THE ESCAPE-WHEEL.

477.—The construction of this wheel is an operation of extreme delicacy. A watchmaker who has not had considerable experience in this class of work had better apply at the watch material dealers who keep a supply of very well made wheels of all sizes and thicknesses, or to the manufacturers, sending them by post the old wheel, carefully packed.

But for the benefit of those who are compelled to make the wheel, or of those watchmakers who, having time and patience, are anxious to improve themselves by making a complete cylinder escapement, we proceed to give the practical rules that must be followed. These rules will be of no service to practised escapement-makers, who do not always adopt the same methods or tools, and are endowed with unusual skill from daily experience; we are not writing for the very small number of those who do know, but for the very large number of those who do not, and wish to learn.

The escape-wheels used in the Geneva factories are, for the most part, roughly finished in that town; the arms are cut in the punching machine, and a very soft quality of steel, prepared with special care, is required for this purpose. They are then sent in the rough to a district of the Savoy where they can be finished at small cost.*

478.—To make a cylinder escape-wheel the workman must be provided with (1) a first-class wheel-cutting engine supplied with a special appliance for forming the U's (unless the pillar-tool is arranged for this purpose); (2) a tool for rounding the pillars; (3) a tool for forming the inclines. These tools must always be kept in perfect working order. Before using them it is well to test them on a trial wheel.

To measure the heights, thicknesses and diameters.

479.—If the old wheel is not available as a pattern, we must begin by ascertaining the dimensions of the required escape-wheel.

THE TOTAL SIZE is, according to the escapement-makers, given by the fourth wheel of the train, a sufficient play being allowed between its pinion and the heels of the escape-wheel teeth.

This mode of measuring assumes that the fourth wheel

* The Besançon district is also well known to manufacture, on a large scale, escape-wheels, cylinders, etc.

is properly proportioned; but, as we have already pointed out (**399**), in the case of very many modern callipers, we should by proceeding thus make the wheel too large.

When the total size has been ascertained, a circle, B (fig. 38, page 278), is drawn on a smooth sheet of brass of the exact diameter determined upon.

A brass disc of this diameter is now turned out on the lathe; it is introduced into the wheel-cutting machine and its rim divided into twice as many parts as the wheel is required to have teeth. This subdivision is accomplished by means of the cutter subsequently employed in forming the wheel itself. It must be specially selected, for its thickness gives the measure of that of the shell of the cylinder (**405**), that is to say, its maximum thickness is one-eighth the length of the inclined plane.

One of the brass teeth together with the spaces on either side will give, very approximately, the diameter of the cylinder. This diameter is accurately measured by means of a fine pointed pinion gauge, and a smooth arbor, passing with very slight play between its two points, can be taken to represent the cylinder. The arbor is now placed between the longer arms of the incline compass (**503**) in the correct position, that is to say, against the figure indicating the lift that it is desired the escapement shall possess (**397**). The interval between the two points of the compass indicates the distance of the circle D (fig. 38, page 278) from the circle B, the two being, as is evident, concentric.

The external circle gives the total size of the wheel; the inner one marks the portion that has to be hollowed out. It must be remembered that we are here only considering the dimensions of a finished wheel. (See the subsequent article **483**.)

In the absence of the compass above referred to, a micrometer, with jaws between which the arbor is placed, can be employed to determine the height of the incline in accordance with the explanations given in article **397**.

480.—The TOTAL THICKNESS OF THE WHEEL, when the workman has no pattern to go by, must depend upon the amount of space available without detriment to the correct proportioning of the other parts of the escapement. Introduce a small piece of brass, filed to a convenient shape, between the cock and chariot when these two are connected together apart from the plate, and by this means ascertain the exact distance between the two jewels. Mark on the edge of the brass with the fine corner of a file; (1) the length absolutely required for each axis, in order to keep the two ends of the cylinder at a sufficient distance from the jewels and their settings; (2) the height necessary to ensure strength in the lower shell; (3) the thickness of the collet. The remaining space gives the total height of the great lip, and it will be easy to determine the most convenient total thickness that can be given to the wheel. In well planned modern watches this thickness equals about two-thirds the height of the opening.

481.—The THICKNESS OF THE FLAT OF THE WHEEL should be no more than is required for the due solidity of the arms. The *flange* (giving the width of the rubbing faces of the teeth) has the same thickness as the flat (sometimes it is rather greater when this latter is very thin), and the thickness of metal appropriated to the pillars is somewhat greater, but it will depend on the elevation of the impulse plane.

482.—With the help of these practical details any intelligent and skilful watchmaker will be enabled to make a well-proportioned wheel. But anyone who finds difficulty in accurately determining the several dimensions had better take them from a well-made wheel with the required number of teeth. The diameter, thicknesses, etc., may be increased or decreased so that the two wheels are proportional to the thickness and diameters of the watches to which they belong.

483.—*The proportions here given for the height of the teeth, the thickness of the flange, and the height of the pillars, etc., refer to a finished wheel; the workman, in roughing it out, must always remember to leave it from a third to a quarter larger, for the stoning and polishing will reduce it by at least this amount.*

It is, as we have already observed, advisable to make at least one wheel as an experiment, not merely in order to make sure of the accuracy of the proportions and to try the tools, but also to test the cutter employed in forming the U-spaces, as it is essential to know the exact depth to which they are cut before marking out the arms of the wheel.

To make the Wheel.

484.—English cast steel, known as square steel, is excellent for making escape-wheels. It is first reduced in thickness by forging, very great care being taken to prevent burning of the metal, and, when nearly of the desired thickness, is subjected to a gentle hammering while cold, after which it is annealed. This treatment renders it very soft for working. (The article on *Steel* gives other modes of preparing the metal.)

In the factories bands of ready-prepared rolled steel are kept, and this is very easily worked with the graver.

A square piece of such metal is taken, and after drilling a hole in the centre of a convenient size for riveting the pinion, the metal is rounded with a file. This hole must be broached out with care, and perfectly straight, employing for this purpose a broach that is very little tapered. The wheel is turned carefully of the required diameter and thickness on a rather short arbor, round and corresponding in form to the broach employed.

The metal is now turned down in such a manner as to leave a flange (in which the inclines are cut) projecting.

In factories the escapement-makers hollow out their wheels on a small mandril with a slide-rest, which is worked by the foot, an intermediate distributing wheel being employed. When this or an analogous process cannot be resorted to, they hollow out the interior of the wheel, which must be kept perfectly flat, and work from the centre towards the rim, using a cutter the nose of which is hooked and very carefully ground. It is necessary that only a small quantity of metal be removed at a time, for otherwise there would be some danger of distorting the wheel or bending the arbor; and if the cutter has not a good edge it will, as it were, rub the metal instead of cutting it keenly. This will render it the more apt to lose its shape in the hardening, and might even make the flat of the wheel, when it is thin, become *cockled* and move up and down under the pressure of the tool. Or the wheel can be hollowed by the use of an ordinary graver.

The cord of the bow should pass round the ferrule in a converse direction, that is to say it must cross on the opposite side. By this means the movement of the bow will cause the ferrule to rotate backwards.

The tool-rest being so placed that the point of the graver can travel past the arbor, the interior of the wheel is hollowed out and shaped by presenting the tool to the side farthest from the workman.

A small mass of metal or boss is left untouched at the centre to ensure that the wheel may always be set true on the arbor. This is not finally removed until the wheel is quite finished, and then the thickness must be left sufficient for riveting the pinion.

In measuring the several thicknesses a gauge known in the trade as a *douzième gauge* is employed. This will be found described in the chapter on tools (**1484**). The wheel must never be removed from the arbor by means of a hammer.

485.—After smoothing the flange with oilstone-dust, the arms are roughed out so as to admit the screws by which the wheel is fastened to the table of the cutting engine. The under-side of the wheel and the flat of the teeth are then stoned down, either on a sheet of ground glass, or a large polishing iron, or on a lap. A thick steel disc fastened to the end of an axis carrying a ferrule (fig. 34, page 246) is employed for stoning down the interior of the wheel. This disc is drilled out at its centre so as to admit the small boss in the middle of the wheel. Its face must be perfectly flat, and its diameter should be such that it just enters the hollow with a slight amount of play; rotating the axis with a rather light bow, the wheel is stoned down by holding it with the finger against the face of the disc.

486.—The wheel is now ready for cutting, and if the workman has any fear of breakage he may strengthen it with brass.

For this purpose take a brass disc rather larger than the wheel and of at least twice its thickness. A hole smaller than that of the wheel is drilled at its centre, and, with a sinking tool, this hole is increased to half its depth so as to admit the boss of the wheel without contact. The disc is now placed on an arbor and turned perfectly true on its two faces; a flange is turned on the edge, forming a shoulder, so that the wheel can be adjusted on it; and, while the interior will thus be exactly filled with the brass, the flat of the teeth will rest firmly against the projecting lip.

It will be seen that when thus protected we can mount the wheel on the table, form the U spaces, and cut the teeth without fear of distorting it—an accident that might very easily occur without this backing if the workman has not considerable experience in the making of escape-wheels. The best makers manage to do very well without such an addition. They are thoroughly at home with their tools, and their hands are steady.

487.—The wheel is divided into twice as many parts as it is required to possess teeth, for each space represents the length of a tooth plus twice the thickness of the cylinder.

The flange must at first be only partially cut through, as indicated at *n*, *l*, *h*, fig. 38. It will thus retain sufficient firmness to avoid all danger of distortion when the U-spaces are cut, or if the arms are finished before making the inclines.

The flat circular cutter employed must be of the exact thickness of the shell of the cylinder; that is, it must be at most one-eighth the length of the inclined plane. It is necessary to slightly *dish* the two faces of the cutter.

The surface of this cutter is prepared either with a wheel-cutting engine or a chisel. It must be quick in its action, for otherwise the operation would strain the wheel.

In the absence of any better means the necessary roughness can be imparted to the edge of the cutter by pressing it firmly on a fine new file and drawing it along in the direction of the cut. Any burrs that may be formed on the sides of the cutter are afterwards carefully removed.

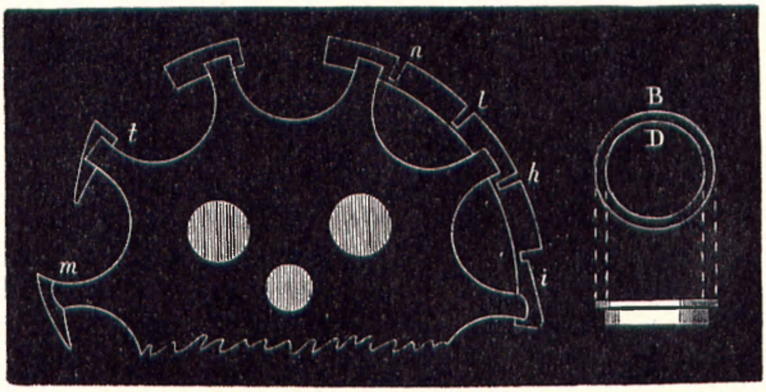

Fig. 38.

It must be placed directly in a line with the centre of the wheel and must cut sharply, a little oil being applied from time to time. The workman should remember that the heels of the teeth are to be very near the U-arms so that, when subsequently sloped, the curves may be continuous (see *t* and *m*, fig. 38).

After partly dividing the teeth in the manner explained, and while the wheel is still on the table of the cutting engine, the inclines may be roughed out (*i* fig. 38) by means of a conical cutter or by sloping the axis of an ordinary cutter.

Pillar Tool and tool for forming the U's.

188.—This consists mainly of a sort of mandril lathe represented in fig. 3, plate IV. The arbor H carries a circular cutter *a* (also shown at B, fig. 6), which is held in position by a clamping screw J (fig. 3). The cutter is only roughened on its outer curved surface, and any workman can make it for himself by using the sharp angle of a new file. The slide B B is caused to traverse a slot in the frame by means of the screw G. The plate *r*, seen in side elevation, is perforated to admit the cutter *a*. This plate, used in rounding the pillars, moves with the slide B B, being attached to it by two feet and a screw, the extremities of which are seen at *d*, *d'*. It can thus be detached from B when required.

The following accessories to this apparatus are necessary:

(1) The carriage shown in side elevation in fig. 4, and in end elevation in fig. 5, which, when cutting the U's, must take the place of *r*, being attached to B by the projecting piece P of the frame P *i k* that supports the carriage.

(2) A rest that is supported in the piece *f g* (fig. 3) by means of the clamping screw *h*. It is mainly of use in rotating the cutter *a*.

To form the U's.

489.—The carriage shown in figures 4 and 5 is used as follows in forming the U's: the wheel *s e* (fig. 4), after being divided into twice as many parts as it is required to possess teeth, is placed with its fiat resting against the plate X of the tool where it is centred by the screw *b*, the conical point of which projects just so far as to prevent any shake of the wheel when lying flat. The plug *o* (fig. 4), also shown at A, fig. 6, is now placed within the wheel and pressed by the screw M (fig. 4): the wheel is thus rigidly fixed. The screw M, however, must allow of the wheel being rotated with some friction.

The point of the detent or guide D (fig. 5) is now placed in one of the cuts in the rim of the wheel and the carriage is fixed to the slide B B by its arm P in the manner already explained. The entire carriage rises and falls on the vertical piece *i k*, being limited in its path by the screw N. The screw G is first moved until the extremity of the cutter *a* is level with the lower side of the teeth. The exact depth to which the U's are cut can be regulated by the screw N. The position of the wheel can be adjusted by the screw F as it moves the support that carries the detent D. After making sure that all the screws are properly clamped, the workman proceeds to cut the U's, working the bow placed on the ferrule *l* (fig. 3) with his right hand, while the left holds the carriage, gradually lowering it until it rests on the set-screw N, when the cutter will cease to act. The screw M having been eased, the guide D is raised and introduced into the next cut but one; the screws are again clamped firmly and the second U is cut, etc.

490.—At this stage the division of the wheel may be completed by introducing a fine equalling file, stoned on its faces and thinned towards the back so that it only acts with its edge, into the cuts *h*, *l*, *n*, etc. (fig. 38). The removal of a very little metal should suffice to detach the several pieces.

The heels of the teeth, *t*, are next sloped by means of a smooth curved file stoned at its edge, so that they take the curvature of the U's as at *m*. Care is essential in this operation to avoid straining the teeth or touching their points with the back of the file, for then their lengths would no longer be equal.

Some workmen employ a special tool for this purpose which is also available for adjusting the length of the teeth when they require to be equalized. It is very similar to that employed in forming the inclines.*

Rounding of the Pillars.

491.—This operation can be performed by the aid of various tools, and the lathe described in article **488** is available for the purpose. In some cases the cutter is arranged so that it rotates round the pillar, while in others it remains stationary, and a semi-circular movement is imparted to the wheel itself. This wheel is held by the finger with its teeth upwards against a firm support (*r*, fig. 3, plate IV.), which can be so placed by the adjusting screw G, that the flat end of the cutter is in a plane with the under surface of the teeth. Holding the wheel by a finger of the left hand with its flat against *r*, and working the bow which drives the ferrule *l* with the right hand, the wheel must be moved about so that the cutter rounds off the pillar in the manner required.

This cutter is driven by means of a horsehair bow, and only cuts with its cylindrical surface. A watchmaker that possesses neither a tool for making pinions nor a wheel-cutting engine,

* Escapement-makers sometimes avoid the necessity of filing the heels of the teeth by setting the cutter so that its plane of rotation passes to one side of the centre of the wheel instead of through it; the slope of the heel is thus formed in the first instance. But when such a practice is resorted to, the thickness of the cutter is no longer identical with that of the shell of the cylinder, and much skill is required to choose one of such dimensions as to produce teeth that are neither too long nor too short.

can form the cutting surface with the angle of a new smooth file. The flat end of the cutter must not be at all rough.

It is sometimes better to postpone the rounding of the pillars until after the inclines have been formed, so as to make sure that these project sufficiently from the pillars to prevent the oil from escaping.

492.—We have ourselves adopted the following form of apparatus, for with the method above explained there is some difficulty in rounding all the pillars to the same extent.

The wheel is fixed by a screw *s* (fig. 8, plate IV.) which has a large head (hollowed out below so as to admit the boss of the wheel and enable it to press on the arms), on a previously prepared brass plate P, cut away at the top in order that the cutter may have access to the pillars; the flat of the wheel, of course, is against the plate. One tooth is held by the stop *y*.

At the centre of the curve which it is desired to give to the pillars, *n* for example (which will be nearer to or farther from the pillar according as the curvature is required to be more or less pronounced), a hole is drilled. This hole fits on to a pin fixed in the plate *r* (fig. 3), occupying precisely the same position on this plate with regard to the cutter that the hole *n* (fig. 8) occupies with reference to *b*.

The action will be easily understood; P is held against *r* by a finger of one hand, the entire system E P′ being pivoted on a centre of movement *n*, and the other hand is occupied in giving motion to the cutter, which thus rounds the pillar along the arc *d d*.

After loosening the screw *s*, another tooth is brought against the tongue *y*, *s* is then screwed up, and the rounding of a second pillar proceeded with, and so on.

The diameter of the hole in the wheel is the same as that of the neck of the screw *s*. P P′ may be held by a thumbscrew or nut, and the length of its course may be limited by a set-screw.

The pillars may be stoned down in a similar manner, or by merely holding the wheel against the plate *r*, the cutter being replaced either by one that has not been hardened, but is simply roughened from time to time with a file, or by a ruby file.

In order to avoid confusion in the figures, some of the details given in fig. 5 have been omitted in fig. 4, but the one will complete the other.

Forming the Inclines.

493.—As the teeth have now been completely divided and the pillars rounded, it is a simple matter to ascertain the exact diameter of the cylinder. This dimension will enable the workman to verify the height of the teeth, employing the incline gauge, before he proceeds to form the inclines.

If the teeth are found to be too high the inclines must be cut to the requisite height without regard to this excess, and the points, which will be left large and square, must be reduced by filing inside in the manner indicated at *f* (fig. 2, plate I.).

In forming the inclines the wheel is so placed in the tool specially designed for this purpose that each tooth in turn only allows the metal to project that is required to be removed. This removal of the superfluous metal is accomplished by means of a smooth new file, which must be lightly handled. It must only be allowed to cut during a forward stroke, and should not even rub as it is brought back.

It is necessary to leave a slight excess of metal on the inclines to allow for that removed during the subsequent smoothing and finishing.

Tool for forming the Inclines.

494.—This tool is represented in figure 12, plate IV. The wheel is fixed on an arbor without a ferrule, which is then placed between the two centres L, P; the wheel thus enters between the tongues *a*, *c*, the flat of each tooth resting in turn against the tongue *a* in such a manner that no more matter projects above it than is required to be removed in forming the tooth. Having the heel of the tooth supported against the spring guide C D (the nose of which projects between the tongues to the point *a*), and holding the wheel against this stop by a finger of the left hand, the workman proceeds with his right hand to file away all the projecting matter. The file must only cut during its advance, and should be raised from the wheel when brought back.

The handle D of the guide is now pressed downwards so that its nose is removed from *a*, the wheel is rotated through the interval of a tooth and, after replacing the guide, the formation of the second incline is proceeded with.

REMARKS.—The tooth can be brought against a part of the tongues that is more or less inclined by moving the screw B, and thus altering the position of the nose of the guide.

The carriage E F, which supports the wheel, is raised or lowered by the screw J, and fixed in any position by R.

And similarly, the other sliding frame A is movable by the screw K, and can be fixed by the clamping screw M.

It is almost unnecessary to observe that when each part has been placed in position, and before proceeding to work with the tool, all the clamping screws must be firmly fastened down.

In new tools the extremity of the tongue *a* is hooked upwards to prevent the file from slipping. Some watchmakers, however, find this hook inconvenient, and remove it.

To finish the inclines and the arms of the wheel.

495.—The points of the teeth must be carefully rounded off as well as the inclines (both lengthwise and crosswise), and all sharp angles must be stoned down.

The arms of the wheel may now be finished. It is unnecessary to give elaborate details on this subject, and we would only point out that they must be thin so as to reduce the weight of the wheel, and three files in good condition are required for the purpose: (1) a rounding up file nearly flat on one side and half round on the other; (2) a crossing file, the edges of which are smooth; (3) a small flat file similar to that used for reducing the heels.

In shaping the arms the wheel may be firmly set in wax in a small collar formed with a flange on which the rim of the wheel rests; by this means it is possible to apply a greater amount of pressure, and the risk of straining the teeth is avoided.

In factories the arms are formed either by a punching machine or a special tool in which cutters are arranged to remove the superfluous metal quickly and neatly. Formerly the greater number of escapement-makers employed a kind of universal tool, by the use of which it was possible to form the U's, the arms, and the inclines, to cut the teeth and to round the pillars without displacing the wheel; but, at the present day, cylinder escape-wheels pass through several hands.

Hardening the Wheel.

496.—Various methods are adopted.

Some workmen in factories suspend the wheel by a fine iron wire doubled, the ends of which are formed into hooks, so that the wheel is maintained flat without being in any way strained. A gentle circular movement is given to it while held in a small lamp flame, so that the heat may be uniformly distributed; and it should be in a dark room, in order that the required tint may be the more easily observed. The wheel, held perfectly flat, is immersed in oil as soon as it assumes a cherry-red tint throughout; and this temperature must not be exceeded, lest the metal be burnt. Very great skill is necessary to perform this operation with perfect success.

A Paris watchmaker used to harden his escape-wheels by heating them while completely surrounded with iron filings. He found this method to make the wheels very hard, and they were not distorted.

Some workmen enclose the wheel in a small copper box like a watch barrel without teeth and provided with a lid which enters freely and rests on the flat of the teeth. The whole is heated to a cherry-red and plunged in oil.

Others place the wheel between two plates which are not screwed together but are held in position by three or four pins.

Others again employ a tube heated by a lamp. As soon as the tube is hot the wheel is held flat (with an iron wire) in the middle of it and transferred to the bath of oil immediately on assuming a cherry red tint.

The following method is, however, best for those who have not considerable experience in hardening delicate objects.

A plate of iron, or preferably of red copper, about 5 millimetres (0·2 ins.) thick is hollowed out to a depth of 1 or 2 millimetres. It should be provided with a handle, or formed so that it can be easily held in the pliers. This plate is rested on burning fuel (glowing turf is best) in a small furnace. Immediately on acquiring a cherry-red colour it is removed, and the wheel is placed flat on its surface. The wheel will thus be heated uniformly merely from its contact with the plate (which should be lightly struck), and, when it is raised to a cherry-red tint, should be introduced horizontally into the oil.

The reason why the plate should have a certain mass is evident; if too thin it would lose its heat rapidly, and thus be incapable of raising the temperature of the wheel to the requisite extent.

A method of hardening in which the oxidation of the metal is avoided, and that may be applied with advantage to these wheels, was suggested by F. Houriet for hardening spherical balance-springs.

497.—*Houriet Process.*—"The core on which the spring is coiled is to be enclosed in an iron cylinder, and fixed in its place by a brass lid held by very slight friction. This cylinder is placed concentrically in an open iron cage mounted on supports. At the upper end of the cylinder, that is to say, at the end opposite the brass cover, is screwed a long rod terminating with a T-piece, so that the cylinder can be rotated without inconvenience from the heat. The cage thus arranged is introduced into a small charcoal furnace, taking care that as much heat as possible is applied at the circumference of the cage, so that the spring may be uniformly heated throughout; the handle is turned from time to time in order to make this uniformity the more certain. When the cylinder is sufficiently heated it is withdrawn by means of the handle, and at once introduced in a vertical direction into slightly warm water; the brass cover of the cylinder is first chilled, and as it is more expanded by heat than iron, it becomes detached and falls to the bottom of the water; the core immediately follows it, and the balance-spring is thus hardened without being in any way damaged by the air. As in this state the spring is hardened to a maximum it could not be used without at once breaking, and must be tempered with oil in the ordinary way; it then assumes a bronze tint which in no way disfigures it."

Completion and Correction of the Wheel.

498.—The inside and outside of the wheel and the flat of the teeth are now cleaned with great care, for the metal is very brittle from being hardened to its highest point; and when thus cleaned the wheel is tempered, being adjusted with slight friction on the end of a brass rod, which is held in the flame at a distance of about an inch from the wheel. This brass wire must be rotated between the fingers, so as to ensure that all parts are equally heated. As soon as the blue tint, commencing at the centre, has reached the feet of the pillars, the wheel is dipped in water, for the teeth must, so far as possible, be tempered to not more than a straw-yellow; if let down farther, although less fragile, they are not so well adapted to preserve the surfaces of the cylinder edges.

Or the wheel may be tempered by laying it on a plate previously heated, and at the same time resting on the flat of the teeth a rather heavy steel collet. As the temperature of this latter can only be raised gradually, it follows that the flat of the wheel and the feet of the pillars may be let down to the requisite degree before the teeth themselves have changed colour. But if some teeth do not touch the mass of steel, or only do so imperfectly, these will change colour more rapidly and to a greater extent than the others.

499.—The wheel is often distorted in the process of hardening, and it may be corrected as follows:—

A disc of steel, hardened and let down to a blue colour, is turned with its faces perfectly flat and parallel, and of such a size as to fit the interior of the wheel. The wheel, fitted with this disc, is gripped in a kind of clamp, the jaws of which are provided with flat, well-fitting buttons; the whole is then held above the flame of a spirit lamp until the disc assumes a blue and the wheel a yellow tint, when it is placed in a vice and allowed to cool. Or the pressure may be applied by means of a weight, providing it is sufficient.

500.—The wheel is now placed on an arbor and delicately touched with a hard stone and oil, or in the manner adopted with duplex escape-wheels (**553**). The inside is smoothed with fine white oilstone-dust, as already explained; but a very light bow must be used lest the polisher slips, or the wheel, which it is necessary to hold with extreme care. When it is desired to impart an extra smooth surface to the inside, this may be accomplished with a wooden polisher and oil, supplemented by the residue left by the steel polisher.

The heels are prepared with a flat iron file and oilstone.

The inside of the U-spaces and the curved surface of the pillars are smoothed in the pillar tool, the steel cutter being replaced by a ruby cutter, or by one of soft steel roughened with a file. The arms of the wheel are smoothed with an iron file, and finished off with a piece of wood.

The lower face of the wheel and the flat of the teeth are stoned down, as we have already indicated, on a sheet of ground glass, a smooth piece of iron, or a lap.

501.—After verifying all the spaces, in order to make sure that none of the teeth have been distorted in the hardening, the heels are very slightly rounded with a polishing iron and coarse rouge (or a ruby file). They are polished first with medium and then fine rouge, and finally the angles, the points of the teeth, and the inclines are finished with a burnisher. These inclines, however, may, for their better preservation, be polished and burnished *lengthwise* in the tool used for their formation. It will be remembered that the incline itself is to be what is known as *beaded*.

The inclines of the commoner class of escape-wheels produced in factories are polished in the foot-lathe with a strip of spring charged with rouge, which, being fixed to the rest of the lathe, is drawn along the inclines. It cannot be considered a satisfactory method, as it is essential that the points and heels of the teeth be afterwards polished by hand; but being very expeditious it should be mentioned.

It is fully described and illustrated by a figure in Chapter VIII. (Article **509**).

The wheel is cleaned with soap and water applied gently with a brush of moderate strength; it is then transferred first to pure water, and afterwards to spirits of wine. On removal it is delicately wiped until quite dry with a fine linen rag, followed by a soft brush.

To Pivot an Escape-wheel Pinion and set the Wheel in Position.

502.—When the old pinion is available it is easy to make a counterpart, and accurately adjust the several dimensions.

But, in the absence of such exact data, either of the following methods may be adopted for determining the position the wheel should occupy; and, with this known, it is easy to fix where to turn the rivet and the two pivots.

(1) A brass washer is placed in the escape-wheel hollow of the plate, and the wheel itself is laid upon it. The wheel is thus held against the cylinder, and it is only necessary to gradually reduce the thickness of the washer until these two mobiles are suitably placed with reference to each other.

The height of the rivet above the shoulder of the bottom pivot is equal to the distance between the jewel-hole and the upper face of the washer, a distance which may be easily ascertained by any one of the following methods.

(2) A thin disc, similar to the flat of an ordinary wheel, and cut away at *a* (H, fig. 7, plate IV.) is laid in the hollow of the plate. It rests on three small screws as feet; two of these are short, and stand in the escape-wheel hollow, while the third is longer, as it is supported in the hollow of the fourth wheel.

By turning the screws the disc is caused to lie in the horizontal plane that the escape-wheel should occupy, the projecting piece *d* of the disc lying in the middle of the banking slot of the cylinder.

The distance between the lower jewel, in the plate, and the under surface of the disc H, is now measured with very great accuracy either by a small rule (R, fig. 7, plate IV.), in which a slot is cut, held vertically over the pivot-hole *a*, or by the adjustable square (C, fig. 37, page 270), resting its pivot in the pivot-hole. This measurement gives the exact distance between the shoulder of the rivet and that of the lower pivot.

The escape-wheel bar having been fixed in position, the workman now measures, carefully and without bending the bar, the interval between the two jewels; this gives the point at which the shoulder of the top pivot should be turned.

If these several operations have been properly performed, it only requires a little attention to ensure success.

Some watchmakers finish off the rivet and pivots before riveting the wheel in position. They use an ordinary thin screw ferrule, or one having two screws sunk in the groove and clamping between the leaves of the pinion, or a plain ferrule chamfered on either side, in which the pinion is fixed with wax.

Others first complete the rivet and the top pivot; they then fix the wheel, cement a very light ferrule, such as that shown in side elevation at F (fig. 7, plate IV.), to the flat of the teeth, and finally turn and finish the lower pivot.

The surface of this ferrule must, of course, be covered with sealing wax after it has been heated to a sufficient degree, and it should be detached from the wheel in the manner explained when speaking of the cylinder (**476**).

It is best to use a pliable black horsehair, or ordinary hair, on the bow, as the hand is less sensitive to the varying resistance of the work when one of greater stiffness is employed.

CHAPTER VIII.

MISCELLANEOUS TOOLS.—TO RE-SET A RUBY CYLINDER.

Incline Gauge.

503.—Two strips of steel, as *a b c d* (fig. 1, plate IV.), are carefully shaped with the file, and, after drawing the line E G, the position of the centre or hinge is marked at *r*; the length

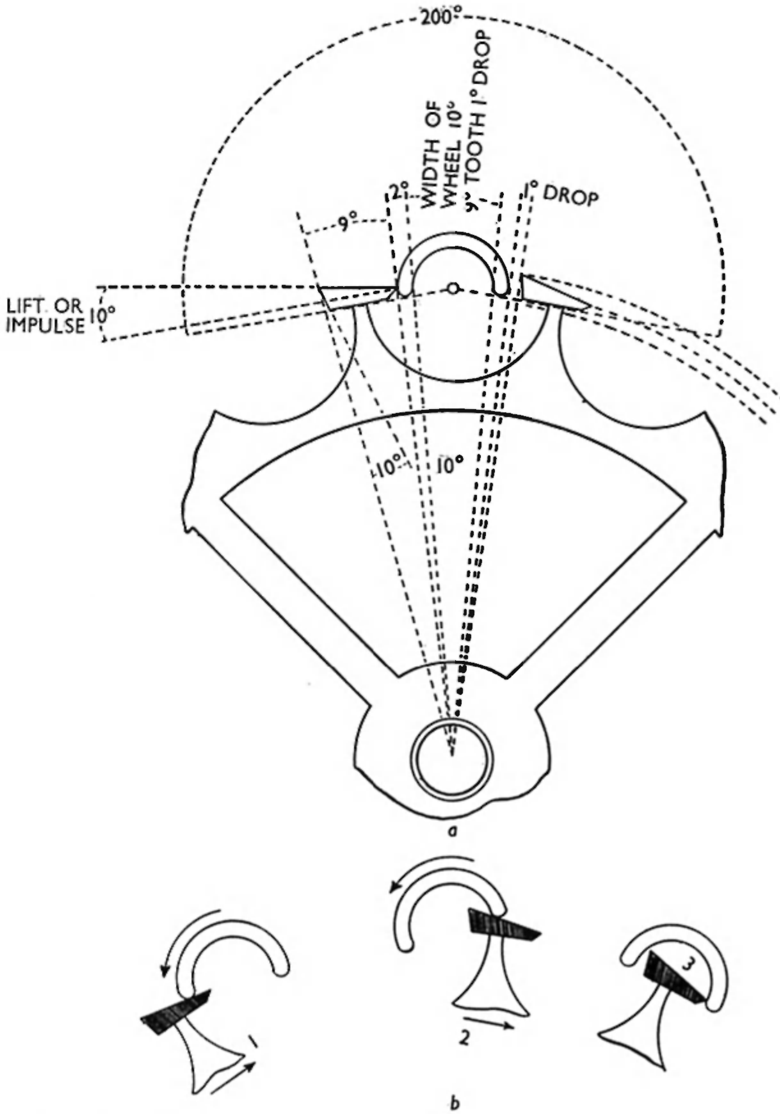

Figure 78. Cylinder escapement with 10° impulse or lift using a wheel of 15 teeth. The impulse given to the entrance lip is shown at (1). Impulse given to exit lip (2) and (3) shows the tooth locked inside the cylinder.