of size; for if we make an attachment to the back spindle precisely like the die as described, and cut away a portion of each of the steel pieces let into the dovetail so that a sharp cutting edge will be formed, and as the steel cutters can be made slightly convex, there can be no mistake in getting a perfect size up to the shoulder. It will hardly pay the repairer to go into a full range of taps and dies, as the ready made screws, whether jewel, plate or cock, are usually accompanied by taps, which, if treated as mentioned before in this article, answer all the purposes required by the repairer. Yet there are cases where a screw has to be made for a special job; in such cases the ordinary jamb plate, either Swiss or English, serves the purpose. The dies described, however, do the work much better and with less risk of breakage. There is hardly a repairer that has not a screw plate with half the holes plugged up by broken screw blanks.

In preparing the tap for use it is always best to *flute* it with a thin equalizing file, the thickness of which must necessarily be in proportion to the size of the tap. This plan, though involving more trouble, is much better than simply filing off three sides, as the last-formed tap merely squeezes out the thread, while the fluted one may be used in a smaller hole, as the sharp edges of the flutings *cut* out the metal, leaving the thread in the hole solid metal, not forced into shape; this gives a much stronger thread, and a screw may be removed a greater number of times without the danger of stripping.

We have mentioned the importance of having a perfectly parallel head to the jewel screws; the remark is perfectly applicable to any other screw that is intended to go into a countersink, and it will be apparent that it is important that the heads should be concentric with the screw, if a neat fit is to be made in the countersink.

There is a very meretricious practice with some members of the trade, of, in case of too close an end shake, burring the bottom of the cock with the point of a graver. The evils arising are, first, that there is no solid foundation for holding the bridge, and next, that the hole end being thrown up, the jewel is brought out of place and the wheel is brought out of upright; but the worst fault is that the successive screwing down will continually tend to flatten down the points of bearing, and thus the watch will never again go together the same. Altogether the practice is beneath any one who aspires to do good work. If the balance staff has too little end shake, the true way is to round off the pivots enough to give the requisite shake; where the shake depends on shoulders of the pinions, the shoulder should be reduced, and the repairer will find in the end that he has profited by doing his work in a correct manner.

Sometimes, in the ordinary Swiss watch, one of the ends of the balance will be found broken; to replace the upper is but a slight job, as the steel disk that holds the regulator as well as the end stone, can be removed; if, however the repairer cannot find among his stock of materials an end stone of just the right size he may be bothered. He has two modes open to him; he may reduce the stone in the lathe, provided he has a diamond tool, being careful to keep the diameter such that the face of the stone shall not rest on the jewel; if the only stone that he can find near the right size is too thick, the trouble becomes greater; as the steel cover is generally hard, it is difficult to enlarge the hole in depth by any steel tool without first drawing the temper, and this implies repolishing—a troublesome process. The remedy is to use a copper wire, rounded on the end, with oil-stone powder, the steel cover being set up in the lathe, and the drill may be run either with a bow or in the lathe. Where the lower stone is broken, the task is much easier, as the brass cap may be easily enlarged.