The Art of Working Precious Stones For Use in Watchmaking and Optics, Taught in Ten Lessons; a completely new work, and the first to have appeared on this subject; by N. Dumontier, professor of mechanics.

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[French publishers traditionally put the table of contents at the back of the book; I have moved it to the front. Also, all asterisks and footnote details have been moved to right when the asterisk or footnote first occurs, and in a smaller font.]

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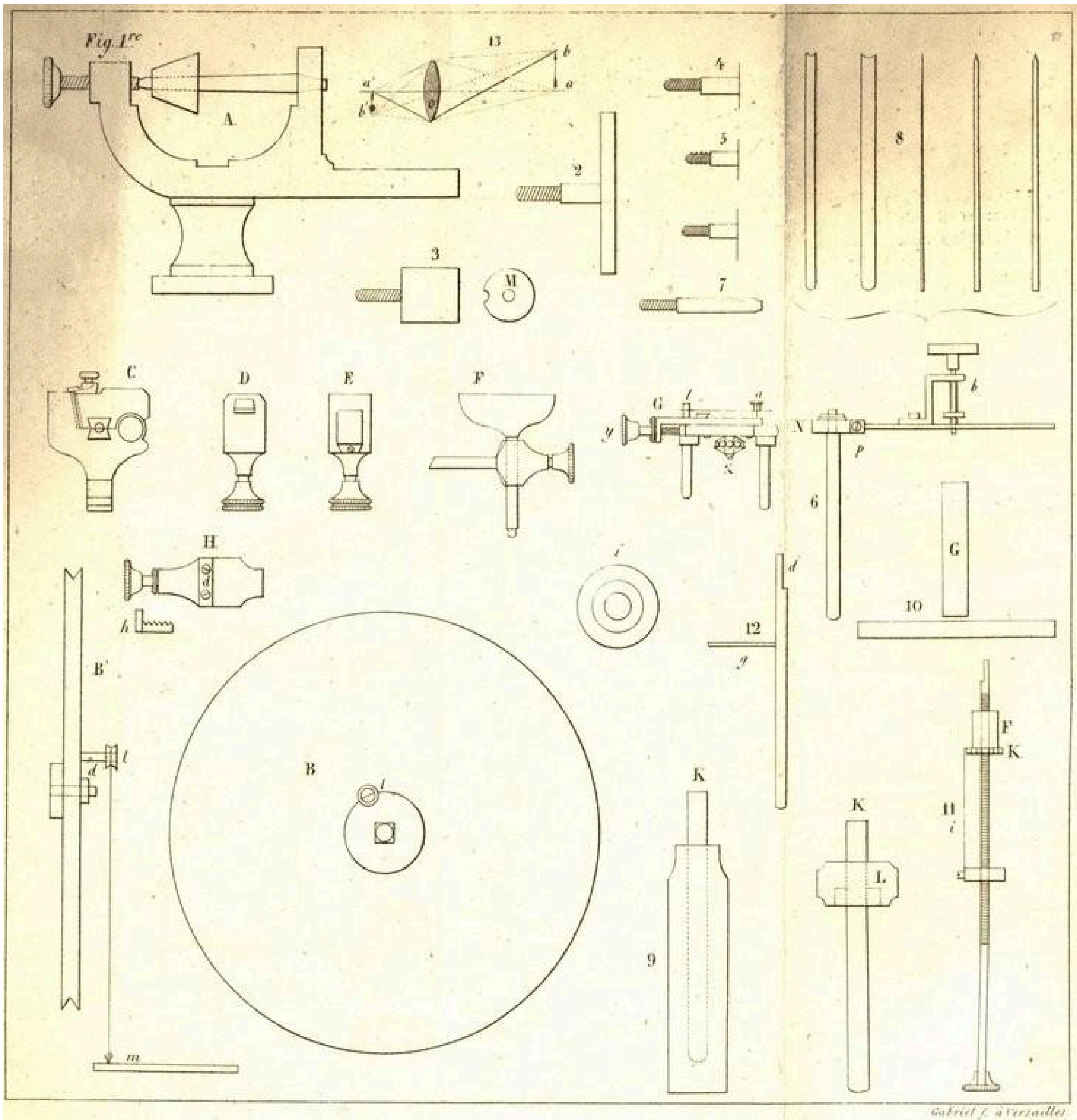
Fig. 1re
Gabriel f. à Versailles

Explanation Of Figures.

Fig. 1.re A, the tower seen in profile.

B, the wheel of the lathe seen from the front.

B', the same wheel seen in profile: d, the wheel axis; 1, the crank; m, the pedal.

D, the flow of the support seen in profile.

E, the same flow seen from the front.

G, the cart seen from the front.

H, the slide of the carriage. It is against the piece d of the slide that the slide h is slid to drill the stones, and it is with the two screws y and z that they are centered. Several stones can be glued to the slide and centered as they are drilled. l, piece adjusted to the slide; it is put in place to notch the small cylinders or rollers of the Duplex escapements; the screw a is used to place them horizontally under the cutter.

Fig. 2. Large millstone.

Fig. 3. Barrel; M, barrel cover.

Fig. 4. Steel cutter for cutting stones.

Fig. 5. Small cutter used to polish the edges of the tiles for cylinder escapements. It is with a similar cutter, but smaller and made of steel, that the rollers of Duplex escapements are notched.

Fig. 6. Tool used for polishing cylinders; it is placed in place of the support of the lathe, it has a horizontal movement by means of the part N, which is held by a washer and a pin, and another movement at point p. At this point the part N has two small arms between which the part which carries the grinding wheel no. 6 is tightened by two screws, so that it can be raised at will according to the size of the cylinder which is to be polished; a bow is placed on the copper of the axis b, and by this means three combined movements are obtained so as to cross the lines in all directions.

Fig. 7. A block used to wax various parts of the pulleys to be worked.

Fig. 8. Basins, bowls, cones and spindles used to polish holes and lenses.

Fig. 9. A mortar used to crush diamonds; K the pestle; L the ring fitted to the mortar so that the diamond powder is not lost; a piece of latex is placed in the bottom of this ring; i the same ring seen from the front.

Fig. 10. A hardened steel plate used to grind diamond powder; G the mass.

Fig. 11. It is on this tool that the tiles of cylinder escapements and the semi-cylindrical rests are waxed to cut them; it is with the same tool that flat stones are shaped; the end of this tool above part F is screwed and can be changed at will, according to the use to be made of it. K is a wheel divided into thirty-six teeth; i is a needle or alidade which presses quite strongly against the gap of the teeth of the wheel K. If we want to make a triangular stone, we pass twelve teeth under the alidade.

Fig. 12. This tool is placed in place of the support of the lathe; it is against the angle of part d that we press part F of the tool (fig. 11) to wear down the stones, give them the shape they must have and polish them. The arm g is used to approach or move the tool away from the grindstone figure 11.

Foreword

The watchmaker who wants to make good watches must adhere to various very important conditions, indicated by the laws of mechanics and physics, and which consist 1: in choosing certain metals which ensure the parts of a watch the greatest possible solidity; 2: to give each part the precise shape that suits it; 3: to maintain certain ratios of dimensions between the various parts; 4: to give the work the greatest possible perfection.

But these conditions are not the only ones; there is another without which a watch would not retain for a long time the regularity of operation that one would have managed to give it after much trouble.

The pivots, in their continuous movement of rotation, undergo rapid wear, the effects of which are soon felt; the use of precious stones has made it possible to attenuate this wear; but we have not yet succeeded in withdrawing from these substances all the utility that one can expect from them.

These stones indeed have a very different hardness depending on the direction in which they are drilled, and they are also susceptible to a degree of polish that varies considerably with this direction.

Up to now, in the use that has been made of them, this important aspect has not been taken into account, and it can be affirmed that we have no other guide than chance.

The work that we are publishing has as its main object to make known a very simple process in practice and certain in its results, with the help of which precious stones can be cut and polished in the direction that is most favorable. This process was suggested to us by reading a scientific notice by Mr. Arago, relating to polarized light. We have, moreover, set forth the improvements that long practice has shown us in the art of working precious stones, as well as the tools we used, and the manner of using these tools.

THE ART OF WORKING PRECIOUS STONES FOR WATCHMAKING.

[Lesson I, pgs. 1-21]

In the state of perfection in which watchmaking now finds itself, the art of working precious stones has become a very important branch of this industry: this is due to the use they are made of in good quality watches, and particularly in precision instruments, in order to obviate the differences produced by wear, to reduce and regularize friction.

Although this industry has almost remained a secret, it is nevertheless known that it is with the crushed and powdered diamond that the precious stones are put to work and that they are polished; but until this day the stoners have kept a secret of the means that they use to cut, turn, drill and polish these crystals; and very often the watchmakers find themselves in great embarrassment when they have to replace a broken stone or made by an unskilled worker: however they carry out daily works that require at least as much skill as that which one must have to work precious stones.

We therefore think that by publishing the processes that we put into practice for this kind of work, the watchmakers will in a very short time be capable of making, without the help of any teacher, all sorts of pieces in precious stones, whatever figures they want to give them.

In general, watchmakers believe that the tools used to work precious stones cannot be used for anything else, and it is often the fear of a considerable expenditure on tools or training costs which is the reason why this profession is still practiced today by a very small number of artists. However, any lathe can be used, provided that it is equipped with a doll [poupée: puppet, toy] to turn in the air *. *Almost all towers are now built in this way.

Here is the designation of the tools needed to work precious stones:

- A lathe mounted on a workbench, equipped with a wheel to turn at the foot, shown in fig. 1, pl. I.
- Two copper millstones and one tin millstone, each fifty millimeters in diameter and about three millimeters thick, for wearing down, smoothing and polishing precious stones, fig. 2.
- A barrel and six brass covers on which the pierced stones are placed in wax, to enlarge the holes, smooth them and polish them, fig. 3.
- A small steel milling cutter of twelve millimeters in diameter, for cutting stones, fig. h.
- Two small cutters, one of copper, the other of tin, twelve millimeters in diameter each, to give the proper shape to the edges of the tiles of cylinder escapements; these two cutters are cutting on the edges, fig. 5.
- Two small grinding wheels, one of copper, the other of tin, for smoothing and polishing cylindrical stones; these grinding wheels are mounted on the axis of the tool, fig. 6.
- Twelve small blocks on which the stones are set in wax to drill, turn and polish them, fig. 7. * The grinding wheels, the barrel, the cutters and the blocks are screwed onto the lathe shaft.
- Several spindles and basins used to enlarge, smooth and polish the holes, the oilers and the lenses or culs-de-poule, fig. 8.

* Some stonecutters cleave precious stones with a small chisel made of hardened steel. This operation is not always the most effective, because the stones do not always break in the desired direction.

- A small mortar with its pestle in tempered steel, to break and reduce to powder the diamond, fig. 9.
- A plate and a mass in tempered steel, to grind the diamond powder, no. 2, which is used to drill the holes, fig. 10.

We will explain, as the opportunity arises, the use of these tools; we will make known the manner of preparing the diamond powder, and of mounting the chisels and drills.

Before speaking of the means that we put into practice to work rubies, sapphires and chrysolites, we must first recommend studying these stones with the greatest attention.

The choice that must be made is very important; one must, with the help of a powerful microscope, ensure that they contain neither ice, nor crack, nor bubble, nor toad; Milky stones should also be avoided; the hardest stones are the best; they are recognized by the fact that they are jaspered and that the crystallization needles appear to cross.

We have made several experiments on the difference in hardness of stones. and we believe we can affirm that the ruby holds the first rank after the diamond. Next come the sapphire and the chrysolite.

We will not list all the precious stones according to their order of hardness: it will be easily understood that this would become useless in this work; that is why we will only speak of those used in watchmaking. The choice of the ruby is the most difficult, because it is found in several species; only the ruby of the Orient should be used. *The name ruby has been applied to various bodies of a red color; some in the species of corundum, others in that of spinel, and others in that of topaz. Spinel rubies and broom rubies should be rejected; the last one especially because of its low hardness: it will be recognized quite easily; because, besides having less specific gravity than the oriental ruby, it is of a vinegar red; it does not have a milky reflection. The oriental ruby usually has a violet tint combined with a velvety appearance, which alters its transparency a little, whereas the red color of the spinel ruby is purer and also has more clarity. On the other hand, the shine of the oriental ruby is more lively; it has another character taken from among those called physical characters, and artists attach great importance to it: it is, as we have already said, that which is derived from its hardness. We estimate its degree roughly by the more or less resistance that the stone opposes to the friction of the grindstone used to roughen it. *We can use this other means to realize the different degrees of hardness of precious stones: that which, by friction, can scratch the others. The hardness of the precious stone is of great value, by the advantage it has of favoring the beauty of the polish and of making it less susceptible to alteration.

The oriental ruby has obtained preeminence over the sapphire, and the latter over the chrysolite; now, the oriental stones which belong to the corundum, containing various proportions of iron oxide, do not always present the same fabric to the light, and by mixing alternately with the ruby, the sapphire, the chrysolite, etc., they offer us nuances which cover almost all the degrees of the solar spectrum. *This is the name given to the colored image that is created on a white surface by sunlight that has passed through a prism. The colors with which it is painted are successively: violet, indigo, blue, green, yellow, orange and red.

These varied proportions of iron oxide sometimes make the same individual pass abruptly from one tint to another, so that we find in its different parts and separately the yellow of the topaz, the blue of the sapphire, or this last color and the red of the ruby. Very often accessory tints blend imperceptibly into the main color, the tone of which they modify. Thus, a shade of blue, when combined with a very high red and tending somewhat towards the dark, gives cochineal red. If, in the same case, the dominant color is bright red, and a crimson red; if the additional shade is violet, the mixture will be deep rose red or wallflower red.

Chromic acid, which colors spinel, also admits accessory shades of yellow and blue.

Often the spinel ruby, of a beautiful red color, can be taken for an oriental ruby; this is why we recommend studying with the greatest attention the stones that one wants to use.

The indications that we have just given relative to precious stones could appear superfluous if we did not pay attention to the fact that it is a question of executing with the greatest perfection parts whose properties and precision are of great importance for the accuracy of the running and the duration of the watches.

We will now indicate the apparatus we use to find the axis of crystallization of stones that must be pierced, and of those that can be used to make the rests. The artists who will use these processes will easily appreciate all the advantages that result from them.

We have often heard stone workers, very skilled in the art of working precious stones, complain that rubies are drilled with difficulty; that they are polished with difficulty; that the edges of the holes become rough when the corners are rounded, and finally that we very often encounter stones that are not homogeneous (or equally hard). Well! all these inconveniences would not have occurred if the holes had been drilled in the axis of crystallization of the stone; but no stone worker has, to this day, conceived the idea of drilling rubies in this way; ordinarily when we buy rough stones, we choose them in such a way as to find ten or twelve in a karat, and we look for the smallest and the flattest, because they give less work: it follows from this that they are drilled perpendicularly to the most favorable surface that they naturally present, without having regard to the intimate texture of the stone, to the direction of its axis of crystallization, and consequently to the differences in hardness which relate to this very axis. If we continue to regulate the choice and the work in this manner, we will always find the same harmful circumstances that we have just pointed out; but this will no longer be the case when we carefully seek the direction of the axis of crystallization in order to drill the stone following this direction. This search will be done with ease with the following apparatus. This apparatus is composed of two plates of tourmaline cut parallel to the axis of crystallization, and polished. They are set in two pieces of cork, which are in turn set in two brass rings having a groove on their outside, then we take a piece of brass wire three decimeters long; we turn the two ends of this wire around the groove of the two rings containing the tourmalines, tightening the wire quite tightly so that the rings can only turn with hard friction. Then, taking the brass wire in the middle of its length between the two tourmaline plates, it will be turned around a piece of wood or round iron of twenty-four or thirty centimeters in diameter; this piece of wood or iron is a mandrel on which the brass wire is made to make a complete turn, in order to give it the shape it must have to hold the precious stone between the two tourmaline plates, so that the two plates, when crossing, can be faced with each other and form a kind of clamp. If one looks at the sky through the two tourmaline plates, in general one will see it with a yellowish-green tint which depends on the color of the tourmaline itself. In this position, if one of the tourmalines is rotated without touching the other, the sky will appear more or less bright. Let us suppose that the rotation is in the direction in which the light of the sky is diminishing, by rotating the tourmaline very slowly, we will easily reach a position where the sky will cease to be visible, or at least will be only very little so. We will judge the quality of the tourmalines by the degree of obscurity that we obtain in this experiment; the position that we have just indicated where the extinction of light is the greatest possible is that which is suitable for the test of precious stones, and here is how we direct this test.

The precious stone being cut along two facets perpendicular to the line that we suppose to be the axis of crystallization *We very often succeed in recognizing the axis of crystallization at the first inspection. This knowledge is acquired fairly quickly through practice. , and being polished on these two facets, we place it between the plates of tourmaline arranged to extinguish the light as much as possible. Then we will receive the light from the sky again through the apparatus, and, moreover, there will be this very remarkable circumstance, that we will perceive in the field of vision iridescent fringes.

If these iridescent fringes have a circular shape, we will conclude that the precious stone has been cut perpendicular to the axis of crystallization; if these fringes are not circular, we will place a small piece of wax under the stone in the apparatus, so as to incline it on the tourmaline plates by a quantity that we will vary until the fringes appear circular and concentric. We will thus determine the planes along which the stone must be cut: these planes will be parallel to the facet that the wax takes on by pressing it on the tourmaline, when the colored rings appear in all their perfection. If by this means we do not see the rings, we will cut the stone perpendicular to the plane already obtained, and we will try it again; if this test did not give a better result, it would be necessary to give up cutting this stone to make holes; but it would not be lost for that; it could be used to make levees or recesses.

The stones, implemented by this means, cost a little more, because they must be larger than those of ten or twelve to the carat; but this difference in price of the rough stone is almost zero due to the ease with which they can be drilled and polished, and consequently the time that is saved by working them in this way. If one can obtain rubies in barrel shape, as is frequently found in this form in the trade, it will suffice to cut them perpendicular to the axis of the barrel, and to drill them perpendicular to their facet.

When we construct instruments of a certain value, such as marine watches, portable chronometers, astronomical clocks, where only six or eight holes are ordinarily used, the difference in the cost price of the stones must certainly not be taken into too great a consideration, on account of the favorable results obtained when the stones are worked in this way; but for the holes used in ordinary or common watches, they are made at so low a price, that such care would perhaps not be practicable. In this case, one is forced to work them in the most favorable way to the figure they present, and with the greatest economy; it is true that with bad stones the pivots wear out very quickly; but as most often buyers want to have cheap watches, manufacturers find themselves forced to economize on each part that composes the watch. Nevertheless, it is pompously written on the bowl: Escapement with cylinder with four holes in jewels; as if it were enough that one hole be in stone to be good, etc.; it is therefore very necessary, even in ordinary or common watches, to use only stones of good quality.

When therefore one has chosen good stones free from the defects indicated, one will take a large number, that is to say twenty or thirty, of approximately equal height; they will be fixed with shellac on a well-dressed copper or brass plate, which plate will have to be heated with a small spirit lamp, so that the gum can melt and stick the stones; after which we will present this plate filled with stones against the millstone no. 1. *This grindstone should only be used for roughing. This millstone must be made of copper; we will have previously encrusted on it, by means of a strong pressure and with a mass of tempered steel, the diamond that we will have reduced to powder; we will use this millstone by impregnating it with a little water.

When the stones have been dressed on one side, we will heat the plate to de-gum them, we will soap them and we will put them in a small cassolette filled with spirits of wine; we will heat this casserole [?] on the lamp, in order to dissolve the gum which is on the stones and to clean them. *Every time that we remove the gum from any tool, they will have to clean them in the same way before putting them in wax. We will do the same operation on the plate, we will wipe it carefully, we will put the stones back in wax on the side where they were dressed, then they will be presented again to the millstone in order to wear them down to a thickness suitable for the use that one wishes to make of them. When they are of the thickness that one wishes to give them, one can, after having soaped them, pass them through spirits of wine, wipe them without degumming them, and present them to millstone no. 2, which must be made of brass, and on which one will have fixed diamond powder no. 3, by the means indicated for millstone no. 1. *This powder must be passed to oil in the manner that we will indicate when we speak of the preparation of diamond powder. This second operation will serve to soften them. One can, by this means, dress a large quantity of stones at a time, and have them all of equal thickness; by using this process it takes no more time to dress twenty or thirty stones than to dress a single one when one holds it with the finger. Practice will enable the artist promptly to appreciate the amount of pressure he must exert on the grinding wheel. We believe we should refrain from indicating the thickness that must be given to the stones; this thickness being always in proportion to the plates, bridges or caps in which they must be set. This thickness varies considerably from the smallest watch to the largest regulator.

The stones being thus prepared, we must proceed to drilling the holes.

There are two ways of drilling the holes: one is done with powder, the other with the diamond splinter. To drill with powder, we will glue the stone to the slide of the support of the lathe with very fine sealing wax, or with shellac, by heating the slide with the spirit lamp; after which we will drill a hole in one of the cleats of the lathe shaft: we will drive into this hole a piece of tempered and gray tempered steel, we will turn the end of this piece of steel (this piece of steel must serve as a drill bit) by the length of about two pivots; we will pay attention that this part is a little strangled; because, if the drill were also cylindrical, it could seize up in the hole and break the stone. The end of the drill must be flat so that the diamond powder can fix itself and become embedded in it.

Things being thus arranged, the stone will be centered by means of the two support screws of the lathe. When the stone is well centered opposite the drill, a little diamond powder No. 2, which has been suitably ground, will be placed on the end of the drill; then, setting the drill in a rotating motion *By means of the large wheel at the foot., and pressing lightly against the drill with the finger the slide which carries the stone, and agitating it continuously parallel to the drill, the hole will be easily drilled. During this operation, which lasts from eight to fifteen minutes, depending on the depth and size of the hole, it is necessary to put diamond powder two or three times at the end of the drill; because, without this precaution, the hole would be polished and would not be drilled. When the hole is of the depth it should have, the stone is unstuck and put back in wax on a cover of the barrel; the stone is placed on the cover so that the hole turns concentrically; the oiler is hollowed out with a diamond chisel of suitable shape. When the hole is discovered, one checks again whether it turns concentrically; if not, one recenters it. For this purpose one uses a conical spindle made of untempered steel; one places the support of the lathe at six or eight millimeters from the stone, a little higher than the hole. The small spirit lamp is held under the barrel, in order to heat and soften the wax, then the point of the spindle is lightly pressed against the hole in the stone and its extension against the support of the lathe, and the hole is easily centered. A little practice makes this operation very easy. If the oiler does not turn concentrically to the hole, it is touched with the diamond chisel until it turns round.

Method of drilling with a diamond splinter or drill.

[Lesson II, pgs. 22-31]

When a good stone has been chosen, it is placed in wax on a block, after which either take a very sharp diamond chisel, set the block on which the stone is gummed into rotation, and lightly press the point of the chisel against the stone, and its handle against the support of the lathe; by this means the chisel makes a perfectly concentric point.

This operation serves only to center the point so that the splinter, which serves as a drill, does not turn circularly with the stone (because if this point were not well centered the hole would not be drilled); it is absolutely necessary that the hole be marked concentrically, but it is not necessary that it be drilled through: its depth is always in proportion to its thickness. The hole being marked concentrically by the means of the chisel, we will choose a drill bit of a size proportional to the hole that we want to drill; it will suffice to wet it with a little saliva, to present it at the point marked on the stone, and to press lightly so that the hole is drilled. The pressure that we must exert with the splinter can only be well appreciated by practice. We understand that it is always advantageous to drill a large quantity of stones before carrying out the rest of the work further; because, having the tools and the hand arranged for this purpose, we save a lot of time. When the holes are drilled with the splinter, we can round the outside of the stone, then we remove the rubber, and we put it back in wax on one of the covers of the barrel in the manner indicated above; it is always necessary to drill the hole of a smaller diameter than that of the pivot for which it is to be used: it is made to the necessary size and smoothed with diamond powder No. 3. To this end, the barrel is set in rotation, and with a brass pin that is impregnated with said powder No. 3, and that one introduces into the hole by holding it between the index finger and the thumb, in order to be able to communicate to it a rectilinear back and forth movement as hasty as possible to cross the lines well. As this small pin is filed in a conical shape, one must avoid forcing it into the hole, because the stone could break in two; one must not tighten the pin too tightly; if it happens that it gets into the hole, one should let it turn freely between the fingers, then change the action of the movement of the large wheel of the lathe, and then the stone turning in an opposite direction, it will suffice to tighten the pin in the fingers to remove it.

When the hole is well smoothed, one cleans it properly with rotten wood or breadcrumbs, and one takes another small copper pin with powder n. ° k. When the hole appears well polished, it is cleaned again, and with a small tin pin and powder No. 5, it is finished giving the final polish (this last operation is called shining the hole); then with small bone cones, the angles of the hole are knocked down *We can round the corners of the holes with a pewter spindle, and do this operation only when the oiler is polished.; there is usually enough diamond powder left in the hole for this; then with a small copper shaft, one of the ends of which is turned into a half-spherical shape (or a cul-de-poule), the oiler is started to be smoothed with diamond powder No. 3. This work is done by moving the shaft in a circular motion; this is called lapping. When the oiler is well smoothed, it must be cleaned carefully in the manner indicated for the hole; then, with a pewter shaft of the same shape as the copper one, we polish it with powder No. 4, and we finish polishing it with powder No. 5. When the oiler is well polished, we take a small spindle of charcoal wood that we cut as thin as possible in order to be able to insert it into the hole, and, with what remains of the diamond powder, we grind it as we did with the small pewter spindle to match the new angles * To marry the angles is to round them that have been made with the small bone cones; then, taking a small copper shaft in the shape of a hound's-eye, but of a larger diameter than that which was used to polish the oil-pot, it is impregnated with a little diamond powder no. 5, in order to knock down the external angle of the oil-pot; it is necessary to press very lightly on the stone when beginning this operation, and not to grind, because the angles could become dull. This work completed, a diamond chisel is used to knock down the external angle of the stone; then, with a small copper shaft, one of the ends of which is hollowed out in the shape of a basin, the external angle is polished by putting a little diamond powder no. 4 in the basin, and by lightly shaking the basin on the stone. This done, we polish the small flat part of the stone with a small copper plate and powder no. 4; we press the plate lightly with the finger against the stone, making it describe a circular movement. When the powder no longer bites, the stone is cleaned and the polishing is completed with a pewter plate and powder No. 5, in the same manner as with the copper plate.

This flat part of the stone can also be polished on a mirror. To do this, the stone is removed from its rubber, it is carefully cleaned, a perfectly polished mirror is taken, a little diamond powder No. 5 is put on it, and, with a wooden spindle sharp enough to enter the hole in the stone, the stone is ground in a circle on the mirror; it is polished easily and quickly: little pressure must be exerted when beginning this operation. Practice alone can help you assess the proper degree. The polishing is considered to be complete when there is no longer any grip between the stone and the mirror. We look at the stone to ensure that there are no more lines left, and that the polish is as desired; after which we put it back in wax on a block on the side where we have just polished it; we must take care to center it well on the block; for this we use a spindle made of charcoal wood, whose point is pressed lightly against the hole of the stone, and the spindle is pressed on the support of the lathe, so that the stone can turn concentrically to its hole; this is done by placing the spirit lamp under the block, in order to be able to soften the wax, as said above. When the hole is seen to be turned concentrically, the lamp is removed to allow the wax to cool; after this the stone is turned with a diamond chisel to give it the shape of a bowl. When this operation is finished, a brass spindle is used, one of the ends of which is hollowed out in the shape of a basin, and having the same shape as the bowl of the stone; this basin is impregnated with diamond powder no. 3, it is presented to the stone, and it is ground circularly by pressing very lightly at the beginning; the pressure is increased as the powder wears out. When there is no longer any seizing, the stone and the basin are cleaned, and polishing is started with powder no. 4, in the same way as with powder no. 3. When the powder No. 4 has ceased to bite and is found to be worn out, the stone is carefully cleaned, and a basin of tin or alloy (composed of two parts of tin and one part of lead) is then used, and having the same shape as the brass basin. It is lapped in the same manner as was said above, until the bottom of the stone is completely polished; the small cones used to knock down and round the corners of the hole are then used, and the charcoal wood is used to match the new corners. The stone being thus finished, it is ensured that the hole is perfectly polished, using a very powerful magnifying glass; we look carefully if the angles are well rounded, and, if there is no defect in the hole, then we can prepare to set the stone, either in a plate, in a bridge or in a cap. In either case, the piece in which we want to set it, must be put in wax on a block, and the hole centered exactly. It will be hollowed out according to the diameter and thickness of the stone, a small groove will be made around the hollow with a chisel, rounded at the end; only a very thin line will be left between the groove and the hollow; the stone must enter the hollow freely, but without play. The depth of the hollow must be such that the stone is a little lower than the outer surface of the piece., if the pivot must bear against a plate or cap; it is understood that it is not the same if the pivot has neither a plate nor a cap, because then it is the bearings of the axis or pinion which must determine the play or play that these pieces must have. The stones must then be set accordingly.

We said that the stones should be placed a little lower than the outer surface of the pieces, where there were plates or coves; this is so that the oil that is put to reduce friction can always be maintained at the end of the pivots.

The hollow being made properly, care will be taken to clean it perfectly; a little oil will be put in the bottom of the hollow, so that the rotational movement that must be communicated to the piece when the stone is set, cannot make it leak. For greater safety, it can be held with a small cone of charcoal wood, which is pressed against the hole, and which is held with the hand; the stone is set with a small burnisher made of tempered and perfectly polished steel; the small portion of brass which forms a thin thread around the hollow is spread by pressure, and, with a steel chisel, the brass covering the stone is removed (if there is too much) so as to leave only what is necessary for the stone to be fixed firmly in the hollow *The English method is practiced in the following manner: no groove is made, a small protruding line is left around the hollow, which is folded back onto the stone with the burnisher. ; after that, the brass is softened with a piece of hemp wood and tripoli ground with oil, and it is polished with gold polishing rouge diluted in spirits-of-wine.

We believe we have said enough for the intelligent artist to be able to make the holes in stones and to set them.

Manner of making the Plates or Coquerets which must serve as counter-pivots.

[Lesson III, pg. 32]

A diamond cut in the shape of a rose *This is what diamond cutters call a diamond cut with facets on one side and flat on the side opposite the facets; it is very necessary that the flat part be perfectly polished is chosen, a block is hollowed out so that the diamond can be housed in the hollow, it is fixed in the hollow with sealing wax or with shellac; then, with a diamond chisel, the corners of the diamond are turned round in order to be able to set it in a steel or brass plate, and in the manner that we have indicated for setting the holes in rubies. If one wants to make lenses in ruby, sapphire or chrysolite , to serve as counter-pivots, it is necessary to roughen the flat part of the stone on the grindstone n.° 1, to smooth it on the grindstone n.° 2, and to polish it on the grindstone n.° 3. It is also possible to polish this flat part on a mirror in the manner that we have indicated; then the wax stone is placed on a block, and the lenticular part is worked as we have already said when speaking of pierced stones. The curvature is given with a diamond chisel. This operation completed, one begins to polish with a copper basin and powder n.° h, one cleans and finishes polishing with a tin basin and powder n.° 5; one sets in the same manner as the holes.

Manner of making flat stones, that is to say the rises, the recesses, etc.

[Lesson IV, pgs. 33-34]

Flat stones can be made either on the grindstone or by using files made of untempered steel, copper and tin: to shape them on the grindstone, start by roughing them on grindstone No. 1, holding them with the finger in order to straighten them; after that, they are put in wax on the tool, fig. 12., to give them the shape they must have; when they have the proper shape, they are cleaned, smoothed on grindstone No. 2, and polished on grindstone No. 3.

To make flat stones by hand, they must also be given the proper shape on grindstone No. 1; then they are put in wax on a steel or brass brandy, in order to be able to smooth and polish them on their different faces without it being necessary to degumming them; they are smoothed with the steel file and powder No. 3; they are cleaned and begin to polish them with the copper file and powder No. 4; the polishing is finished with the tin file and powder No. 5; the corners are knocked down and rounded off with the same file. It is absolutely essential to dress the files well.

The corners can be rounded with a copper file and powder No. 1: the work is quicker, but you must press very lightly, so as not to roughen them.

The shape of flat stones varies so much that you cannot go into any detail on this subject: it is enough to know how to work them to give them at will the shape necessary for the functions they must perform.

Manner of making the semi-cylindrical rests.

[Lesson V, pgs. 35-36]

To make the semi-cylindrical rests, it is first necessary to give on the roughing wheel a roughly cylindrical shape to the stone, that is to say to rough it out so as to be able to turn it with a diamond chisel. When it is thus prepared, a hole is drilled in a block, the wax stone is placed in the drilled hole and it is turned with the diamond chisel. When it is also turned cylindrical, of a diameter and length suitable for the use to be made of it, the projecting end of the stone is turned into a lenticular (or pancake) shape, this end is smoothed with a small basin in which a little diamond powder no. 3 has been placed, and it is polished with diamond powder no. 11; then, with another small basin of a more pronounced curvature, the angle of the cylinder is knocked down and polished. The remaining diamond powder on the stone is sufficient for this operation. After that, with the tool shown in Fig. 6, the copper cutter No. 1 and the diamond powder No. 3, the cylindrical part is smoothed; then, with the tin cutter and the diamond powder No. 4, polishing is started. When the diamond powder No. 4 no longer bites, the diamond powder No. 5 is used and polishing is completed; then a hole is drilled in another small block, this hole must be the diameter of the cylinder that has just been polished; the cylinder is degumming from the first block, and it is placed in wax in the second to turn the part of the cylinder that was gummy in the first, and the same is done to finish the cylinder and polish it; after that the wax stone is placed on the tool Fig. 12, we calibrate with a micrometer and we see what is the diameter of the stone and the tool; if the stone had, before being put in the tool, 16 / 48 in diameter, and if, after being put in wax in the tool the stone and the tool together have 26 / 48 in diameter, we will wear the stone on grinding wheel no. 1, we will soften it on grinding wheel no. 2, and it will be polished on the grindstone No. 3, so that only 18 / 48 of the stone and the tool remain in diameter, the 8 / 48 remaining of the stone form the rest.

The stone can be worn down and the rest formed with a brass file and No. 3 diamond powder; begin to polish it with a copper file and No. 4 powder, and finish polishing it with a tin file and No. 5 powder. This method of forming the rest takes much more time than the grindstone; we thought nevertheless that we could not avoid mentioning it. When the rest is well polished, the corners are knocked down with No. 5 diamond powder, pressing as lightly as possible, so as not to roughen them.

A method of making tiles for cylinder escapements.

[Lesson VI, pgs. 37-39]

We choose a ruby whose crystallization is perfect; we form two parallel planes of suitable height, that is to say, of the height that the tile must have, rather a little more than less; we put this stone on a cleat, we center it, we turn it externally, we give it a little more diameter than the interval or the void which is found between two teeth of the cylinder wheel. The stone thus turned, we drill the hole with a diamond splinter: this hole must be drilled a little smaller than the length of the inclined plane of one of the teeth of the cylinder wheel, so that after being smoothed and polished, the tooth of the wheel is a little free in the hole. This operation completed, we put the cylinder in wax on a small steel pivot driven into a cleat; it is polished on the outside in the manner indicated for the semi-cylindrical rests, and with the same tool, so that there is a little freedom or play between the gap of the two teeth of the cylinder wheel; it is then degumming and placed in wax in the hole of a barrel cover set to size. For this purpose, it is polished in the same manner as the holes which are to serve for the pivots, but taking care to take a much longer spindle than the one used for the pivot holes, so that when polishing the hole, it can be kept equally cylindrical. For this purpose, one could place the support of the lathe at the height of the hole, and move it back to a fairly large distance from the stone. The cylinder being polished inside and out, it is necessary, before opening it, to put it at the height it should have, either by turning it with a diamond chisel or by wearing it on the grinding wheel no. 2; it is then ready to be opened.

This opening must be 175 degrees of the circle, so that there will remain 185 degrees of the cylinder after it has been worn, that is to say, 5 degrees more than half; which will give 2 1/2 degrees of rest to the tooth of the cylinder wheel.

This done, the stone will be degumming and it will be put in wax on the tool shown in fig. 12, in order to give the edges or lips the forms they must have. The entry edge must be of a semi-cylindrical shape, and the exit edge must be rounded from the inside to the outside. To give these slices or lips the proper shapes, as we have just said, it is not necessary to use diamond powder No. 3. The slices being very thin, we will use the grinding wheel or cutter No. 1, and the diamond powder No. 4, and then, with the tin cutter and the diamond powder No. 5, we will finish polishing them.

How to make the small Cylinder or Rest of the Duplex Escapement.

[Lesson VII, pgs. 40-41]

We must, as has been said for the tiles, choose a very pure ruby, pierce it with a splinter (if the splinter is not long enough to pierce the hole through and through, we will pierce it half on one side, half on the other side of the stone), turn it round after it has been pierced, smooth it and polish it in the same way and with the same tool that we used to polish the semi-circular rests.

The notch will be made with a cutter, shown in fig. 5; this cutter will be made of very thin steel, and riveted to a block; the cylinder or rest will be set in wax on the tool H fig. 1. re , which tool slides in the slide fixed on the platform of the lathe support; the cutter must have a centimeter in diameter [be one (1) centimeter in diameter].

When the rest or cylinder is suitably placed under the cutter, a little diamond powder No. 4 is put on the cutter, then the cutter is given a rotational movement as quickly as possible by means of the large wheel of the lathe, and by pushing the tool on which the rest is erased into the slide, it is easily notched as it passes under the cutter. The screw A, represented on the tool H fig. 1.re is used to adjust the depth of the notch of the rest.

The notch is polished with a small copper file of suitable shape and diamond powder No. 5; the corners of the notch are rounded with a small tin file, square in shape, and powder No. 5. One of the corners of the file enters the notch of the stone; both sides of the file round the corners at the same time. This work requires a little skill and a lot of lightness in the hand.

How to prepare Diamond Powder.

[Lesson VIII, pgs. 42-46]

You must obtain rough diamond, that is, diamond that has not been cut.

In Paris, several merchants sell it, notably MM. Alplien, rue Richelieu, ; David jeune, rue Jean-Jacques-Rousseau, 12 ; Léon and W. Nathan, rue de Bondi, 62 ; madame V. c Chritin, rue Montmorency, 39, etc.

You can also use diamond that has already been cut; but it is considered to be less good than rough diamond, because the latter is harder, because it has kept its crust; one karat is usually prepared at a time. The karat of rough diamond costs from 24 to 30 francs. This price varies very often, and according to the merchants to whom one addresses oneself.

The diamond which has a blackish tint is the best.

The pieces should be chosen as large as possible, so that four or five pieces give the weight of about one karat.

The powder is obtained by pounding the diamond in the small mortar shown in Fig. 9; but, before proceeding with this operation, one of the pieces is introduced into the mortar, one places the pestle on top, and with a blow of a hammer hit sharply, it is broken; after which one removes the pestle, and one looks at the end which was used to break the diamond: it sometimes happens that some particles or splinters of diamond are attached to it; if there are any, they are detached, then one turns the mortar over and pours the pieces of diamond onto a sheet of very smooth black paper, one looks among the largest pieces to see if there are any of a suitable shape for making chisels; one stores them to mount them; we also look to see if, among the smallest pieces, there are any of a favorable shape for making drills, that is to say, of a half or a third of a millimeter approximately in length, and triangular as much as possible: this is what is called a diamond splinter or needle. If you do not find the quantity of chisels and drills that you want to have, you operate in the same way on the second piece of diamond, and so on until the last, in order to have a sufficient number of chisels and drills. Once this is finished, you put all the other pieces of diamond back in the mortar, and you begin to pound them by hitting the head of the pestle with a hammer. This work is quite long, you have to spend two and a half or three consecutive hours on it, taking care to turn the pestle from right to left in the mortar each time you have struck six or eight hammer blows. Without this precaution, the diamond would sink into the mortar, stick to it and not reduce to powder. When you no longer feel any sticking when turning the pestle, the diamond will be at the right point; all that remains is to mix it with oil so that it is ready to be used: for this purpose, you will take the clearest oil that you can obtain; purified olive oil is the best; a large and deep watch glass will be filled with it; the diamond that has been powdered will be poured into this oil. Often a part of the powder remains fixed at the bottom of the mortar; it is detached by scraping with a steel spatula whose end has the shape of the inside bottom of the mortar, and by striking a few blows with a hammer on the sides and the outside bottom. When it is certain that all the powder has fallen into the glass, it is mixed with the oil, and it is divided as much as possible by pressing it with the spatula against the walls of the glass. When the mixture is made, it is left to rest for an hour, after which it is decanted, that is, the oil containing the diamond is poured into a second watch glass, taking care to leave the largest pieces of diamond that have precipitated there in the bottom of the first glass: the oil and the diamond that have been poured into the second glass are left to rest for four hours, then it is poured into a third glass, also taking care not to pour the diamond that has precipitated to the bottom; it is left to rest for eight hours and poured into a fourth glass; it is left to rest for sixteen hours and the oil is poured into the fifth glass; then the whole is left to rest for a few days. When all the powder has fallen into the bottom of the glasses and the oil has returned perfectly clear, it is decanted from each glass; the operation is finished: the powder can then be used in the manner indicated. It is important not to neglect to number the glasses from one to five, starting the order of numbers with the first glass used. If you do not want to take the trouble to pulverize the diamond, you can buy it crushed from the merchants whose addresses I have given; but I believe it is better to do this work yourself.

Before mixing the diamond powder with oil, some stonemasons mix it with 15 grams of sulfuric acid and 15 grams of nitric acid, and leave it in these acids for two or three days, so that the steel particles that have come off the mortar and pestle are completely oxidized; then a large quantity of water is added to the acids, mixed, left to rest for a few days, decanted; after which 60 grams of rectified alcohol are poured onto the powder, mixed, left to rest for two days, decanted again, dried the powder and prepared with oil. This operation is long and I believe unnecessary.

When one wants to give a very fine polish to precious stones, one karat of rubies is pounded in the same way as one pounded the diamond, put the powder in oil, mixed well and left to rest for thirty hours, and decanted.

It is not necessary to make several numbers. When the oil has become very clear, it is poured into another glass, and this powder thus prepared is used with lime wood for holes, oilers, etc.

How to assemble chisels and splinters for drills.

[Lesson IX, pgs. 47-48]

A hole is drilled or a notch is made (with a file) in a piece of brass wire according to the shape of the piece of diamond that is to be used as a chisel; the end of the brass wire is heated in a spirit lamp, on which a little good sealing wax or shellac is put. When the shellac or wax begins to melt, the diamond is placed in the hole or in the notch, and the wax is allowed to cool. The chisel is ready to be used; the splinter is usually mounted on the end of a pin, to which a light file is given on the point; a small point is marked in the center with a steel chisel and a hole is drilled the size of the splinter. This hole must be very shallow. The pin is then placed in a pin clamp so that the side where the hole has been marked protrudes only by about a line; we heat the pliers in the spirit lamp, we put a little wax or shellac on the point of the pin, and we place the splinter in the hole. This work requires a little skill, but practice makes it quite easy.

Lenses made of precious stones are used in certain optical instruments. To guide the manufacturer in the construction of these lenses, we believe it is necessary to say a few words about their general properties. [Lesson X?]

Any transparent body terminated by flat or curved surfaces which, by the properties of refraction, give it the ability to converge light rays or their extensions towards the same point, can be called a lens.

Usually the surfaces of lenses are portions of a sphere or plane differently combined with each other. They are divided into two types, that of converging lenses and that of diverging lenses. In the first type are biconvex, plano-convex, and convergent meniscus lenses. They are easily recognized by the property they have of substantially uniting the rays of the sun at one point; moreover their thickness decreases from the center of the lens to the edges. It will be noted that, in the converging meniscus, the curvature of the convex face is greater than that of the concave face. In the second type are the biconcave, plano-concave, and diverging meniscus lenses. These lenses, when exposed to the sun's rays, instead of making them converge, make them diverge; their thickness increases from the center to the edges, and the diverging meniscus has its concave face more curved than its convex face.

The optical axis of a lens is called the straight line drawn by the centers of curvature of its two faces; when one of these is plane, the axis is the straight line perpendicular to this plane drawn by the center of curvature of the other face. The figure axis of a lens is called the line joining the two centers of figure of its two faces. If this axis coincides with the optical axis, the lens is said to be centered. Lenses that are not centered should generally be rejected.

Any light ray that passes through a lens by passing through the optical axis, does not experience any deviation. Calculation proves that a ray near the axis can, after passing through the lens, return to its original direction. For this, it is necessary that in its path through the lens, it passes through a particular point called the optical center. This point is located on its axis, at distances from the faces that are in direct ratio to their radius of curvature.

Let l be the refractive index of the substance of the lens, rr' the radii of curvature of its two faces, p and p' the distances from a luminous point located on the axis and from its focus to the lens, we will have to determine p' the equation $(1/p') + (1/p) = ((l\text{-}1)/r) + ((l\text{-}1)/r')$; or, as all the quantities that make up the second member are known for a given lens, we can designate it by $1/a'$ so that the equation will be reduced to $(1/p')+(1/p)=(1/a)$ and we see that if we make $p = a$, in the case of an infinitely distant luminous point we have $(1/p') = (1/a)$, so a is nothing other than the principal focal length.

For any conjugate focus we will have $(1/p') = (1/a) - (1/p)$, this is the relation reported above.

From the equation above we derive $p' = ((ap)/(a\text{-}p))$ it should be noted that to adapt this expression to the different types of lenses, it will be necessary to calculate the value of a for each of them, giving r and r' suitable signs. Let us confine ourselves to examining the biconvex lens and the biconcave lens. In the first case, r and r' retain the signs they have in the fundamental equation, and as l is always greater than unity [the whole], a will be positive; which means that the main focus is on the side of the axis opposite to that where the luminous point is located.

The formula $p' = ((ap)/(p\text{-}a))$ shows us that as the value of p, decreasing, approaches that of a, the value of p' increases and becomes infinite when $p = a$ for $p < a$ p' becomes negative; in this case the focus is only virtual: the rays, after having passed through the lens, remain divergent. In the case of the biconcave lens, r and r' must be taken with the negative sign, a therefore also has this sign for a', and to determine the position of the focus we have $p' = -((ap)/(p+a))$; therefore this kind of lens never gives anything but a virtual focus, and in fact it is easy to see by the very shape of the lens that it must increase the divergence of the rays.

The lenses of the first type have properties analogous to those we have just studied on the biconvex lens; those of the second type are analogous to the biconcave.

We also see, from the above, that the rays which emerge from a biconvex lens have their focus all the closer to the lens, the more distant the luminous point is.

When any luminous object is placed in front of a biconvex lens beyond its principal focus, the point a which is on the axis forms its focus as we have just said; but a point b which is not on this straight line forms a focus b' on the secondary axis bcb' which passes through the optical center o (fig. 13) and the point b. The set of foci of the different points of the body forms a reversed image which can be easily seen by receiving it on an opaque or translucent body. According to the proportion which we have indicated above, we see that the size of the image is to that of the object in the ratio of $oa' : oa$.

END.