EDITOR'S PREFACE

In this practical handbook on the cleaning and repair of domestic clocks, a clever and practical horologist, who prefers to hide his identity under the initial "G." gives the result of a life's experience at the watch and clock trade. Writing with authority, he is yet able to put his instruction into such simple form that no reader will have difficulty in understanding it.

It will be seen that the book has a very wide scope and that it covers almost every conceivable job that comes the way of the clock repairer, either amateur or professional.

B. E. J.

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CONTENTS

CLOCK CLEANING AND REPAIRING

CHAPTER I

How a Simple Clock Works

A Spring-driven Pendulum Clock.—It is customary to regard the mechanism of a clock as something that is either mysterious or remarkably complicated. As a matter of fact, the ordinary domestic clock is neither one nor the other. The cheap wood-cased clock of American or Continental origin has a works or movement of the kind shown in the photographs (Figs. 1 and 2) and in the diagrammatic plan and elevation (Figs. 3 and 4). A pendulum (not shown) hangs from the split stud illustrated at o (Fig. 1), its stem passing through the wire loop or crutch shown. The wheels are driven by spring-power, there being a mainspring which turns the main-wheel axle ("arbor") to which it is fixed. The main wheel drives a pinion on the shaft of the second wheel, which wheel, in turn, drives (*a*) the pinion on the axle of the third wheel, and (*b*) the wheel on the arbor of the minute hand. Taking (*a*) first, the third wheel drives the escape wheel by means of the pinion on the arbor of that wheel, but the speed of the escape wheel is regulated by the escapement, which consists of a pair of

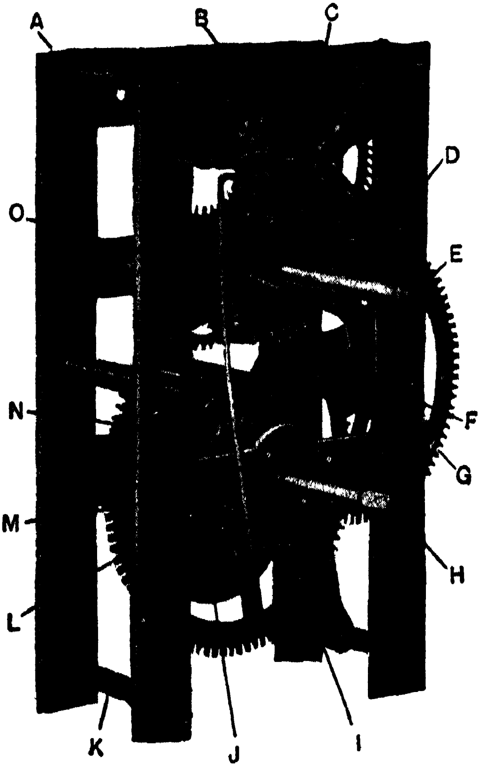


Fig. 1.—Cheap American or Continental Clock Movement: Motion-work Side

A, frame; B, pallets; C, escape wheel; D, centre for hour hand; E, centre square for minute hand; F, hour wheel; G, second wheel; H, winding square; I, main spring hooked to pillar; J, main spring coiled up; K, pillar; L, main wheel; M, crutch; N, clickwheel on main wheel; O, split stud for pendulum.

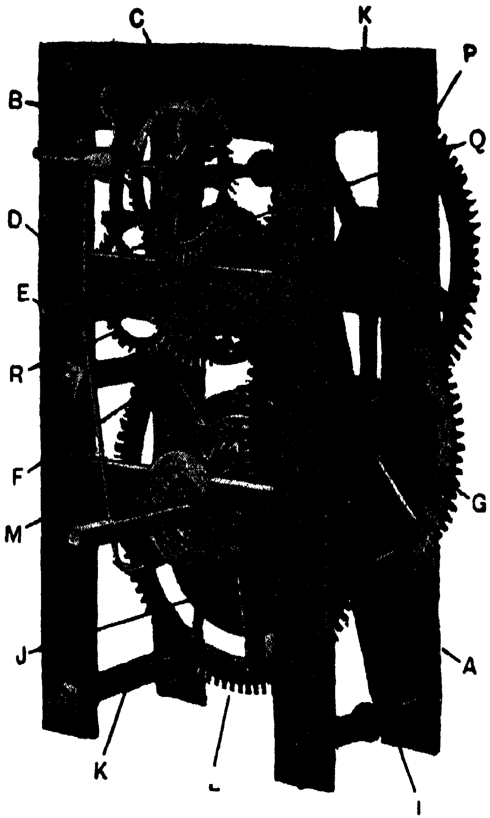
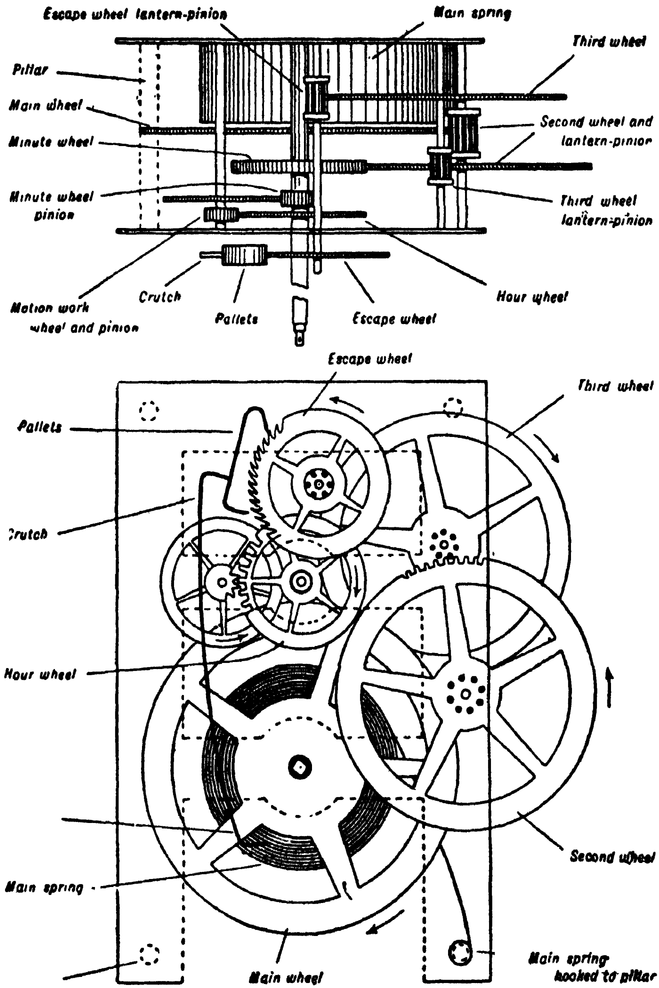


Fig. 2.—Cheap American or Continental Clock Movement: Third-wheel Side

A, frame; B, pallets; C, escape wheel; D, centre for hour hand; E, centre square for minute hand; F, hour wheel; G, second wheel; I, main spring hooked to pillar; J, main spring coiled up; K, pillar; L, main wheel; M, crutch; P, third wheel; Q, minute wheel; R, motion-work wheel.

pallets which allow only one tooth to pass at a time. To the pallets is attached a bent wire known as a crutch, which communicates the necessary impulses to the pendulum, the length of which is carefully determined. Whilst, therefore, the mainspring provides the necessary energy to cause the wheels to revolve, the speed at which they do so is controlled by the escapement and pendulum. It will be remembered that the second wheel imparts motion to the minute hand direct by means of the toothed wheel fixed on the minute-hand axle; and this is the only connection between the running mechanism and the clock hands. There must be means of moving the hour hand at one-twelfth the speed of the minute hand, and this means consists of a simple reducing gear known as "motion work." The plan (Fig. 4) shows an axle to the left of the minute-hand arbor and parallel with it. This axle carries a wheel and pinion as shown, these meshing respectively with a pinion on the minute-hand arbor and with a wheel mounted on a sleeve, tube, or "pipe" which surrounds the minute-hand arbor and carries the hour hand. Thus, the first arbor drives the second one at a slower speed than itself; and the second one drives the hour-hand pipe at a still slower speed. Study of the diagrams will show clearly how this is accomplished. The above description includes all the essentials of the plainest type of domestic spring-driven clock.

The Escapement.—The most important part of a clock is the escapement, while at the same time it is the most difficult to understand and put into correct



Figs. 3 and 4.—Plan and Elevation of Cheap American or Continental Clock

going order. A little inaccuracy in the escapement is quite sufficient to spoil the going of a clock, or even to stop it altogether.* There are many amateur clock-makers capable of cleaning clocks and putting them together correctly; but they frequently fail to detect escapement faults, and they therefore render their work of no avail.

All pendulum escapements consist of an escape wheel and a pair of pallets (see Figs. 3 and 4). The object is to regulate the running of the train of wheels, only allowing one tooth of the escape wheel to pass at a time, and that at definite and regular intervals. The pendulum is the time measurer, and at each swing, or "vibration," as it is termed, it moves the pallets, allowing a tooth of the escape wheel to pass at each swing. At the same time, the power of the clock derived either from a spring or a weight is transmitted to the pallets, and through them to the pendulum by means of the "crutch," giving it a little push or impulse at each swing, just enough to keep it going.

It will therefore be seen that the escapement has a double duty to perform. First, it has to transmit the power to the pendulum, and, second, it regulates the running of the clock. In transmitting the power to the pendulum there must be as little wasted as possible, or sufficient may not reach the pendulum to keep it moving through a large enough arc to allow the escape-wheel teeth to pass. This suggests a common cause of stoppage.

A Weight-driven Pendulum Clock. — This is much the same as the spring-driven clock, but the

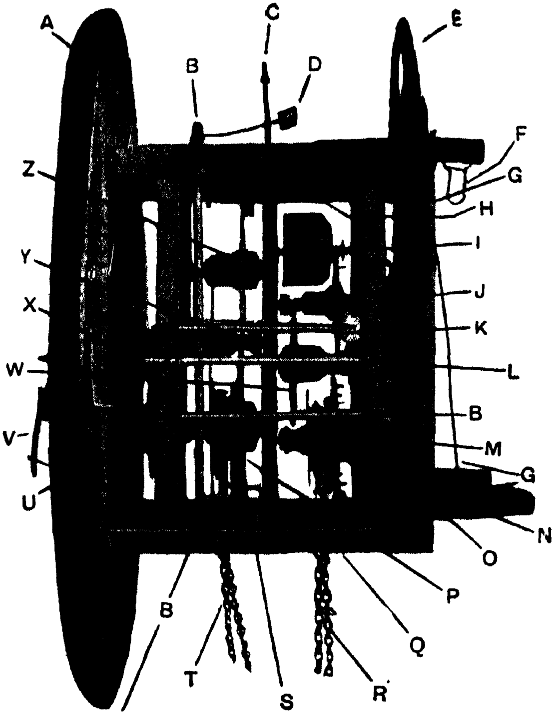


Fig. 5.—Movement of Dutch Clock

A, board of frame and dial; B, hammer detent and spring; C, bell stand; D, hammer head; E, hang-up back board; F, pendulum suspension; G, crutch; H, verge and pallets; I, fly and pinion; J, warning wheel; K, locking detent; L, lifting detent; M, locking plate; N, pin wheel; O, feet (to keep board clear of wall); P, going train wheel and pulley; Q, frame; R, chain (striking mechanism); S, going-chain wheel; T, chain (going); U, two-hour wheel and lift pins; V, hand; W, hoop wheel; X, hour and minute wheels; Y, third wheel; Z, escape wheel.

driving force is a weight suspended by a cord or chain which tends to turn an axle, and does succeed in doing so by a slight amount when the escapement permits a tooth to pass. The movement of a typical weight-driven clock—the Dutch—is shown by Fig. 5. In this the wheels are of the ordinary kind, but often the pinions (the small, wider wheels) are of the kind known as "lantern" pinions (Fig. 6), which consist of two sides, known as shrouds, connected together by a number of round rods, known as trundles, the number of which depends on requirements.

Fig. 6.—Two Elevations of "Lantern" Pinion

A Spring-driven Balance Clock.—Neither of the clocks so far described is truly portable. Moving them means a temporary interference with their time-keeping function. The commonest portable clock is, to all intents and purposes, a large edition of a watch (see Fig. 7). Instead of a pendulum, it has a balance (see A, Fig. 8), which is a flywheel mounted on pivots so as to spin quite freely. Attached to it is a hair-spring which causes the balance, when given an impulse, to vibrate backwards and forwards, moving a less and less distance each time, until it comes to rest. It thus acts in a similar way to a pendulum and forms a time measurer, because each vibration, whether long or short, is performed in a certain time. By connecting such a balance and hairspring with a suitable

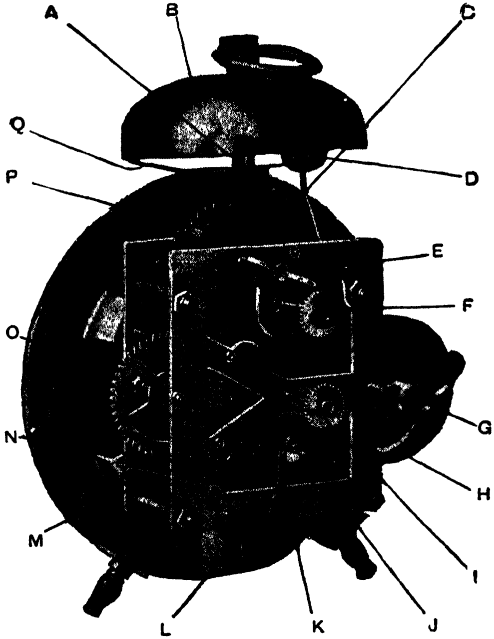


Fig. 7.—Movement of Ordinary Lever Drum Alarm Clock

A, bell or gong standard; B, bell or gong; C, alarm escape wheel; D, hammer; E, alarm winding key; F, set-alarm nut; G, winding key; H, main spring; I, set-hand nut; J, plate or frame; K regulator; L, balance and hairspring; M, lever and pallets; N, escape wheel; O train wheel; P, alarm spring Q, alarm silencer.

escapement, that, like a penaulum escapement, will give the balance a little impulse at each beat to keep it going, and at the same time allow one tooth to pass the pallets B, a timekeeper will result which is nearly as good as a pendulum clock, and is portable, for clocks with balances may be moved or carried about in various positions without greatly affecting their accuracy. There is no crutch attached to the pallets, as in a pendulum clock. Its place is taken by a lever E, at one end of which is a fork which engages with the

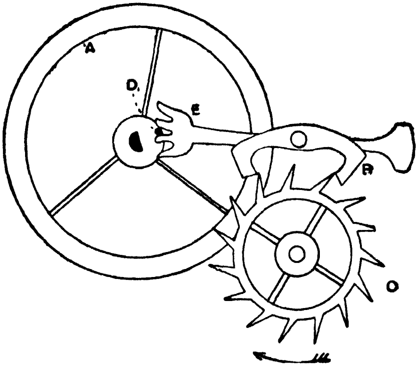


Fig. 8.—Escapement, Lever and Balance of Drum Clock

impulse pin D, and so gives impulse to the balance A. The other end of the lever is enlarged merely to balance it. This escapement, which is common to all lever drum clocks, is further referred to on p. 95.

It may be said that a watch lever escapement acts in exactly the same way as these drum-clock escapements; but the parts are more accurately and more solidly made, the impulse pin being a ruby and the lever of hardened steel polished, etc. In general, a study of these clocks will go far towards explaining the action of a lever watch

CHAPTER II

Clock Repairers' Tools and Materials

It is not proposed to deal with tools and materials at length, inasmuch as the space in this book is wanted for practical instruction on watch cleaning and repairing, and the workman can undertake a variety of jobs with quite a small tool outfit. The tools illustrated

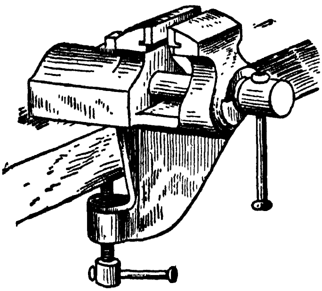


Fig. 9.—Parallel Bench Vice

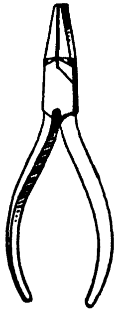


Fig. 10.—Square-nose Pliers

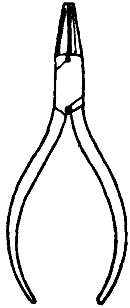


Fig. 11.—Round-nose Pliers

will be useful in different sizes for both watch and clock work. Indeed, ordinary watchmakers' tools are used, supplemented by a larger pair of pliers, a stronger screwdriver, a pair of hand tongs, and larger broaches, drills, and files. A clock lathe is longer, but otherwise similar to a watch lathe. There must be: A suitable bench or board; a vice (Fig. 9), several pairs of pliers and tweezers (Figs. 10 to 15); cutting nippers; a pair of sliding tongs (Fig. 16); a stout pin-vice (Fig. 17); and a strong hand vice (Fig. 18). Of screwdrivers several are required: a watch screwdriver (Fig. 19) for one, and another with a blade ¼ in. wide and a good strong handle. A star key or an adjustable key is a necessity. A stake and several small punches, round and flat ended, and a pillar file and a potance file will be required in addition. Also a set of broaches for opening out holes, similar to watch broaches, only larger, some clock drills and a drill-stock (those bought ready-made answer every purpose), and a good cane-bow made from a half-penny cane: a nice thin one, about 18 in. long, and strung with crochet cotton. Some clock peg-wood and one or two fine emery sticks (emery-paper on wood) will almost complete the outfit. Those who possess a small lathe of 2½ in. or 3 in. centre will find it very useful for drilling and turning arbors, pinions, etc., and also for cleaning up certain parts. Special watch and clock lathes are shown by Figs. 20 and 21, and turns by Figs. 22 and 23. Steel turns are preferable to brass because the back centre is adjustable to any distance along the bed on which it is fixed; therefore it is capable of doing a greater variety in turning. The turns as a means of turning is almost obsolete, as all the work that can be done in the turns can be accomplished in a lathe, in a great deal less time, and for this reason it would be idle to follow the example set by earlier books on watch and clock work, which often deal at length with the method of using turns. An average worker using the turns would stand a poor chance in competition with a man

Fig. 12

Fig. 13

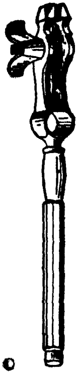


Fig. 17.—Dog-nose Pin-vice

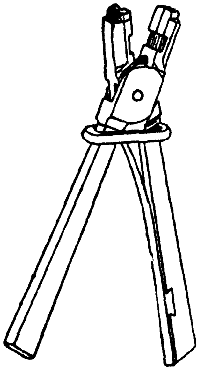


Fig. 16.—Dog-nose Sliding Tongs

Fig. 14

Fig. 15

Figs. 12 to 15.—Various Tweezers

Fig. 19.—Watch Screwdriver

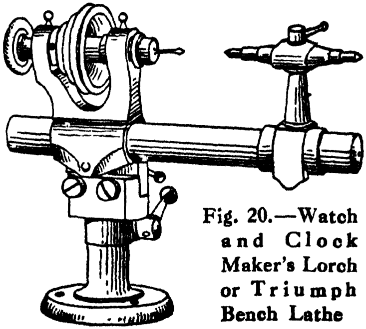


Fig. 20.—Watch and Clock Maker's Lorch or Triumph Bench Lathe

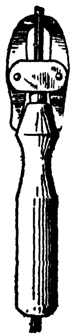


Fig. 18.—Lowell Hand Vice

of similar ability using a lathe. There is no comparison in the speed, taking quality of the work into con-

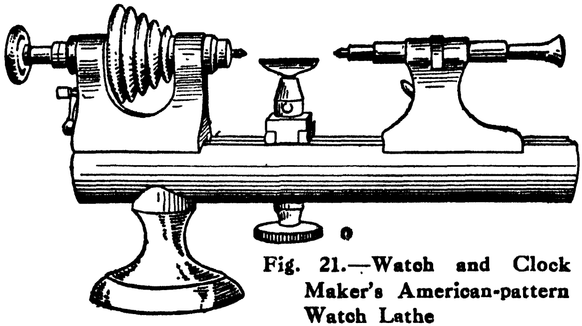


Fig. 21.—Watch and Clock Maker's American-pattern Watch Lathe

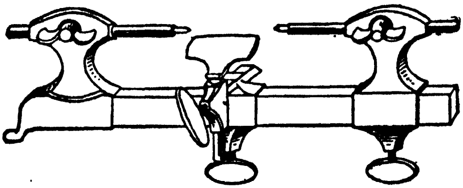


Fig. 22.—English-pattern Turns

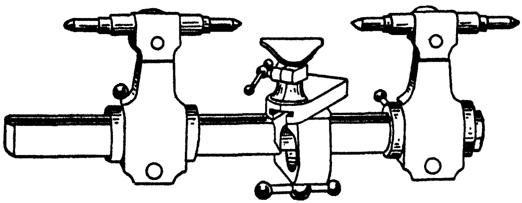


Fig. 23.—Boley-pattern Turns

sideration. The special hammer is shown by Fig. 24; the oiler by Fig. 25; the oil-cup by Fig. 26; the brush by Fig. 27; and the eyeglass used for watchwork and fine clockwork by Fig. 28.

Petrol will be required for dissolving the old oil and grease, and there must be a bowl to put it in; rotten-stone for scouring; and a brush already illustrated (a

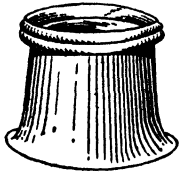


Fig. 28.—Eye-glass

Fig. 24.—Watch and Clock Maker's Hammer

Fig. 25.—Oiler

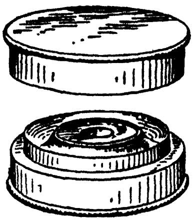


Fig. 26.—Oil-pot or Oil-cup

Fig. 27.—Brush

soft clock brush) to use with it. Hot soda water and soap are also used for removing oil, etc., but thorough drying afterwards is required, and every detachable part must be first removed, as otherwise the wet will remain and rust in all crevices. The following is good for cleansing clock plates: Boil 8 oz. of soft soap in 1 gal. of water, and when cold add 8 oz. of ammonia

Soak the plates, etc., in the solution until clean, and then well brush. Hyposulphate of soda is the simplest and most effective cleansing solution for silverware, it operates quickly and is cheap. A saturated solution should be made. A moistened brush or rag cleans strongly oxidised silver surfaces quickly. The article should afterwards be well washed.

Clock oil is generally refined sperm oil, though other oils are used. The essential properties are: it should not dry up or set hard for several years, it should remain fluid at low temperatures (say to 15° below freezing), and it should not decompose or corrode the metal plates or pivots. On clocks of any value it is not advisable to use any other than the best quality clock oil. "Kelly's" oil is reliable. Oil drying off is a common occurrence, and is attributed to too much oil applied to the pivot holes (any oil getting over the oil sink is drawn away by capillary attraction); particles of dirt left on the pivots or in the holes; particles of rust left on the pivots; or inferior oil.

For turret clocks sperm oil, as used for small machinery, does very well; and may be thinned, for the lighter moving parts of the clock, with just a little paraffin. A more highly refined oil is required for grandfather clocks; for these, ordinary clock oil as purchased at material shops should be used. Most clock oil is refined sperm.

For polishing and grinding, whiting and a soft brush and fine emery will be required.

CHAPTER III

General Repairs to Escapements

Worn Pivots.—Power is wasted sometimes by worn and rough pivots to the escape wheel and pallets. Therefore, make a point of examining them, and if they are rough, polish them. Side-play of the pivots in their holes will also waste power; it is remedied by bushing the holes and making them a good fit. Another cause of wasted power is want of smoothness of the pallet faces. Often they are worn into ruts and holes, and will need to be smoothed and polished.

Adjusting the Pendulum Crutch. — Pendulum clocks nearly all have a "crutch" attached to the pallets for the purpose of driving the pendulum. Sometimes the crutch is a loop or fork, in which the pendulum rod hangs. At other times the crutch has a pin that enters a slot in the pendulum rod. In both kinds the principle is the same. The crutch should not bind the pendulum rod, but be quite easy and free, and it should have hardly any perceptible side-play. If it has side-play or "shake" it will waste much of the impulse that should be transmitted to the pendulum. If it is in the least tight, it will cause such a resistance as to stop the clock.

The pendulum rod itself where the crutch touches it should be smooth and polished, and the crutch polished to diminish friction. Although the centre of suspension and motion of the pendulum is supposed to be in line with the centre of motion of the pallets, and the two should work together as one, yet in practice this is an impossibility, and there is always a little sliding friction at the point of contact of the pendulum and crutch, just sufficient for any roughness or tightness to cause stoppage. A trace of oil (not a big drop) should always be placed here.

Another little point is that the pendulum rod should not rest against the bottom of the slot in the crutch; but should be about its centre, so that it is free to move a little backwards or forwards.

As the foregoing faults are common to all pendulum clocks, the way to remedy them will be first described, and other causes of wasted power peculiar to individual types of escapements will be left until each special escapement is treated.

Repairing Pivots. — A worn pivot should be levelled down by turning in a pair of turns or a clock or watch lathe. Or it may be rested on a brass or steel runner with a hollow in it, and filed down while revolving. When levelled down it must be smoothed by a watch-pivot file, and finally by a flat burnisher, all the while rapidly revolving. This gives an ordinary or common finish. A better finish may be given by smoothing with oilstone dust and oil mixed into a paste and spread on a flat steel polisher made of soft mild steel. This has its surface filed flat to impart a slight grain and give a hold to the polishing material. The polisher may be 8 in. long, $\frac{3}{16}$ in. wide, and $\frac{1}{16}$ in.

thick, and is used as a file or emery stick would be, being held flat on the pivot and moved to and fro as the latter revolves in the lathe. When the oilstone dust ceases to cut, wipe it off, re-file the surface of the polisher, and apply fresh.

When smoothed until no cuts or turning marks remain, clean off and re-file the polisher, thoroughly clean the pivot, and charge the polisher afresh with a paste made of red-stuff and oil. Red-stuff is a polishing medium bought at clock-material shops, and looks like dark rouge. Use this in the same manner as before, until a brilliant polish is obtained on the pivot.

Fig. 29.—Polishing a Pivot between Lathe Centres

This polishing process would be altogether out of place in a cheap American or Continental clock, but is worth doing in a good movement. A section of the polisher as it lies on a pivot in the lathe is shown in Fig. 29, where A represents the polisher, B the back centre, and C the wheel arbor. A bevel will be noticed on the edge that touches the pivot shoulder.

A rough-and-ready way, better than none at all, is to file and burnish worn pivots down by hand, holding the arbor in a pin-vice, and resting the pivot on a box-wood block in the bench vice. When very carefully done this is passable, and is often the readiest way to do up a pallet staff pivot that has a long crutch fixed to it, and cannot easily be revolved in a lathe. But to make a really good job of such a pivot the crutch must be got off somehow if possible, and put on again after the pivot has been burnished.

Bushing Pivot Holes.—A worn pivot hole is bushed by broaching it out with a broach (sold at clock-material shops), and inserting a brass "bush" (also sold for the purpose). For small clocks, bushes can be bought that are already cut off in short lengths; for larger clocks like grandfather and English dial clocks brass bushing wire is used. Bushing wire is brass rod drawn with a hole through its centre, like a brass tube with a very small bore.

Suppose a clock has a wide worn escape pivot hole. A bush or a piece of bushing wire is selected, the central hole of which will not quite go on the pivot. This is very slightly and evenly tapered down with a file on the outside at one end. The pivot hole is opened out by broaching until the bush goes in tight, not quite through the plate, oil being used with the broach. The wire is then cut off and filed on each end, so that, according to the judgment of the workman, it can be hammered into the plate flat and not project much. The bush is then inserted from the inside of the frame plate, hammered in until the inside surface is flush and level, and then riveted a little with a punch on the outside where the oil sink is. The inside surface can then be smoothed by a fine, flat file, followed by grinding with Ayr-stone or slate and water until level, and, if desired, polished with Globe metal polish on a rag. Globe metal polish, it may here be observed, does well for polishing clock plates; but should be well washed off afterwards with benzoline or petrol.

The outside surface of the bush may be chamfered out to the level of the oil sink with a circular-faced cutting tool or drill, to form a nice finish. Finally the new bush is opened out by broaching until it fits on the pivot, and when the wheel is put in the frame it spins quite freely and has a sufficient amount of end-shake. In opening out a bush by broaching to fit a pivot, the broach should be kept quite upright, or else the hole will be made too large before the wheel will spin freely.

Some clockmakers for a rough job punch up worn pivot holes to close them. This is a bad practice, as it knocks the plates about, and, after all, only closes the edges of the pivot hole, which very soon wear down again.

Smoothing Pallet Faces.—Steel pallets are, or should be, quite hard, and therefore cannot be filed. When worn they can be smoothed down level with emery sticks (paper on wood), or by a soft-iron polisher like the pivot polisher already described, but larger and wider, used with a paste of emery and water. To polish them, for ordinary clocks use a finer emery stick, and a finer still, until a 0/3 is used to finish, the strokes being made lengthwise on the pallet faces and not across them. This emery stick will leave almost a polish. For a clock of special quality follow this with a flat pivot polisher and red-stuff and oil, as previously described for polishing pivots, the pallets being screwed in the bench vice.

Repairing a Crutch.—The inside of the fork of a crutch or a slot in a pendulum rod should be burnished smooth with an oval burnisher set in a wooden handle, using a little oil to lubricate it. A crutch that is tight may be eased by a watch-pivot file before burnishing; but care must be taken not to file much off and make it too easy. A crutch that is too wide and rattles should be filed wider on one side, and a slip of brass inserted and soft-soldered in, washing the acid off well with water after soldering. The crutch can then be opened out and burnished to fit the pendulum. Fig. 30 shows what is meant, A being the slip of brass soldered in. If the crutch is a pin and the pendulum rod has a slot, the same method may be pursued and a slip inserted in the pendulum slot. Do not attempt to hammer up or squeeze up a rod or a crutch, as the slot is never smooth or parallel afterwards.

Pendulum Suspension Springs.—A faulty suspension spring will often stop a clock. The spring should be straight and have no buckle or kink in it, or the pendulum will not swing straight. It should also be easy where pinned to the top of the pendulum rod, so that when the pendulum hangs the spring goes exactly in line. Too stiff and short a spring makes the clock require more power to drive it, while a spring too long and thin allows the pendulum to wobble or roll as it swings.

There is no remedy for a buckled or kinked suspension spring; a new one must be fitted. For English eight-day dials, grandfather clocks, or bracket clocks, thin watch spring does very well. Cut off a piece to the correct length, soften it for ¼ in. at each end by heating nearly to redness in a flame, and punch a round hole at each end, broaching them out to take the pins. Suspension springs for American, French and other Continental clocks can be bought very cheaply

Fig. 30.—Brass Slip Soldered inside Crutch

and do not pay to make, as a difficulty is found in obtaining steel spring of suitable thickness, etc.

Pendulum Rods.—Pendulum rods should be straight. If curved the pendulum has a tendency to swing in a curve or roll. The bob should be a good fit, and the rating nut and screw fairly tight. A clock with a loose bob and rating screw is a great nuisance, and difficulty will be found in regulating it.

CHAPTER IV

Recoil Escapements and their Repair

THE escapements of domestic clocks are mainly of two forms. By far the greater number are "recoil" escapements (Figs. 31, 36 and 37); a smaller number, including the best timekeepers, are "dead-beat" escapements (Figs. 39 to 56).

Recoil and Dead-beat Escapements Compared.—A recoil escapement is so called because the 'scape wheel recoils, or goes backwards a trifle at each beat; whereas, in a dead-beat escapement the 'scape-wheel teeth drop dead upon the locking faces of the pallets and remain stationary until the next beat. Recoil escapements are easy to make, cheap, quickly readjusted when worn, and generally easy to maintain in fairly good order; but they cause the train wheels and pinions to wear rapidly, owing to the recoil causing a grinding backwards of pinions on the driving wheels. Also, this form of escapement interferes with the free motion of the pendulum, and controls it instead of leaving the pendulum free.

Dead-beat escapements are more difficult to make correctly, consequently more costly, and they are not so readily readjusted after repair; but they require less driving power and cause less wear and tear, carrying a heavier pendulum and allowing it to swing more freely than with recoil escapements. These mechanical advantages combined result in far superior timekeeping. The best dead-beat escapements have the pallet faces, upon which the wear comes, jewelled as shown in Fig. 32, thus making the escapement almost everlasting.

When a cheap clock, such as an American spring

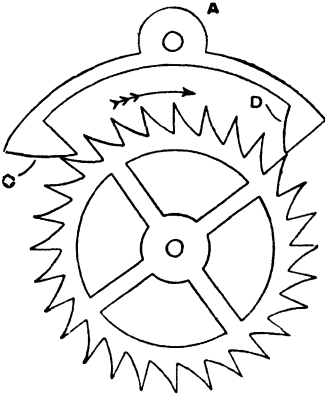


Fig. 31.—English Recoil Escapement

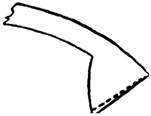


Fig. 33.—Shortening a Pallet

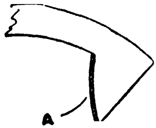


Fig. 34.—Pallet faced with Watch Spring

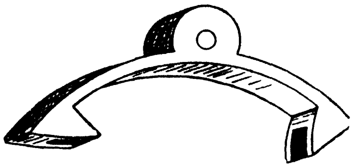


Fig. 32.—Jewelled Pallets

clock without a fusee, is first wound up, the motive power is very great, and when the same clock is nearly run down, the power has diminished to perhaps less than half. The effect of this with a recoil escapement and a light pendulum is to make the clock go gradually slower as it runs down. With a heavy pendulum, possible with a dead-beat escapement, the error is less. The last-named escapement has a very small error in the opposite direction, and the same clock fitted with it would gradually gain as it ran down. Therefore, to keep correct time, the escapement must not have much recoil, nor must it be perfectly "dead." A cheap clock with a light pendulum should have an escapement with a moderate recoil only, and a good clock with a heavy pendulum should have a nearly dead-beat escapement, or what is known as a "half dead," that is, a dead-beat with a very slight amount of recoil on the resting surfaces, but hardly perceptible. The amount of recoil is determined by the shape of the pallets.

English Recoil Escapements

"Drop."—Fig. 31 shows an English recoil escapement as used in grandfather, eight-day dial, and English bracket clocks. It will be observed that the face of the entering pallet C lies horizontally, while that of the exit pallet D is about perpendicular. When so, the angles of impulse will be about correct, and when not so, as sometimes will be seen in clocks, the escapement is sure to be faulty. The great point to be observed carefully in this escapement, after noting the impulse faces as above mentioned, is the "drop" of the teeth on the pallets A. When a tooth passes along the face of pallet C and slides off its tip, another tooth "drops" on the face of the pallet D. And when this tooth escapes from pallet D, the next tooth in order "drops" on pallet C. The drop should be small, being just enough to ensure that as the pendulum swings, the pallet point will not catch on the back of the tooth that has just left it. A very small amount suffices for this. Then the drop on each pallet should be equal, and the drop should be equal all round the escape wheel on each tooth.

When the drop is unequal round the wheel, being slight in one place and more in another, it shows that the wheel is not true, or that it is not truly mounted on its pinion. When the wheel is not quite true it can be mounted in the lathe or turns, and rapidly revolved while a very fine file, like a watch-pivot file, is gently held to the teeth points. This should be continued until every tooth point has just been touched. This process leaves a slight burr on the teeth, and this should be removed by a watch-pivot file. If any teeth points are thick they may be filed thinner by a half-round file, operating on the curved parts only. Do not touch the straight sides. The wheel being topped true, if the drop is still unequal at different parts of it, it is caused by untrue mounting on its pinions, and cannot very well be altered.

As before stated, the drop should be equal on each pallet; very often it is unequal, and excessive drop on one or both pallets means power wasted. If excessive on both, the pallets may be brought nearer to the escape wheel by lowering the back cock. Bending its steady pins and filing the screw holes slightly oval will effect a little alteration. More may be done by opening out one pivot hole, filing it towards the escape wheel with a rat-tail file, and re-bushing.

When got as deep or close as it can be set, the drop may be unequal on each pallet. If it is more on pallet C, while there is hardly any at all on pallet D, a little taken off the point of pallet C will equalise matters by allowing teeth to drop off it earlier, and so give more drop on D. Then if too much on both, bring the pallets a little nearer to the escape wheel.

If the drop is too great on pallet D and just right or not enough on pallet C, take a little off the point of pallet D, as shown by the dotted line in Fig. 33, in which the effect is exaggerated. Emery sticks will make these little alterations, and should be used on the backs of the pallets, not on their impulse faces, as shown in Fig. 33. After this, see that there is no burr on the pallet corner. When made equal thus, the pallets may again need bringing a little nearer to the wheel.

If the teeth points catch, there is evidently not enough drop, and a little may be taken off the pallet back, or the pallets may be got a little farther from the wheel. Bringing the pallets nearer to the wheel will always be found to decrease the drop on C and increase that on D, so that if there is insufficient on D and too much on C, simply bringing the pallets a little closer will often do.

Remedying Worn Pallets.—When pallets have been badly worn, and the wear buffed out with emery, there is often not enough metal left in them to correct the escapement in the way just described. Then there are two courses open. The pallets may be softened by making them red-hot, brought much nearer to the wheel by drawing the pivot holes downwards, and then filed up to give correct impulse and drop, following the rules just explained. After this they must be hardened by heating to a bright red and plunging into water, and finally smoothed and polished with emery buffs. An easier method is to face such pallets with pieces of watch spring.

Obtain a piece of watch spring as wide as the pallet faces, file it bright on one side, and tin it with soft solder. Tin the pallet faces, and then, laying on the spring, heat gently until the spring goes down flat. If heated carefully the spring need not be softened, and will then remain at a blue temper that, though not so hard as hard steel, will yet wear for some years, and when worn may be readily replaced. After soldering wash off the acid well with plenty of water, and polish up the faces, adjusting the "drops" as before. Fig. 34 shows a pallet "faced" as described. A represents the piece of watch spring.

Another way of getting over this difficulty when the pallet faces are wide enough is to move them along on their arbor until the escape-wheel teeth work on a fresh and unworn part, when, of course, they will be correct again. A difficulty may perhaps be found in moving the pallets, as very often the brass collet to which they are riveted is brazed on. If so, perhaps the escape wheel can be moved, which will come to the same thing, but is more difficult and needs some skill. Moving a wheel collet bodily along its arbor always throws the wheel a little out of truth, and in moving an escape wheel the wheel should be taken off its collet by turning the riveted part away, the brass collet turned back so that the wheel goes farther on, and the wheel re-mounted and riveted on as before. After re-mounting, the wheel always should be "topped" as before described, and this having a tendency to increase the drop in the escapement, moving the escape wheel is not so good a way of overcoming wear as moving the pallets would be.

A third way is bodily to move the escape wheel and pinion or the pallet arbor, by turning back one pivot shoulder and putting in a "raised bush" at the other end to make the endshake correct. When the escape pinion is badly worn as well as the pallets, moving the escape wheel and pinion thus will correct both faults. Fig. 35 shows an escape wheel and pinion moved thus. A represents the raised bush, B the pivot turned back, and C the plates. The arrow shows the direction in which the wheel has been moved. If it is inconvenient to move the escape wheel in this way, the pallet arbor may be moved instead.

Making New Pallets.—Sometimes pallets are so badly worn, and have been doctored up so many times, that there is really nothing for it but to make and fit a new pair. A steel forging can be bought at the clock-material shop, and will save much heavy filing. Before beginning work on the forging, draw out the escapement exactly to scale on writing paper. Lay the paper on the clock plate, and mark the escape and pallet pivot holes, so as to get the distance of the centres. Then enlarge the escape pivot hole truly until the arbor goes through. Push it through, and press the escape-wheel teeth points on to the paper, so as to get an impression or mark. Now taking Fig. 31, draw in the impulse face of pallet D, its point coming exactly to a tooth point. Let it be vertical and a trifle curved. Draw in the impulse face of pallet c, letting it be horizontal and also slightly curved. Its point should penetrate the escape wheel exactly midway between two teeth, and its face should just touch the tooth point before it as shown. The backs of the pallets should be straight lines pointing to the escape wheel centre. The pallet body may be drawn in any shape.

Then cut out the paper to the exact shape of the pallets. Lay it on the forging, and mark and drill

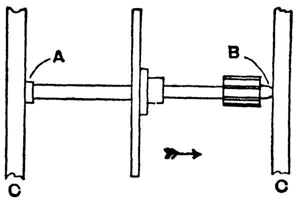


Fig. 35.—Escape Wheel and Pinion moved to New Position

the central hole, after which the outline may be scratched on the steel with a graver point, and the forging filed up to shape and size. When approaching the right size fit the rough pallets on to the arbor rather a tight fit, and place in the clock frame together with the escape wheel, and file a little off as shown to be necessary, so that the teeth can be just forced past the pallets with no drop. In this condition they may be hardened by heating to a bright red and plunging in water. After hardening, place in the frame, and, trying as before, ease the depth and give just a little drop on each pallet by smoothing with buff sticks, finally polishing the impulse faces.

French Recoil Escapement

Setting the Depth. — Fig. 36 shows the ordinary recoil escapement found in French clocks. It acts in exactly the same way as the English recoil escapement, but the 'scape wheel has more teeth than the English one, and the pallets do not embrace so large a portion of the wheel, consequently the angles of the pallet faces are different, and cannot be relied on as an indication of correctness as in the English form. Also, being more "on the top of the wheel," placing the pallets a little closer deepens the action without very much affecting the equality of the drop on each pallet. To alter the depth, the front pallet pivot is always in an eccentric brass disc with a screwdriver slit across it, by means of which it may be turned round, and the pallets moved a trifle nearer to the wheel. When worn, these pallets become cut into grooves, which should be ground out with emery buffs, as before described, and, being small, great care must be taken that the corners are not unduly rounded off. After buffing and polishing, the depth will need a little readjustment by means of the eccentric disc just referred to, and if the drop becomes unequal, a trifle off one pallet back as described in connection with the English recoil escapement will correct it.

Moving the Pallets.—If very badly worn, the pallets of French clocks can easily be shifted on their axis. They fit on a long tapered square, and to get them a little farther along knock them off, reduce the square just the least trifle, and knock them on again. Do not attempt to knock them farther along the tapered square without first reducing the square, or, the pallets being as hard as glass, they will very likely split across the centre hole and be in two parts.

Soldering Pallets Together.—In case such an accident happens, the pallets can be reunited by soft-soldering, pressing them well together as the solder runs, and washing the acid off well with plenty of water, to prevent rusting. When soldered and washed, the square hole may be cleaned out with a fine file, and the pallets replaced on the arbor. Very little force must be used to drive them on, or the soldered joint will part again, so it is best to let them go on fairly easily, and set them by warming a little shellac and making sure it runs well along. The heat necessary to run the shellac will not affect the solder, and it is well to remember that shellac only requires just enough heat to make it liquid. More will only burn and destroy it, burnt shellac having no holding power.

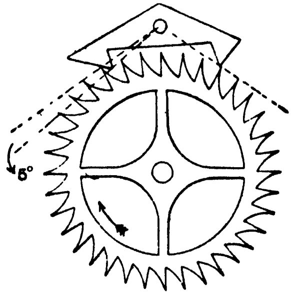


Fig. 36.—French Recoil Escapement

In case this method of repairing a broken pair of pallets is not deemed good enough for the clock in hand, a new pair may be made, following the directions already given for English clock pallets.

American Recoil Escapement

These (see Figs. 37 and 38) are found in nearly all small American pendulum clocks and many of the larger ones. It follows the same rules exactly as the French escapement, as far as setting the depth is concerned. These pallets should not be allowed to rock on their pin pivot. Either fit a larger pin, or bush the brass holes until a good fit is obtained. Also look particularly to the top escape-wheel pivot, and see that it has no side play. These are weak points in this escapement. Should these pallets be very unequal in their drop, it is an easy matter to soften them, bend until correct, and re-harden them. New pallets can be bought for a few pence, therefore it is only wasted time doing much in the way of repairing old ones; but should anyone care to try, the same instructions apply as have been given in connection with the English recoil escapement.

The "American striker" is one of the most general house clocks. Very frequently, it is constructed for cheapness with very thin plates, consequently holes worn wide are quite common, and often cause faults in the escapement. With the hands and dial removed a general view of the escapement is attained. Move the pendulum bob in both directions until a tooth drops, and examine the crutch. The fork of the crutch should be perfectly free of the pendulum rod, with just slight shake. Too much shake is a common fault, and would cause a clock to stop. It means a loss of impulse, and will record itself by the crutch kicking. Closing the slot or fork with a pair of pliers is a simple matter; but care must be taken not to get it tight.

Lift off the pendulum bob, and move the crutch in both directions until a tooth drops, to examine the action of the escapement. The escapement should be as deep as possible to attain the least amount of drop which is required, so that the backs of the pallets are just clear of the wheel teeth. The drops must be equal on both pallets. The pin axle of the pallet centre is fixed to the pallet cock, and the latter can be shifted

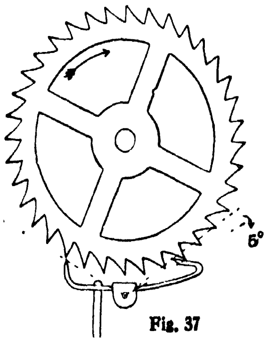


Fig. 37

Fig. 38

Figs. 37 and 38.—American Recoil Escapement

over nearer the centre of the escape wheel in the event of the escapement pitching too shallow.

The next procedure is to examine the pallet and escape-wheel holes. Try the side shake of both with a pair of tweezers. As the plates are very thin, the holes and pivots often become worn wide, which consequently creates a combination of faults in the escapement. To set deeper or shallower an escapement with worn-wide holes is time wasted.

CHAPTER V

Dead-beat Escapements and their Repair

English Dead-beat Escapement

FIG. 39 shows an English dead-beat escapement, such as may sometimes be seen in a grandfather clock or an English bracket clock, and as generally used in regulators. It was invented early in the eighteenth century by George Graham, whose name is often linked with it. The term "dead-beat" is used because the escape-wheel teeth rest motionless on the faces of the pallets between each beat. Each pallet has two acting faces; A is the resting or "dead" face, B is the impulse face.

Mislocking.—In these escapements the tendency of wear is to cut a groove on the dead face and across the impulse face, rounding off the corner, which should be sharp, and causing the teeth to mislock. When a tooth has traversed the impulse face of one pallet, another one should drop on the dead face of the other pallet, as near to the corner as possible without missing it. When the corner becomes worn, the teeth in dropping just miss it and fall direct on the impulse face, instead of being locked motionless on the dead face. This is termed mislocking. To remedy it, the wear must be buffed out of the impulse faces only, and the pallets closed in a vice (their central portion is generally soft enough to bend, and should first be tried with a file). Close them until the teeth just lock again. If the pallets are hard throughout, and cannot be filed anywhere, they must be removed from their arbor and softened in the centre before closing them. With care this can be done without softening the pallet faces themselves.

Or, like recoil pallets, when worn they may be

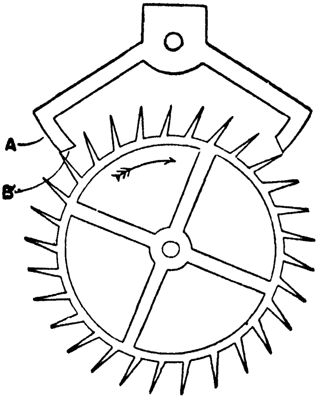


Fig. 39.—English Dead-beat Escapement

moved on their arbor, etc., as described in the preceding chapter. The same directions also apply as to topping the escape wheel, etc.

Jewelling Pallets.—Jewels are inserted in pallets to render them proof against wear (see Fig. 32). To do the work, first soften the pallets by heating. Then slit them where the teeth of the escape wheel traverse them, to a length equal to about twice the run of the teeth, the width of the slit to be one and a half times the width of the escape-wheel teeth. The slits may be cut on a wheel-cutting apparatus or by filing. Then stones—agates or onyx do very well—must be ground flat on both sides to fit the slits in the pallets, and after being ground roughly to shape to follow the outlines of the pallets, may be cemented in by warming and applying shellac. Finally the stones must have their outer surface ground down to the level of the steel pallet faces and polished, trying them in the clock frame as the grinding proceeds, to see that a correct "depth" is being made. An onyx or agate from an old signet ring is a good thing to start upon, as it is already flat on one side and of about the thickness required, and most jewellers have a few such stones amongst their odds and ends. These stones can be ground by emery powder and water on a revolving iron lap wheel or slit by a thin iron wheel fed with emery and water. Putty powder on a hard-wood wheel will polish them. During these processes a tin shield must be fitted to catch the splashings from the revolving lap wheel. The operation requires much patience, as it is a slow one.

Vienna Regulator Escapements

Dead-beat escapements of the same kind as the English, but made slightly different, are found in Vienna regulators and a few other clocks. In these the pallet bodies are often made of brass, in which the pallets lie in grooves. The pallets are curved pieces of steel, and held in place by clamping screws. Fig. 40 shows such a pallet. When the faces of these become worn, the wear may be buffed out, and the pallet advanced by simply loosening the clamping screw. This obviates the necessity of softening and closing the pallets, as in those of English pattern, and is a distinct improvement. When the dead faces of these pallets become so worn that advancing them is not very satisfactory, the pallet may be reversed end for end in its groove, and has a new lease of life, being once more as new.

Many clockmakers who do not give the matter careful study complain of these clocks, and find trouble in

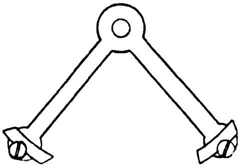


Fig. 40.—Pallets of Vienna Dead-beat Escapements

Fig. 41.—Tooth Locked Properly

Fig. 42.—Tooth Locked too Much

Fig. 43.—Tooth Mislocked

making them work accurately. They are, as a rule, very well made, have light wheels and small pivots, and are driven by a comparatively light weight. This means that they must be kept fairly clean and well oiled; also that the pendulum cannot be expected to swing through a very large arc. As a rule, the pendulum swings very little farther than is necessary to allow the teeth to escape, and there is very little run on the locking or "dead" faces of the pallets. Therefore in these clocks always particularly try the locking of the teeth on the pallets. In many cases where they stop, the teeth lock too much; that is, they fall too far up the dead faces, and not near enough to the corners. This makes a larger swing of the pendulum necessary to allow them to escape, and the power not being sufficient to maintain it, the clock stops. In such cases adjust the pallets so that the teeth only just lock, and the clock will be nearly always cured. Fig. 41 shows a tooth just locking properly; Fig. 42 shows a tooth locking too far up; and Fig. 43 shows a tooth mislocking and falling on the impulse face instead of the locking face.

American Dead-beat Escapement

Some American dial clocks have dead-beat escapements like Fig. 44, and must be served practically the same as the French clock pallets described later. In these clocks, if the pallets begin to rock on their pin, a larger pin must be fitted. As in all dead-beat escapements, see that the teeth just lock and no more. Adjustment is sometimes provided for by a movable stud on which the pallets are mounted. At other times, the bar of the brass frame, or the cock holding the escape wheel in position, must be bent a trifle to correct the locking. Or, failing this, pivot holes may be drawn and bushed, as already described.

French Dead-beat Escapement

The French steel pallet dead-beat escapement sometimes seen in marble and other clocks is shown by Fig. 45. It calls for very little special explanation. Wear must be buffed out on the impulse faces only, and as in these escapements very few teeth are embraced by the pallets, setting the pallets nearer to the escape wheel will cause it to lock properly. The front pallet pivot hole is in a brass eccentric disc, and can be turned with a screwdriver to adjust the depth of the pallets and escape wheel. It will be observed that when only a few teeth are spanned by the pallets, the pallets are, as it were, on the top of the wheel, and setting them a little nearer makes the teeth lock better. When the pallets span more teeth or a larger

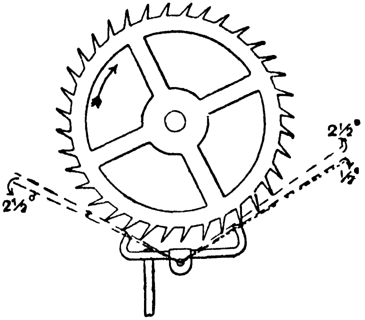


Fig. 44.—American Dead-beat Escapement

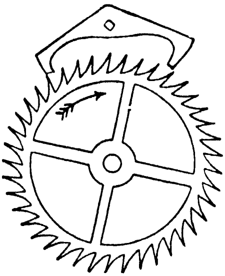


Fig. 45.—French Dead-beat Escapement

part of the wheel, as in English regulators, setting the pallets nearer to the wheel alters the drop, and makes it unequal without making the teeth lock better.

French "Tictac" Escapement

This (see Fig. 46) is found in French brass drum clocks with little, short pendulums about 3 in. long, fortunately not made now. Fig. 47 shows the escape wheel and pallets. The face A is circular, as from the pallet staff, consequently there is no impulse on it, the escape-wheel tooth resting "dead" on it, until it drops on B, which is the single impulse pallet. This arrangement wastes power, and consequently the clocks continually stop, especially when they get a little old, as all now are. Some clock repairers try to alter the pallets as in Fig. 48 by the dotted line, giving the entrance or "dead" pallet a little impulse, and bringing the pallets nearer to the escape wheel to equalise the drop. But this is not a very satisfactory procedure. A better way is to make a new pair of recoil pallets embracing three more teeth. The clocks then go; but they are poor timekeepers.

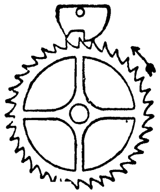


Fig. 46.—French Tictac Escapement

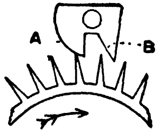


Fig. 47.—Escape Wheel and Pallets of Tictac Escapement

Fig. 48.—Altering Pallet of Tictac Escapement

Some repairers convert these clocks by taking away the pallets and pendulum, and fitting on a platform with a watch-cylinder escapement. But when the cost of this and the labour is counted, also the cost of an extra wheel in the train instead of the old escape wheel, it will be found that a new and better clock can be bought for the money, and the old one discarded or used up as material for repairing.

Pin-pallet Dead-beat Escapements

The best known of this type is the French "visible" escapement often seen in front of the dial in marble clocks of good quality. Fig. 49 shows the escapement. The wheel teeth on the fronts, or acting parts, are straight. Their backs are curved to points to clear the pallets, and have as little drop as possible. The pallet arms are usually of brass, and the pin pallets are round, either driven in tight or cemented in with shellac. When driven in they are made of steel; when cemented, agates are used. The round pins are cut

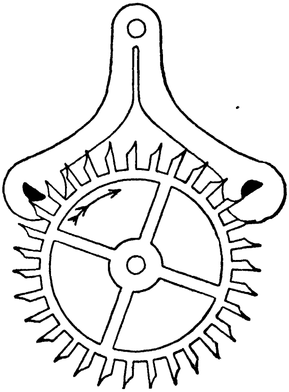


Fig. 49.—French Visible Escapement

Figs. 50 to 52.—Diagrams explaining "Drop" of Escapement-wheel Teeth

away to half, making them D-shaped, having the curved parts as impulse faces and the straight parts as backs. The straight parts should point exactly to the centre of the escape wheel, and the pins should be a little less in full diameter than the space between two teeth points. The pallets should also be set exactly upright in their holes.

"Drop."—This escapement is a puzzle to many inexperienced workmen, but is really simple when its underlying principles have once been mastered. The teeth points should fall exactly on the pin centres when they "drop," as in Fig. 50; then as the pallet continues its motion towards the centre of the escape wheel it slides down the straight front of the tooth, and causes no recoil of the wheel or other movement. In impulse, the tooth point slides off the rounded face of the pin, and, leaving its edge, another tooth drops on to the other pallet as in Fig. 50. If the teeth fall as in Fig. 51, they lock too deeply, and the pallet arms must be separated a little more by bending or by warming and shifting the stone back, until the drop is like Fig. 50. If the teeth drop as in Fig. 52, the locking is not deep enough, and the pallet arms must be closed, or the stone moved towards the wheel.

Then there is the amount of the drop. If too much on the entrance pallet, lower the pallets, bringing them closer to the wheel. If too much on the exit pallet, remove the pallets farther from the wheel. If not enough drop on either and the pallets just catch on the teeth points, while the locking is quite correct, probably one pallet back does not point exactly to the escape-wheel centre. In any case, one or both pallets want a slight twist round, so as to let the teeth points drop earlier.

In a visible escapement, generally the brass escapement cocks are movable a little, and can be strained this way or that as required to adjust the distance between the centres of the escape wheel and pallets. In those in which the pallets are between the plates, the front pivot is carried in an eccentric. like recoil

French clocks. But the locking can only be regulated by either closing the brass pallet arms by bending, or by warming the shellac and moving the stones away from or towards the wheel.

Worn Pallets.—If the agate pallets become worn or chipped, they can be warmed to soften the shellac and pushed in more or drawn out, to bring the action on a new part. After this, some considerable adjustment on the lines already described is always needed, as the stones being a slack fit in their holes, it is nearly impossible to re-cement them in exactly the same positions as before. Should a stone be broken or lost, a new one may be obtained from a clock-material shop and cemented in.

Worn steel pin pallets are best replaced with new ones. Generally they are driven in tight, and may be knocked out. New pins must be very carefully made from steel wire, filed flat to size, and hardened, a good polish being put on finally.

Bent Teeth.—In French pin-pallet escapements there is very little drop, and the teeth points are thin. This being so, a tooth just a little bent causes the pallets to catch it and the clock to stop. Therefore in examining such an escapement it is not sufficient to try the drop on a few teeth; but it must be carefully tested on every tooth of the wheel for a complete revolution, and any faulty teeth straightened.

Worn pivots or pivot holes to the escape wheel or pallets will also cause an apparently correct escapement to catch and stop.

Other Pin-pallet Escapements.—A few clocks have pin-pallet escapements like Fig. 53, in which the impulse is on the wheel teeth, and the pallets are small, round hard-steel pins. The pins wear rapidly, and when worn must be replaced with new ones filed up from needles tempered blue to allow of being filed. These escapements are adjusted like the other pin-

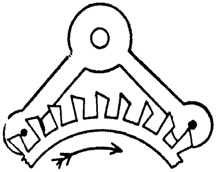


Fig. 53.—Another Pin-pallet Escapement

Fig. 54

Fig. 55

Figs. 54 and 55.—"Drop" of Pin-pallet Escapement Teeth

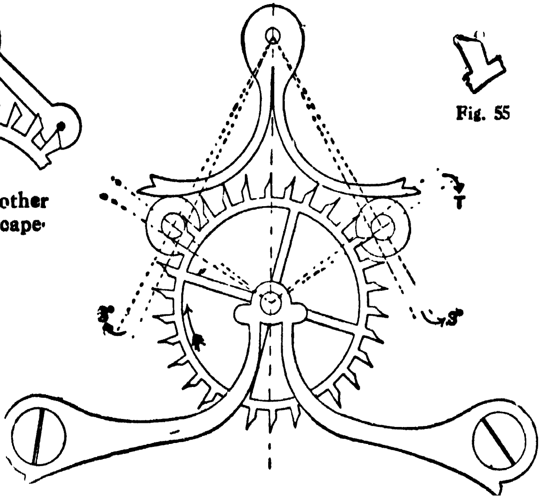


Fig. 56.—Brocot Visible Dead-beat Escapement

pallet ones above described, and the really important point is the locking. The teeth must drop on the pins as in Fig. 54, just below the corner, and as little below as possible. If like Fig. 55, the pallets must be closed and brought a little nearer to the wheel.

Another form of the French visible dead-beat escapement—the Brocot—is shown by Fig. 56.

CHAPTER VI

Cleaning Simple Clocks

THE methods of cleaning two kinds of domestic clocks —the common American or Continental spring-driven pendulum clock and the Dutch weight-driven pendulum clock—will be explained in this and the following chapter.

Whether a clock is English, French, American, etc., can only be told by experience, as the style of workmanship is the main guide. In general, an eight-day clock with a fusee is English, a clock with going barrel, pendulum, and small circular movement with polished plates is French. A carriage clock with polished brass plates is French. Clocks with stamped brass frame plates and lantern pinions are either American or Continental (not French).

Cleaning Cheap American Clock

Taking to Pieces.—The simplest clock for the beginner to take in hand is one in which the motive power, a weight or spring, is applied to a short train of wheels and pinions, and controlled by a pendulum, no striking or alarm work of any kind being added. The ordinary American wood-cased timepiece being a common variety, a start will be made with this kind of clock. In order to get at the works, the first thing to do is to take off the hands. Draw out the pin from the centre square with the pliers, and remove the washer beneath it, putting both in a safe place. The minute hand can then be lifted off. Next take hold of the hour-hand socket firmly with the fingers and pull it off; it will be found to be pushed on to the centre friction-tight only.

This done, remove the dial, which will be found to be tacked or screwed on at the corners. Unhook the pendulum-bob for safety, and proceed to unscrew the clock movement from the back of the case. When this is out it will be found to be much like Figs. 1 to 4 (see first chapter). These clocks are by no means all made alike; every make differs slightly in details and arrangement of wheels, but the same parts can be traced in any make from the description of one, as their use is the same in all cases.

The outer end of the mainspring is hooked on to one of the pillars of the frame, and the inner end to the axle or arbor of the main wheel. The second wheel drives the minute-hand arbor, and the hour hand is worked by the "motion work." There is an intermediate wheel leading to the escapement, or 'scape wheel, and "pallets." Attached to the pallets is a long wire, the crutch, terminating in a loop, through which hangs the pendulum-rod.

In proceeding to take the clock to pieces, the first thing to do is to remove the pendulum-rod. With the small blade of a pocket-knife prise open the split brass stud, and lift out the pendulum-rod, drawing it through the crutch. On no account undo the pins holding the frame together until the power of the mainspring is either held in or allowed to spend itself, or disaster will result.

One way of taking the clock to pieces would be to take off the pallets, let the wheels run until the power of the spring is spent, and then take the frame apart. This method is all very well as far as mere taking apart is concerned, but will in all probability give a great deal of trouble when the time comes to put all together again, on account of the spread condition of

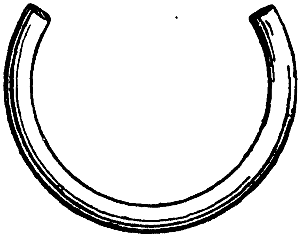


Fig. 57.—Mainspring Clamp

the mainspring and the difficulty of confining it sufficiently to allow the wheels to be placed in position; therefore, the way to proceed is first of all to wind the spring *right up*, and then clamp it by means of a mainspring clamp (Fig. 57), which is sent out with a new mainspring, and serves to confine it. To apply the clamp, slip it over the wound-up spring, hold it in position while removing the pallets, and then let the clock run. The spring will expand and tighten the clamp. The clock can then be taken apart safely, leaving the clamp on until the clock is again put together.

With one of these mainspring clamps in use, the worker can wind the spring up full, and pass a piece of string round it, pillar and all, and tie it up, letting the wheels run as before until the spring will unwind no further. This method is not so good as the first, inasmuch as the spring and main wheel cannot be removed from the back plate for cleaning.

The mainspring of a clock can easily be let down by the following method: First secure the spring with strong twine, tying this tightly round the circumference of the spring when wound up, or nearly so; then raise the click spring sufficiently to allow it to slip on the outside of the click. Then take hold of the key or winding button with pliers, or anything that will give a tight grip, and that can be held firmly in the hand, and commence to turn as described above, with the click downwards. Hold the movement in the left hand, and as the spring pulls it round, let the edge of the plates rest against the chest; then carefully move the fingers back to a natural position and again let the hand turn to the chest. Repeat this operation until the spring is down.

In this connection it may be helpful to explain how to put a clock mainspring into its barrel without having to use a mainspring winder. The mainspring can be put in its barrel with the fingers in either of two ways. The best way is first to hook the outer end of the spring on the hook inside the barrel. The barrel is held flat on a table and pressed down firmly while the spring is forced in an inch at a time, working from the outer end to the centre. Each coil should be well pressed down as it is got in. The other method is to screw the arbor by its square in the bench vice, and hook the centre of the spring upon it. Then wrap the spring tightly round the arbor coil by coil until it is all wound up close. Pass a string or wire around it, and then slip on the barrel and let the spring free.

Examining Movement.—Take up the main wheel and spring, and, placing a key upon the winding square, try the "click-work"—that is, see if the click is sound and the ratchet teeth all right. If the click is damaged, take it off, and rivet on a new one, which can be bought very cheaply. Examine all the pivots, and if any are bent, straighten them carefully with a pair of pliers. Look to the wheel teeth, especially those of the escape wheel, to see if there are any bent teeth. If there are, carefully straighten them. Take up the pallets, and see if the faces are cut by the escape-wheel teeth. If they are, treat them as already described. See if the wire crutch is firmly riveted into the pallets, and not loose; also that the pallets are firmly riveted to the brass piece which works on the pivot. Try them on their pivot, to see if the holes are worn very wide and oval. If they are, take a small broach and open them out a trifle—just enough to make the holes round; then knock out the pin which serves as a pivot in the plate, open out the hole a little, and knock in a large-sized steel needle quite tightly, the needle to be sufficiently large for the pallets to work upon it without shake. Then cut the needle off to the correct length.

The escapement will probably be a variety of the American recoil, a type that is found in nearly all small American pendulum clocks and many of the larger ones. Its repair is dealt with in Chapter IV.

Cleaning.—Next immerse all the parts in benzoline or petrol and with a brush wash them thoroughly free from all grease and sticky oil. They may then be dried with a duster, laid by for a few minutes, each wheel well brushed, and the pinions cleared out with a clock-peg cut to a point. The plates are wiped dry, and all the pivot holes "pegged" out clean. Take the minute wheel and try the "set-hand work." It will be seen on examination that the minute wheel is only friction-tight upon its pinion, and on the application of a little force can be turned round upon it. Now the tendency in these cheap clocks is for this to wear loose, and cause the hands to move too easily, thus lagging behind while the clock goes, causing it apparently to lose time. If, therefore, this movement is too easy, give the washer a knock down to tighten it.

Plates that have been cleaned in petrol may be brightened with metal polish. Engraved plates are usually lacquered, and to clean them it is necessary to remove the lacquer, which must be dissolved by spirit. Dirty engraving may be brushed with rottenstone and oil on a stiff brush, the bristles being driven well into the crevices. A wash with petrol will finish. A peg point can be used to clear out any dirt that remains. The rottenstone and oil mixed to a paste and applied with a stiff brush will remove tarnish and corrosion; but if very bad, use bathbrick first to get off the roughness, and then the rottenstone. Another, and a good, way is to get off corrosion with emery cloth and complete the process with emery powder and oil on a clock brush. A quicker way, not recommended, is to clean off quickly with spirit of salt on a rag and plunge instantly into hot water to give a thorough rinse. But this method is always liable to rust the pivots in their holes afterwards. The pinions need not be removed from the wheels. To prevent corrosion, many clock plates are lacquered or varnished. If they are simply vaselined thinly—just a smear—they will resist corrosion for a long time.

Putting Together.—The clock can now be put together again. First, take the bottom plate, and on it place in position the main wheel with the mainspring upon it, clamped, and the other wheels. Then put on the top plate and escape wheel, pinning them on securely. When all the wheels run freely, put on the pallets, observing that the crutch is free of the top plate at its lower end and does not drag. The mainspring can then be wound up and the clamp taken off.

If all is free the clock will at once start off ticking at a rapid rate. By placing a finger on the crutch, and allowing the wheel teeth to pass slowly one at a time, it will be seen that a tooth gives one pallet an impulse, and then the wheel runs till another tooth falls on to the other pallet. Now, to be correct, this distance, the "drop" of the tooth, should be very small compared to the impulse. If it is excessive, power will be wasted, and very little will reach the pendulum. If the wheel has much "drop," the depth is said to be too shallow, and to remedy it the pallets must be made to approach a little nearer to the wheel. To do this, first stick a peg between the wheels to prevent their running; then remove the pallets, and with a pair of pliers turn round by the slightest possible amount the arm that carries the pallet pivot. Then replace the pallet, and try again. If too deep, the teeth will not pass. It is a good rule to deepen these escapements as much as possible without making the escape-wheel teeth catch.

Now put a little clock oil on to each pivot and a little on the pallet faces; also oil the coils of the mainspring and the pallet pivots. Then replace the pendulum-rod, nipping the brass stud tight with a pair of cutting nippers, near its base.

The movement can now be screwed into its case once more. Before putting on the dial and hands, put on the pendulum-bob, and stand the clock on a level shelf, or on the board, if that is quite level, and see that it is "in beat." To test this, let the pendulum swing but little—only just enough to keep the clock going. Listen to see if it ticks evenly, thus—tic-tic-tic-tic—or whether it goes tic-tic, tic-tic—in twos. If the latter, it is not in beat, and the crutch must be bent with pliers until it beats quite evenly.

When in beat, the dial and hands may be put on. See that the hour hand is pushed on properly, or the minute hand when pinned on will bind it and stop the clock; and before putting on the dial, see if the pendulum-rod hangs freely in the crutch, and does not stick; place a very little oil at the point of contact.

CHAPTER VII

Cleaning Dutch Clocks

A FAMILIAR form of this old-fashioned clock is illustrated by Fig. 5 (p. 7), the movement, or works, being shown with the parts named. The framework and part of the wheelwork, too, are of wood, and the pivot holes are little pieces of brass tube inserted into holes in the wood. The pivots are steel pins driven into the centres of the wheels, and the pinions are formed on wooden bodies. In some very old Dutch clocks, the wheels themselves, except the escape wheel, are of wood.

To clean one of these clocks, first detach the weight and pendulum; next unscrew the nut that holds on the minute hand, take off the hands, turn the clock over on to its face, and remove the pins that fasten the front of the clock case to the body. Pull them out boldly with a pair of pliers, and then take off the motion work. For removing the train wheels, one of the centre wooden uprights will be found to come out. Take out a pin near the top end, and pull towards the worker, and it will come out. Care must be taken not to bend the pivots.

Clean all the wheelwork as already described for the American clock, and make a thorough examination as before. The pallets are sure to be cut more or less, and if they will not bear flatting down with the emery stick, recourse must be had to bending the escape wheel backwards or forwards so that the action takes place at another part of the pallets. The wheel, of course, is made to a certain extent cup-shaped by this operation, but that does not much matter.

In these clocks the pallets are often found to have worked loose, and require riveting up again. Beyond that, and the wear of the escapement, there will probably not be much the matter with them. The escape depth can be adjusted by knocking down the bearing of the back pallet pivot. Thoroughly clean the pendulum suspension wires and give them a little oil.

A little fine emery-cloth will improve the appearance of the hands and the brass rim round the glass. As in all clocks, see that it is "in beat" when hung up level. If the pendulum-bob is found to be loose, and drops down, tighten by inserting a piece of cork between it and the pendulum-rod.

CHAPTER VIII

Cleaning French Clocks

THE ordinary French movement, as found usually in a case of wood or black marble, is illustrated by Figs. 58 and 59. A much better finish and sounder frame is found in these clocks than in the American or Dutch clock, They are good timekeepers, their fairly good wheels and pinions and heavy pendulums enabling them to keep correct to within a minute or two a week. They go for eight days, often for fourteen and occasionally for twenty-eight days.

To take out the movement, open the back door and remove the two screws, found one on each side, which hold the movement and prevent its falling forward. Unhook and take off the pendulum, and then draw the movement out from the front of the case. It will be found to be held in place by two brass arms. Take off the hands by unpinning the minute hand, and the movement can then be unpinned from the frame which holds the dial, etc., and the latter put on one side.

The cheapest class of French movements have rough-filed plates and wheels, and rough motion work (hand work). The motion wheels are placed between the plates, and there is a set-hand arrangement somewhat similar to that found in an American clock—that is, the centre wheel turns friction-tight upon its pinion. In the better grades of French movement quite a different arrangement is found, the centre wheel being fast upon its pinion, and the motion wheels placed between the front plate and the dial, after the manner adopted in a watch. In either case, the hands should not be too easy; if they are, the shifting parts must be tightened.

The winding work—that is, the ratchet and click, etc.—will be found on the outside of the front or back plate, according as the clock winds from the front or back. Before the clock can be taken apart the mainspring must be let down. Place the key on the winding square, and, taking off the pressure from the click, with the finger hold the click up, and allow the key to go back half a turn, letting the click fall back into its place again. Repeat this operation until the spring is completely unwound. The back cock can then be unscrewed and the pallets taken out, the pins can be withdrawn and the plates taken apart, and the clock will then be in pieces.

If all the pivots and wheels are right, and the mainspring not broken, cleaning may be proceeded with. The rough movements referred to in the foregoing can be cleaned by immersing them in petrol and then pegging out. The barrel and mainspring, however, must not be put into petrol, but wiped clean, and brushed outside with the chalk brush and dry chalk. The arbor and cover can be washed in petrol, and cleaned thoroughly before being replaced. Put plenty of clock oil on the mainspring before putting on the barrel cover, and do not forget to oil the barrel-arbor pivots.

If any difficulty is experienced in getting the barrel

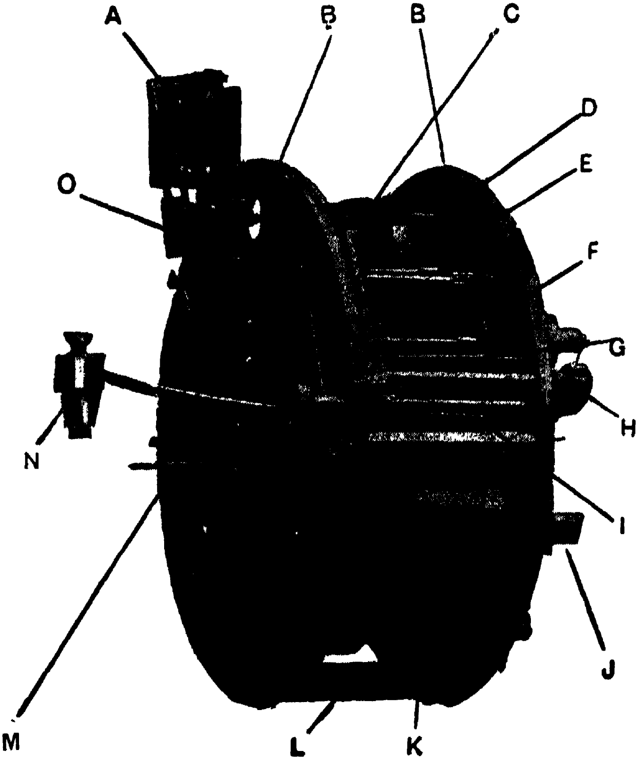


Fig. 58 —Movement of French Clock : Pendulum Side

A, suspension for pendulum; B, plates or frames; C, fly; D, locking piece; E, warning wheel; F, hammer-lifting wheel and pins; G, locking piece and spring; H, rack hook ; I, hammer spring ; J, winding squares and ratchets K, striking barrel; L, pillar; M, crutch; N, hammer ; O, suspension spring.

cover off, hold the barrel in the hand, cover up, and knock the arbor sharply on the bench or floor, driving off the cover at one blow.

To clean the better class of French movements (those with polished plates), a different method is pursued. At least three brushes will be required. Strip the plates, that is, unscrew everything upon them, and mix a little rottenstone powder with sweet-oil (olive or salid oil) to a paste. Put some of this on a rottenstone brush, and vigorously brush the plates and brass wheels, cocks, etc., brushing backwards and forwards straight from top to bottom, to put on an even grain. This done, put all into a hand-bowl containing petrol, and with a brush thoroughly wash all rottenstone and grease from the parts. Take them out and dry with a duster, and put on one side for a few minutes for the last traces of the petrol to dry off. Do not put the barrel into the liquid, but with the rottenstone brush nearly dry, polish its sides, and clean off with the petrol brush rather dry, afterwards wiping clean with the duster. All being dry, take the chalk brush and dry chalk, and proceed to brush up and polish all the parts; then peg out all pivot-holes clean, also between the leaves of pinions, and brush through all wheel teeth, to remove any traces of rottenstone.

The clock can next be put together, applying a little clock oil to pivots and pallets, and just a trace to the crutch where the pendulum hangs.

The pendulum suspension-spring must be treated very carefully or it may easily be spoilt, and it cannot be again got right. In putting the clock back in its

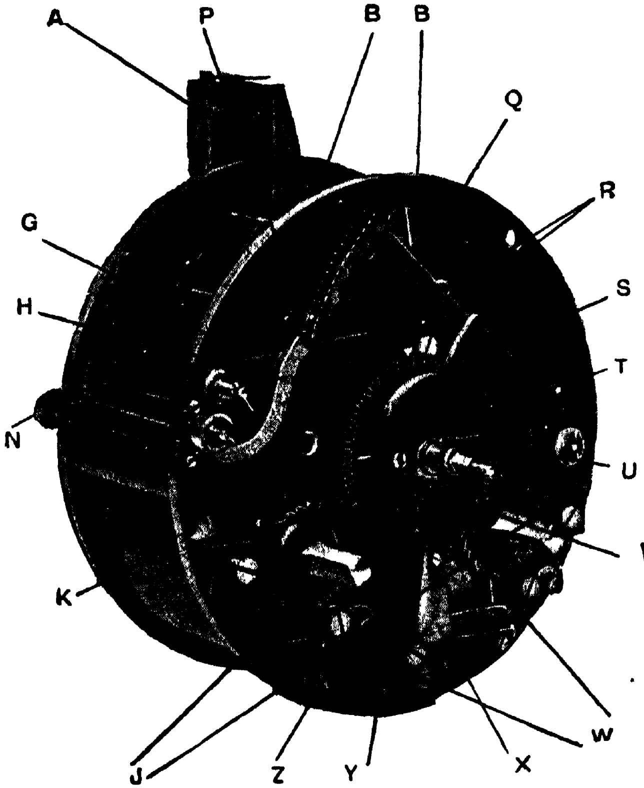


Fig. 59.—Movement of French Clock : Striking-rack Side

A, suspension for pendulum ; B, plates or frames ; G, locking piece ; H, rack hook ; J, winding square and ratchets ; K, striking barrel ; N, hammer ; P, gathering pallet ; Q, striking rack ; R, lifting piece ; S, rack arm ; T, minute wheel or cannon pinion ; U, hour wheel ; V, hour snail ; W, clicks and springs ; X, minute-wheel bridge ; Y, minute pinion ; Z, minute wheel.

case, see that the 12 o'clock is quite upright, and then set in beat by slightly bending the crutch as usual.

French clocks have an excellent regulating arrangement to turn with a small key from the front. Turning to the right shortens the acting part of the pendulum suspension-spring, and so makes the clock go faster, whilst turning to the left has the opposite effect. The entire arrangement is contained in the "back cock," and must be taken apart and carefully cleaned with the rest.

Wire Gongs.—Grandfather, French, and many other clocks are commonly fitted with gongs which consist of a coiled wire. The repairer is sometimes asked to fit a gong of this type, and it is best bought ready-made. The making of clock gongs is a trade to itself, and the reader is not likely to succeed in making a good one at the first attempt. First the wire is brazed into a brass end block, then coiled up into a spiral, and then heated to a bright red evenly all over and hardened. It is next polished, then blued by heat. A gong of round wire is the easiest to make. For a grandfather clock gong, obtain a round steel rod $\frac{3}{16}$ in. thick and 45 in. long. After brazing it to its block, about $1\frac{1}{4}$ in. by $\frac{5}{8}$ in. by $\frac{3}{8}$ in., coil it into a spiral of about three turns and 7 in. outside diameter. To harden the steel, heat it in a forge fire and plunge in water, then polish with fairly quick-cutting emery and finally with the finest. Then blue it in burning charcoal dust or hot sand on an iron plate over a fire. For grandfather clocks, however, a coil of *flat* wire is recommended. A deep-toned hour gong, about 7 in. outer diameter, may be made from flat steel $\frac{3}{16}$ in. wide and $\frac{1}{16}$ in. thick, formed into a spiral of about three complete turns. This will take about 4 ft. 6 in. of wire. The end should be brazed into a slot in a brass block, and the brass block screwed to the gong standard. The quarter gongs may be of wire gradually diminishing to $\frac{1}{8}$ in. wide for the highest note, and thickness in proportion. The diameter may diminish to $4\frac{1}{2}$ in., and the turns from three to two. Several experimental gongs will have to be made to arrive at about the correct notes. The finished gongs can be tuned by shortening from the inner end.

Should a coiled-wire gong be fixed in place of a bell it may fail to give sufficient tone. Generally, the hammer employed to strike the bell of a French clock would be too light to strike a gong, unless the gong was very small. The hammer should be faced with a piece of hard leather, and so adjusted that it is perfectly free of the gong when at rest. See that the gong is fixed perfectly rigid in the metal block, the stalk or gong support being absolutely tight at both ends. The bottom end is screwed with an adjustable nut to the sounding board, and the latter, it is obvious, must be quite firm on its resting place. The gong and support must be free from any other object.

CHAPTER IX

Cleaning English Clocks

Cleaning "Eight-day Dial" Clock.—English clocks are of various patterns, but one style of workmanship will be found in most of them. The ordinary eight-day English shop or kitchen clock, commonly known as an "eight-day dial," is well and solidly made, is a good timekeeper, and will last a lifetime. Its mechanism is extremely simple, and there is nothing to get out of order. The weakest point is the gut line, which chafes through after a few years' wear. In the best clocks the gut is replaced by a steel chain, which is a great improvement.

To take such a clock apart, first remove the pendulum, unpin the minute hand, and remove it. The hour hand is held by a small screw, which should be withdrawn, and the hand taken off. Then lay the clock upon its face, remove the four wooden pegs at the sides, and lift the back of the case right off. The square movement itself will be found to be pinned to the dial and front part of the case. Remove the four pins from the dial feet, and it will come off altogether, leaving the dial alone screwed to the front of the case. This can be put on one side. Do not attempt to let the spring down, but put a little oil on the pivots, and, having removed the motion work and the pallets, let the clock run down. As it does so, notice if the wheels and pinions run smoothly, and if they are true. When quite run down, put a hand-vice or a large key on the square of the barrel arbor, and raise the click, letting the spring down gently. The plates can then be unpinned, and the clock taken apart. The parts may be cleaned with rottenstone, etc., as described in other chapters.

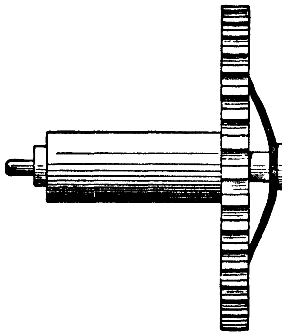


Fig. 60.—Minute Wheel and Brass Spring of English Clock

Before putting together, look to the pallets, and smooth out any marks of wear; examine the pinions, and if any are badly cut, the wheels had better be shifted along their arbors to work in another place. Sometimes these are soldered on, and shifting them gets them out of truth. In that case nothing can be done unless the wheel seat is turned afresh; a shoulder would be turned to receive the wheel tightly, and then be riveted over with a punch. Look for wide pivot holes, and if there are any bad ones, bush them as described on an earlier page. Then put the barrel, fusee, and wheels in position between the plates, and pin together.

Next carefully wind the gut on the barrel, turning

Fig. 61.—End of Gut Line

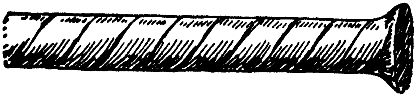


Fig. 61A.—Gut Line after Searing

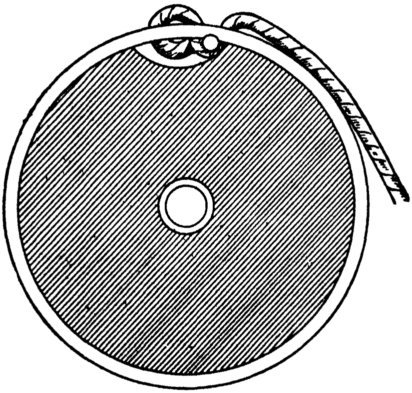


Fig. 61B.—Fastening Gut at Barrel End

the latter with a key; and when all is wound on, put on the outside ratchet, and wind it, or "set it up," about half a turn. Pin the ratchet on, and screw the click tight; then put in the pallets, and wind the clock up. In doing this, the gut must be carefully guided on to the fusee, and not on any account be allowed to run off or drag in a slanting direction. The best way to guide it is to hold a smooth file-handle, or something of a like nature, against it during the winding, bearing sideways upon it, to keep it straight.

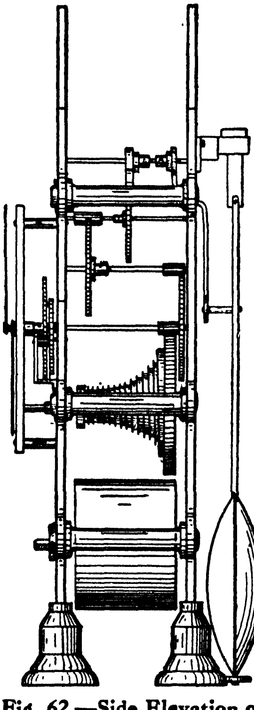


Fig. 62.—Side Elevation of Skeleton Clock Movement

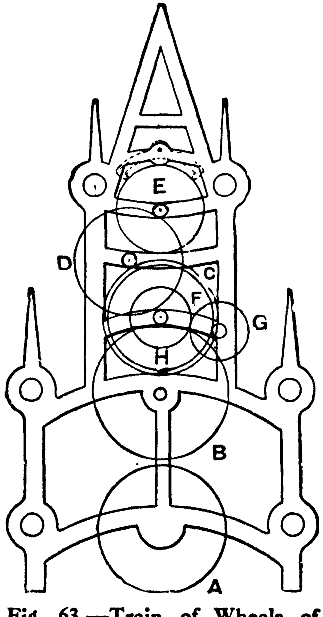


Fig. 63.—Train of Wheels of Skeleton Clock

Where there is a chain instead of a gut line, first hook the chain in the barrel and wind it all upon it, then hook it in the fusee, and then proceed as before explained. Oil all pivots, pallets, etc., and put on the motion work. Note the short brass spring that goes on under the minute wheel, as in Fig. 60. By no means put it on wrong side up, or the clock will certainly stop. The two points should bear on the under side of the minute wheel.

When all together, and ready to hang up, see that the crutch is free in the slot in the pendulum, and does not touch either at the top or bottom, nor stick in it. Just a trace of oil should be put upon the pin. To set these clocks in beat, the crutch must be bent.

Renewing a Gut Line.—To put on a new gut line, take the movement to pieces, and take out the old one from the barrel. To get the fusee end out, the fusee must be taken to pieces. A circular piece of brass will be found outside the fusee wheel or main wheel; it is a kind of key, and requires to be unscrewed or unpinned and then taken off. While it is off it can be cleaned, and the ratchet and click-work oiled. Obtain a new line (Fig. 61) of the same thickness, and measure it to correct length, allowing for fastenings. Make a single knot for the fusee end; and to prevent its coming undone treat the end by "searing" in the following way: get a small, flat piece of iron or brass and heat nearly to redness. Apply this to the end of the gut, which will expand into the shape shown in Fig. 61A. The end cannot now pull through. Fig. 61B shows the method of fastening the barrel end, which must be seared in the same way.

Cleaning Skeleton Clock.—The mechanism of this old-fashioned kind of clock is similar to that of the "eight-day dial"; there is generally added a bell at the top and a hammer which is caused to strike one blow at each hour—not a very complicated affair. These clocks want most careful cleaning. Every part must be thoroughly well cleaned with rottenstone and polished with chalk. The cuttings in the plates must be done with strips of washleather and rottenstone,

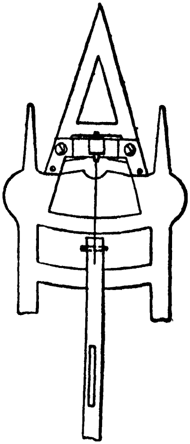


Fig. 63A.—Back Cock and Pendulum Suspension of Skeleton Clock

and afterwards with more leather and a peg. All steel-work needs to be polished and burnished with a burnisher and oil. It is all visible, and therefore no pains should be spared in getting it up well. Fig. 62 is a side elevation of the movement; Fig. 63A shows the back cock and pendulum suspension; and Fig. 63 is a diagram of the train of wheels, A representing the barrel; B, fusee; C, centre wheel; D, third wheel; E, escape wheel; F, cannon pinion; G, minute wheel; and H, hour wheel.

CHAPTER X

Strike and Alarm Work

American Striking Work.—All striking work has much in common, although the details may differ. The first example will be the common striking work to be found in an American dial or a "square" clock.

Fig. 64 shows the striking side of the mechanism. For the sake of simplicity the frame plates are not shown, and some of the wheels are represented by plain circles. A is a wheel mounted upon the same arbor as the main wheel of the striking train. It will be seen that it has twelve slots in it, at distances progressing regularly from one tooth to twelve. Its duty is to determine the number of blows struck by the hammer. The next wheel B is the "pin wheel," and has around its circumference a number of pins which actuate the hammer as the wheel revolves. The pins are so spaced that the distance between each corresponds with a movement of the wheel A equal to *one tooth.* Thus, when A moves through a distance of three teeth, the pins in B strike three blows. The next wheel C is the locking wheel, and its purpose is to effect the stopping of the striking train when the right number of blows has been struck according to the divisions of A. The next is the "fly" D. Its duty is to regulate the speed of striking, and prevent the train running too fast. It also serves the purpose of a warning wheel.

E represents the centre arbor of the clock, which revolves once an hour and carries the minute hand. In it is a projecting arm F which, as it comes round,

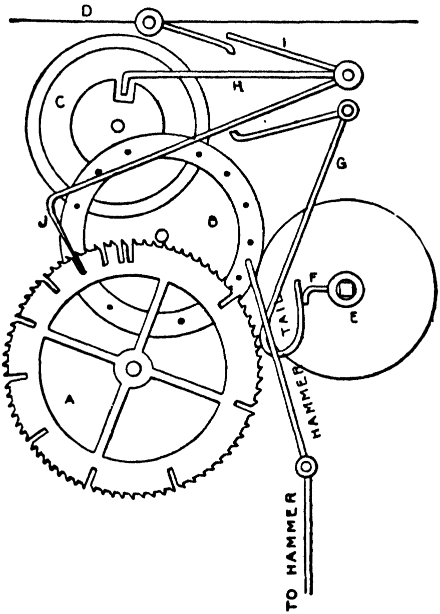


Fig. 64.—American Striking Work

raises the lever G, another arm of which raises H, which rests in the slot in the cam fixed on the wheel C and locks the striking train. It is evident that, on G and H being raised, the wheel C will be released and the train will be free to run until the arm I fixed to H comes into contact with the fly or an arm fixed to it. It thus runs about half a revolution of the fly, which, of course, is not sufficient to strike at all, and is termed the warning; it takes place about five to ten minutes before the hour. The arm on E continuing to advance, at last lets the lever G fall just at the hour. H, I, and J (all one piece) also fall, and I releases the fly, and the striking train commences to run. J, it will be seen, falls upon the wheel A just between two teeth, and H cannot therefore fall into the slot in the cam on C until a deep slot comes round on A and lets J fall into it. Then H falls into the slot and stops C, by which time a number of blows will have been struck by the hammer equal to the number of teeth passed in the wheel A. This entire action should be most carefully studied.

Now for the essential points to be observed in putting together the striking train. First of all, when the arm H stops the train by falling into the slot in the cam on wheel C, one pin on the pin wheel should have *just struck a blow* and released the hammer, and the hammer tail must on no account be in contact with the next pin. If it is so, there will be a resistance to the starting of the striking train which will sometimes stop it. If, when it is put together, this is found to be wrong, the plate must be lifted and the wheel shifted a tooth or so until correct. Secondly, when the striking has stopped, the arm projecting from the fly must be half a revolution or more from I, so as to have at least half a turn at the "warning" before being stopped by I. This is important.

Now these two points—the freedom of the hammer tail from the pins in the pin wheel and the "run" at warning—are common to all striking work.

If the striking does not take place exactly when the minute hand points to the hour, bend the arm fixed to E until correct. If the clock strikes more than it ought—two hours together without any interval—it is because the arm H does not fall into the slot and is *too high.* Remedy: bend it down. If the clock only strikes one at each hour, the arm H is too *low;* bend it up. Sometimes a clock will not stop striking properly because the side of the slot into which H falls is worn away and forces H out again. If so, file it up nice and square, or even undercut it a little. Also see that the point of J falls exactly in the centre of each slot in the wheel A.

This kind of striking, with slight modifications, will be found in Dutch striking clocks, and will need no further explanation. Cuckoo clocks, also, are much the same; but, of course, the double set of wires to the small bellows makes them somewhat more troublesome to properly adjust (see a later chapter).

French Locking-plate Striking Work.—Two distinct kinds of striking work are in use in French clocks. The first, the "locking-plate" striking, is somewhat similar to the American striking mechanism. Fig. 65 is a view under the dial showing the discharging work, and Fig. 65A is a back view showing the locking plate.

Taking Fig. 65 first, A is the cannon pinion which turns once in an hour. In it are two pins, B, opposite each other. These two pins as they revolve lift the end of the lever C every half hour. It will be observed that French clocks invariably strike the hours and half hours. The lever C is pivoted upon a stud fixed to the plate near its edge, and together with the arm D forms one piece. At the end of the arm D is a projection which goes through the plate where an oblong

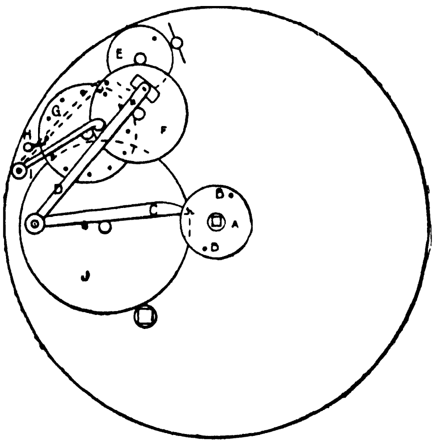


Fig. 65.—Front View of Locking-plate Striking Work

slot is cut, and engages the pin in the warning wheel F. This arm effects the warning in the same manner as in an American clock. The lever I is fixed to an arbor which goes right across the movement, and is raised by D at each half hour. To the same arbor that I is fixed, there is also fixed an arm which engages with a pin in the locking wheel F, and stops the striking train. G is the pin wheel, the pins in which operate the hammer tail H in the same manner as in an American clock.

Turning to Fig. 65A, A is the locking plate which is mounted outside the back plate, upon the extended arbor of the wheel J (Fig. 65), and turns once in twelve hours.

Its circumference is spaced out on the same principle as the locking plate of an American clock. B

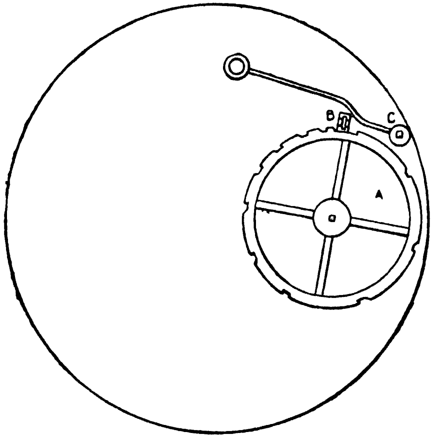


Fig. 65A.—Back View of Striking Work, showing Locking Plate

is a projecting stud, which is fixed to the arm which locks the striking train shown in Fig. 65 by the dotted lines. B comes through an opening in the back plate and rests upon the edge of A. When it is in a hollow of the locking plate, it prevents the wheel F (Fig. 65) revolving, but so long as B rests upon a high portion of A, the wheel F is free to revolve. The pins in the pin wheel are so arranged that one revolution of the wheel F is equivalent to one blow of the hammer.

Now see what happens when the clock is about to strike. First of all the striking train is locked by the pin in F (Fig. 65) resting on the locking arm fixed to I, and B (Fig. 65A) is in a hollow of the locking plate. The pin in the warning wheel E is at the top, as shown in Fig. 65, and half a revolution from the warning lever D.

As the clock goes on, one of the pins, B in A (the cannon pinion), lifts the lever C. Immediately, the pin in the wheel F is released, as the arm I, and consequently the locking arm fixed upon the same arbor, is raised. The striking train then "runs" to the extent of half a turn of E, and is arrested by the pin in the warning wheel E coming in contact with the projection in the arm D. This is the "warning."

There it all rests until the pin B, still advancing, at last passes the point of the lever C, which lever then drops, and, of course, D also. This releases the warning wheel, and the striking runs and continues to do so until the piece B (Fig. 65A) drops into the next hollow in the locking plate, when it at once locks the train by coming into contact with the pin in the locking wheel F (Fig. 65).

At the half hours the same thing occurs, except that as the piece B (Fig. 65A) simply falls back into the same hollow of the locking plate, the wheel F is arrested again after making but one revolution, and therefore having struck one blow.

In putting the clock together, the following points must be observed. When the train is locked by the pin in F resting on the locking arm, one blow should just have been struck, and the hammer tail should be quite free and not touching the next pin in the pin wheel. This is imperative. It can be made so by shifting the pin wheel a tooth or so one way or the other. At the same time, the warning pin must be at least half a revolution from the stop on the arm D to allow for the "run." Shift it till it is so. Should the clock occasionally strike one too many at several of the hours, the locking plate is probably put on the wrong way of the square it fits on to, and it had better be tried on another way. There is usually a dot on it and the square. In putting a striking clock together, observe that dots go next to each other. A dot on a wheel is meant to be placed adjoining the next pinion, and if this rule is observed in putting the striking train together, not much trouble will be experienced in getting it right.

Put a little oil on the pins in pin wheel, on the warning pin, and on the locking pin in F. Oil the pivots of the hammer arbor, and arbor of I. Do not oil the edge of the locking plate, or the pivot of the arm C. Put a little on the pins B.

Should the clock not strike exactly at the hour and half hour, bend the pins B, B a trifle in or out as required.

French Rack Striking Work.—French clocks fitted with rack striking will now be considered. Fig. 66 shows the mechanism, which will be seen to be all on the front plate and underneath the dial.

The train is practically the same as before. The pin wheel H, the locking wheel F, and the warning wheel E, and fly are the same in both. In a rack-striking clock the locking wheel F is called the "pallet wheel," because its front pivot is prolonged and carries a small "pallet" whose duty it is to "gather" up the rack. In Fig. 66, the gathering pallet is shown affixed to the arbor of the wheel F, and pointing towards the rack teeth.

The cannon pinion A (shown by the dotted circle), the pins B, B, and the levers C and D, are the same as in the locking-plate striking. Also the locking arm pivoted between the plates (shown by a dotted line) is the same, but the lever affixed to it, marked G in Fig. 66, is different, and its purpose is to hold up the rack as the gathering pallet gathers it up tooth by tooth. I is the rack, K is the hour wheel which revolves once in twelve hours and carries the snail J. The latter is a piece of brass with steps cut in it corresponding to the different hours to be struck, and determines the distance to which the rack falls at each hour.

How all this mechanism works will now be explained. The striking train is locked by the pin in F resting on the locking arm, and the pin in the warning wheel is half a turn from the stop in the warning lever. As the clock goes, a pin B raises the lever C, and also D. A pin projecting from C also raises G, and the locking arm with it. The immediate effect of this is to let the rack I fall until L falls upon a step of the snail J. Also the locking arm being simultaneously raised, the striking train runs to the extent of half a turn of the warning wheel E, until the warning pin falls upon the stop in D. There it all rests till the pin B passes the lever C, and lets it fall again. This at once releases the warning wheel, and the train runs.

At each revolution of the pallet wheel F, the small gathering pallet upon its front pivot raises the rack to the extent of one tooth, and a pin of the pin wheel

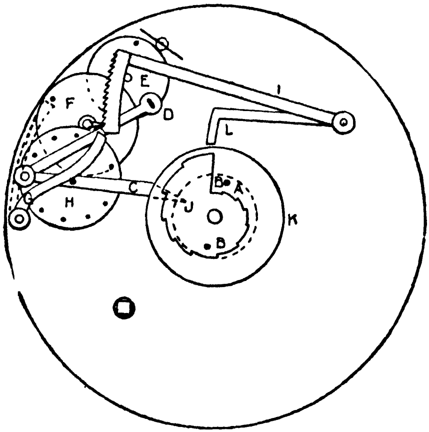


Fig. 66.—Front View of French Rack Striking Work

causes one blow to be struck. The lever, G, meanwhile rests against the rack teeth, and as soon as the rack is all gathered up it falls to the position shown in Fig. 66. This, of course, brings the locking arm into contact with the pin in the pallet wheel and stops the striking train.

The pin B, that lets off the half hours, is a little nearer to the centre of the cannon pinion, and therefore does not lift the levers C, D, and G quite so high. It still must lift them high enough to liberate the striking train, but *not high enough to let the rack fall.* The clock, therefore, only strikes one, and the pallet wheel F is stopped at the next revolution.

The points to be observed in putting rack striking work together are as follows: as in all striking work, see that the hammer tail is free of the pins in pin wheel, and that the warning wheel has half a turn to "run" when the train is locked. Mind the dots in the motion work, and see that the arm L on the rack *falls upon the centres* of the steps of the snail J. The gathering pallet is only pushed on friction tight upon its pivot, and can be pulled off with the pliers.

Oil the pin-wheel pins, the locking and warning pins, and the pins B. Do not put any oil on the pivots of the rack or levers C and D, or they may stick.

Should a rack striking clock be found stopped with the arm L on the rack jammed against the snail at some time between 12 and 1 o'clock, it shows that for some reason or other the striking work has failed, and the clock still going on has jammed the snail against the piece L of the rack. In such a case look for a bent pivot, a want of oil, or a want of endshake somewhere in the striking train. Perhaps the hammer tail is "on the rise"—that is, it is not free of the pins in pin wheel and starting. It may be that the hammer spring is too strong and offers too much resistance to the lifting pins. The gathering pallet may perhaps catch on the points of the rack teeth. A most careful search must be made till the cause of the stoppage is found. When found, it is, as a rule, an easy matter to remedy it.

It may happen that the clock, when put together, only strikes one at each hour. The cause of this is that either the hour pin B wants bending outwards a little, or the pin in the lever C requires bending up a trifle. In any case, the lever C must be made to lift a little higher.

A frequent cause of failure in the striking work of French clocks is that the fly is "out of poise," and when hanging with the heavy side downwards when at rest it offers great resistance to starting. The remedy is to poise the fly carefully by bending or filing the thin brass portion. When a rack striking train is at rest, the gathering pallet should point upwards.

The striking work of French carriage clocks is merely a modification of the rack striking just described, and the reader will not find much difficulty with it.

English striking work will be dealt with in the next chapter.

Alarm Mechanism.—The most common kind of alarm clock is perhaps the nickel-plated drum alarm. In putting together an alarm clock, after putting on the hour and minute hands, turn them round carefully and note the exact time the alarm goes off. Say this is at 6.30, then put the alarm hand on at exactly that hour and it will then be right, and wherever it is set will indicate the correct time of the alarm. Most alarm clocks have "stopwork" to the alarm spring (see Fig. 67). This is to stop the alarm when it has run for a certain distance and prevent its starting again after it has once stopped. To adjust the stopwork, wind up the spring all but half a turn, and put on the piece A in such a position that it can be wound no further. It will then allow some four turns of the mainspring to unwind themselves and again bring it to a stop.

The alarm work on an American pendulum timepiece is arranged somewhat differently, and is simpler. There are the same spring and train of wheels, etc., but the discharging arrangement merely consists of a loose boss placed upon the centre arbor of the clock and attached to the hour wheel, which, of course, revolves once in twelve hours and carries the hour hand. There is a step or depression in this boss which, when it comes round, allows the alarm hammer full play. The boss being movable, and provided with a disc with the hours marked upon it, can be turned by the fingers and set to the desired time by placing the hour at which the alarm is wanted beneath the hour hand wherever it may be at the time of setting. This arrangement is simplicity itself, and cannot be beaten.

In this form the alarm bell is placed on the top of the clock, and the hammer stem comes through a slot in the case.

The mechanism is very simple, being made up by a second small mainspring, one intermediate wheel, and a kind of escapement, something similar to that found in an American pendulum timepiece. To the pallets is fixed the hammer stem, which vibrates backwards and forwards as the train runs down. Fig. 67A shows the alarm train and explains itself. The essential part of the arrangement is the mechanism for letting the alarm train run down at the right moment.

To accomplish this it will be seen that there is a spindle running right through the clock from back to front, with a hand fixed to it which points to the hours on a small dial. Riding loose upon this spindle is a wheel which revolves once in twelve hours. A pro-

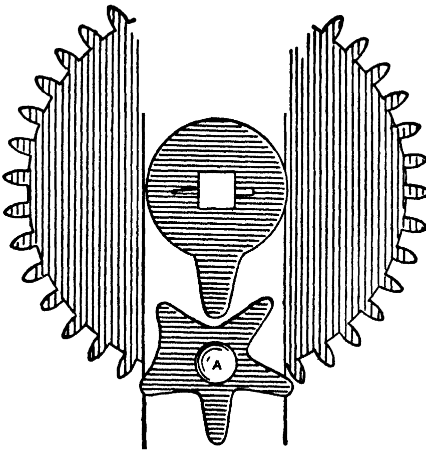


Fig. 67.—Stopwork of Alarm Clock

jecting boss on this wheel has a kind of cam cut upon it which rests against a pin fixed in the spindle. This is so arranged that once in every twelve hours, as the wheel and cam revolve against the fixed pin, the latter allows the wheel to rise, and a spring beneath it forces it up, and by a catch liberates the alarm train.

It is evident that the time of rising of the cam, and consequent discharge of the alarm train, depend on the position of the fixed pin in the spindle. And as the spindle and pin can be revolved by the hand from the back of the clock and set in any position

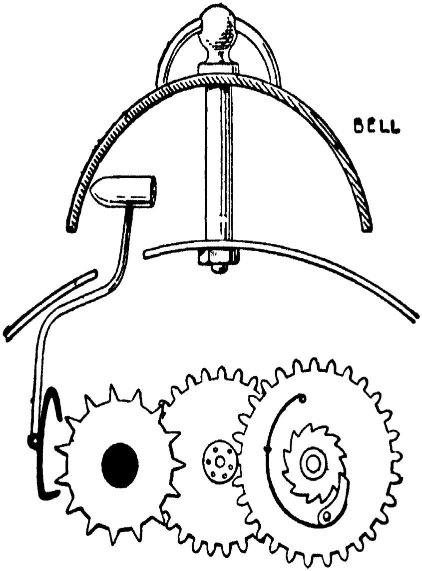


Fig. 67A.—Alarm Work of Drum Clock

desired, the hand will show the hour when the alarm will go off.

The alarm work found in French drum and carriage clocks is merely a modification of that in American drum clocks just described.

CHAPTER XI

Cleaning Grandfather Striking Clocks

PHOTOGRAPHS of the movement of a grandfather striking clock are presented by Figs. 68 and 68A, whilst Fig. 69 is a diagram of a typical movement of the same general kind, the dial having been removed, and shows the usual arrangement of the striking mechanism. Fig. 70 is a key to the train of wheels between the plates, which wheels cannot be shown in the other diagram.

The Sequence of Operations.—When cleaning the clock, before taking anything apart, place the movement with the dial removed, as in Fig. 69, in its case with the hands on and turn them round, causing the clock to strike. Notice exactly what happens, and from it learn how to put the parts together again. On turning the minute hand, as the hour is approached a pin in the minute wheel B lifts the tail end of the warning lever H, which in turn lifts the rack hook G. The rack E is thus liberated and falls until its lower end rests against one of the steps of the snail D. The depth of these steps regulates the number of blows struck at each hour. Before the rack fell, the running of the striking train of wheels was prevented by the gathering pallet F resting upon a stop pin in the rack. But when the rack falls the gathering pallet is released and the train runs until a pin in the warning wheel M (Fig. 69) catches against a stop block attached to the warning lever. This run is called the warning, and takes place a few minutes before the hour. The minute hand continuing to advance, the pin in the minute wheel passes the end of the warning lever, and at the hour the lever falls again and liberates the warning wheel. The striking train then runs; and at each revolution of the pallet wheel L the gathering pallet gathers up one tooth of the rack and a pin in the pin wheel K causes one blow to be struck. Continuing to run and strike, the rack is at last all gathered up and the gathering pallet once more comes to rest against the stop pin in the rack. This action should be studied closely until the functions of each part are thoroughly understood.

Taking Movement Apart.—Then take the movement to pieces. First take out the pallets S and crutch. Then remove the rack, hour wheel C (Fig. 69), warning lever, rack hook, gathering pallet, minute wheel, and cannon pinion A, in the order named. Take off the bell and bell standard, and take the plates apart. Be careful to keep the striking train of wheels separate from the going train.

Cleaning.—With a stiff brush like a tooth-brush bearing powdered rottenstone and oil mixed to a paste, scrub the plates up and down in straight lines until they are bright. Similarly scrub the wheels and all other brass parts. Then pour some petrol or benzoline into a basin, and with the same brush thoroughly wash the rottenstone and oil from all parts, and dry

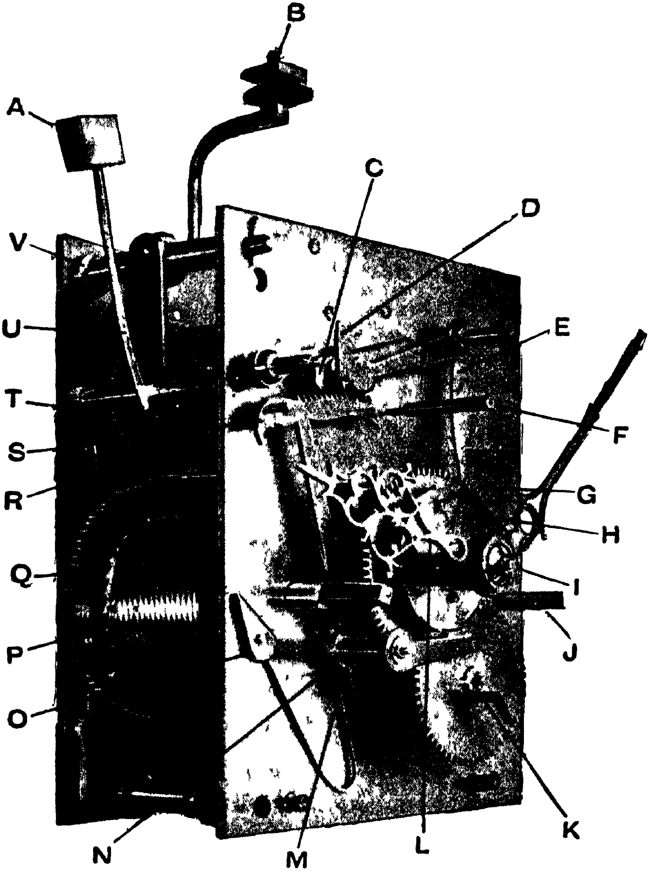


Fig. 68.—Grandfather Clock Movement: Striking-mechanism Side

A, hammer head; B, bell stand and nut; C, rack hook; D, gathering pallet; E, lifting piece; F, seconds hand pipe; G, hour wheel; H snail; I, minute hand and collet; J, winding square; K, month wheel and gathering pallet; L, hour hand and socket; M, strike winding square; N, rack arm; O, rack spring; P, barrel and ratchet; Q, strike main' wheel; R, spring; S, rack; T, hammer detent; U, hammer counter V, pillar.

with a clean duster. With wooden pointed pegs clean out the spaces between the pinion leaves, and peg out the pivot holes in the plates until they are quite clean inside. Brush out the wheel teeth.

Re-assembling. — The movement may now be put together again, a little oil being given to the clicks and click springs on the barrels. When the bell hammer and all the wheels are between the plates and in place, try each to see whether the pivots have much side play in the pivot holes. The most important wheel is the escape wheel R (Fig. 70). If its pivot holes are very wide, they must be bushed, as described on an earlier page. The wire has a central hole in it, and this gets over the difficulty of re-drilling. A bushed hole is smoothed off level inside and opened out by reamering to fit the pivot quite easily but without side play. The pallet holes, if wide, must also be bushed.

Then put on the minute wheel, rack, rack hook, warning lever, and gathering pallet temporarily, to see that the striking train wheels are in correctly.

To test them proceed as follows: Wind up the striking barrel J about a turn and give the gut a twist round the fingers. Then, pulling on the gut, cause the rack to fall a few teeth and let the pallet gather it up slowly. Observe how the train stops when the gathering pallet stops against the rack pin. It should do this immediately after the last blow is struck, so that when the train is at rest the hammer tail is quite free of the lifting pins in the pin wheel. If it stops with a pin against the hammer tail, it is wrong. Shift the gathering pallet to another square, and try it on

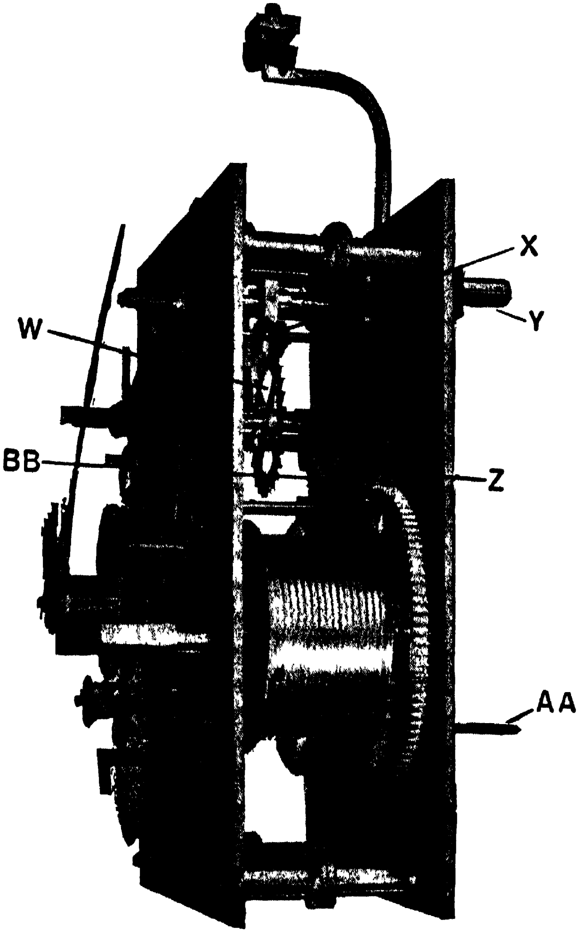


Fig. 68A.—Side View of Grandfather Clock Movement

W, escape wheel; X, pallets; Y, pendulum suspension; Z, third wheel and pinion; AA, crutch; BB, centre wheel and pinion.

all four sides until one is found that is right. If none seems right, but a midway position seems to be required, the top plate of the frame must be gently lifted up and the pin wheel turned one tooth in the pallet-wheel pinion. Then try again, and finally pin on the gathering pallet.

Next see whether the warning is correct. When the striking train stops, the pin in the warning wheel should not be close to the stop block on the warning lever, but should have a run of at least a quarter of a turn before coming to it. If too close, the plate must be raised and the teeth of the pallet wheel shifted in the warning-wheel pinion. These are the two points that must be attended to in any striking clock.

Next oil the front pivot holes with good clock oil, and put on the cannon pinion. Put the minute hand on it and turn it round to see when it strikes. See that when the warning lever falls the minute hand points exactly to the hour; the teeth of the cannon pinion can be shifted in the minute wheel to adjust this. Do not forget the flat brass spring under the cannon pinion. Then pin on the rack, rack hook, warning lever, etc., and put the hour wheel and snail on in such a position that the rack tail falls in the centre of a step at the hour. This can be regulated by shifting the teeth in the minute pinion. Oil the lifting pins in the pin wheel, the hammer spring where it touches the hammer, the rack spring I (Fig. 69) where it touches the rack, the stop pin in the rack, the warning pin in the warning wheel, and the lifting pin in the minute wheel. Also oil the back pivots. Then clean the pallets with petrol, and the crutch in which the pendulum-rod goes. If the pallets are in fair condition, put them in place and oil them and their pivots, also the slot in the crutch. If they are very badly

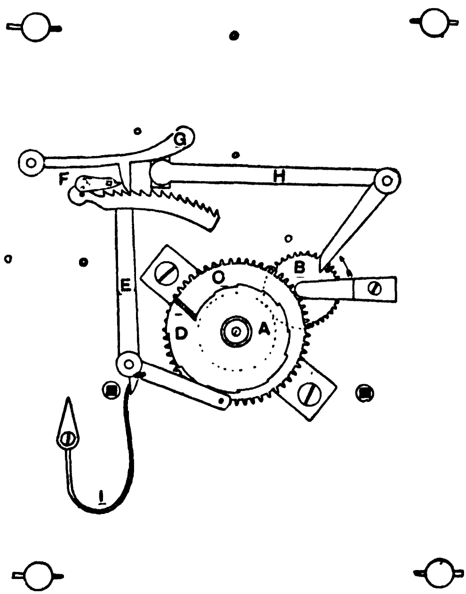


Fig. 69.—Striking Movement of Grandfather Clock

worn, it will be best to buff out the ruts with an emery-stick, and face them with watch mainspring as described earlier. Then try the pallets in the clock, and if necessary trim off the points with a file until the wheel trips through satisfactorily without catching.

The dial can next be put on and the clock started. If after going a little while the pallets catch upon the points of the escape-wheel teeth, reduce the offending point a little by filing the pallet. See that the pendulum-rod is not sticky where it passes through the crutch, and give it a little oil there.

Getting Clock into Beat.—Let the clock be exactly in beat. To test this, bring the pendulum to rest and mark the back of the case with a pencil behind the bottom of the rod. Draw the pendulum to one side until it ticks, mark the point, then draw it to the other side and mark that point. If the clock is in beat, these two marks will be equidistant from the central point. If unequal, bend the wire crutch to one side and note the result. Work in this way until correct. See that the hands are quite free from each other, the dial, and the glass. See that the lines wind up straight upon the barrels to the top, and that they are not long enough to allow the weights when run down to touch the floor, or the lines may twist up.

Moon Disc of Grandfather Clock.—The moon disc has usually two moons painted upon it and revolves once in two months. Only one half of the disc is visible at one time. In all cases the discs are worked from the motion work. The hour wheel that carries the snail is the only wheel that moves slowly enough for the purpose, and motion is communicated from this upwards through either one or two gear wheels, the last of which moves the moon disc one tooth per day or one tooth each twelve hours. When the moon disc moves one tooth per day it has 58 teeth; when it moves one tooth each twelve hours it has 116 teeth. The moon disc itself cannot reach the hour wheel on account of the second pivot between. The method of moving it varies. Sometimes an idle wheel is pivoted on a pipe

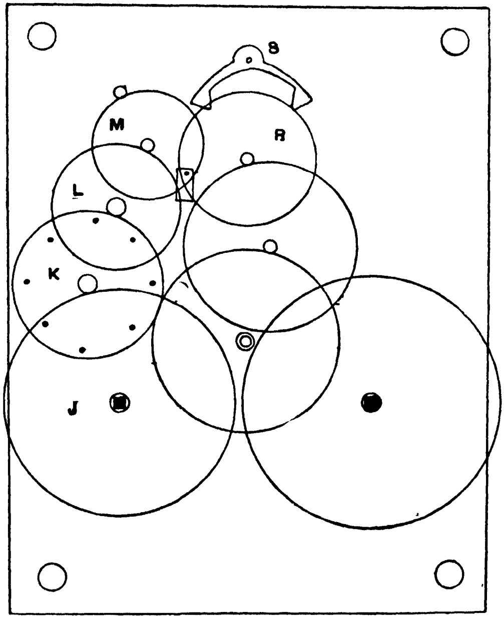


Fig. 70.—Train of Wheels of Grandfather Clock

through which the seconds pivot passes. This wheel runs with the hour wheel and turns once in twelve hours. A projecting pin in it moves the moon disc. The disc is sometimes moved by a lever and "jumper," actuated by the pin in the hour wheel itself; but if all parts are missing, the first method is the easier to supply. The idle wheel should have as many teeth as the wheel on the snail that drives it. The figures on the half-circle, 1 to 30, are for showing the moon's age. There will be no hand, the moon itself pointing to the figure showing its age. A small brass pipe, something like the pipe and bridge on which the hour wheel revolves, can be made to pass over the seconds pivot and the idle wheel run on it.

CHAPTER XII

Cleaning and Repairing American Drum Clocks

THE most-frequently-met-with type of portable clock is the familiar nickel-plated drum clock of American or Continental manufacture, the escapement of which is shown in Fig. 8 (p. 10). The movement, on the whole, is similar to that of the cheap pendulum clock described in Chapters I and VI, and it is cleaned and repaired in much the same manner. But, of course, the escapement is different.

To take a cheap drum clock movement out of its case, unscrew and remove the two feet and take out a small screw or screws found at the top of the case, and the entire movement will then come out from the back. Before doing this, the winding buttons, etc., must be taken off by unscrewing in the reverse direction to that of winding, and the set-hands button pulled off. This liberates the back.

The common form of drum lever escapement is shown in Fig. 8 (p. 10). Attached to a fly wheel or balance which spins freely between pivots is a hairspring which causes the balance, when given an impulse, to vibrate backwards and forwards. The escape wheel C and pallets B are of the dead-beat form, very similar to a French or American dead-beat escapement. Instead of a crutch being attached to the pallets to work with a pendulum, there is a lever E. At one end of this is a fork to give impulse to the balance through an "impulse pin" D. At the other end of the lever is a counterpoise, to balance it. The impulse pin is set upright in the centre boss of the balance, and as it comes round enters the centre notch of the lever fork. This moves the lever a little, unlocking an escape-wheel tooth, and allowing it to give impulse. This impulse is transmitted by the lever to the impulse pin, and thus the balance receives a little push onwards. The balance continuing its motion, is at last brought to rest, and the hairspring causes it to return. The impulse pin enters the centre notch of the lever fork, unlocks a tooth, and the lever gets another impulse, and so on.

Between the impulses the escape-wheel teeth are locked, exactly as in the English dead-beat escapement, and the pallets and lever do not move. The balance, also, is quite free to spin, the lever not touching it. The axis of the balance has a flat filed on it opposite the impulse pin, to allow the prongs of the lever fork to pass. The use of the outer prongs of the lever is to prevent the lever moving and unlocking the escape-wheel teeth between impulses. Fig. 71 shows what is meant, and represents the lever fork and the balance axis between two impulses. If the lever gets a shake or from some accidental cause comes against the balance axis B, the prong A will rest against the axis B, and the lever can get no farther until the impulse pin comes round and enters the centre notch, by which time the flat on the balance axis will be in the proper position to allow the lever fork to pass.

In this escapement there are two depths or actions that must be adjusted correctly. The first is the pallet depth or action between the escape-wheel teeth and pallets. This exactly resembles that in a French or American dead-beat clock, and should be adjusted to "lock" in the same way. The second is the lever depth or action between the lever fork and the balance axis and impulse pin. The lever must have sufficient motion between its banking pins for the horn or prong

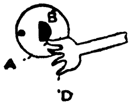


Fig. 71.—Action of Lever Fork in Relation to Balance Axis

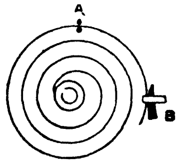


Fig. 72.—Hairspring of Drum Lever Escapement Balance

A (Fig 71) to be quite free of the axis of the balance and have some shake. To test this, hold the balance with the finger, half a turn round, as in Fig. 71. Then place a finger-tip or pair of tweezers on the lever counterpoise, and try the "shake" of the prong A against the balance axis. Let the balance come round, and hold it on the other side, trying the shake of the prong D in the same way. If they touch and have no shake, the balance cannot vibrate freely, and the banking pins must be bent outwards to give a little play. If the points of the lever prongs can pass the balance axis and seem too short, lengthen the lever by straightening up the bend in the lever a little.

In these clocks the balances must be adjusted in their bearings so as to be quite free and have the least trifle of endshake; but on no account must they rock about. It is very important that the points or pivots of the balance are central, true, and sharp. Sometimes they merely wear blunt or rounded; at others they wear all on one side. In each case sharpen them up on an oilstone until they are true and sharp. In doing this the balance must be rotated a little as it is rubbed on the stone, to prevent flats being formed on it. A good way is to hold the axis in a pin-vice during the operation. Or the pivot points may be sharpened up on emery buffs; but the result is not generally so good.

The hairspring (Fig. 72) is an important part of the escapement. It is passed at its outer end through a hole in a brass stud, and held in place by a tapered pin B. The outer coil then passes through a wire loop or between two pins A, which are set in the regulator. The spring should pass freely between these pins, and when the balance is at rest should stand between them, not touching either, as illustrated. Then when the clock is going the spring will play evenly between them. The hairspring should also lie flat in the clock.

If properly "in beat," when the balance is at rest the impulse pin will be in the lever fork, and the balance axis, impulse pin, and pallet axis will be in a straight line. This can be adjusted by loosening the pin B, and either letting out or taking up a little more hairspring, and pinning tight again.

If one of these clocks gains while the regulator is at "slow," and the hairspring is quite free between the regulator pins A, it may be made to go a little slower (up to five minutes per day) by bending the pins A wider apart and giving the spring more play between them. If the alteration required is more than this, the spring must be unpinned at B, and the centre brass collet turned round on the balance axis, so that when again pinned in and in beat the hairspring is longer. If such a clock loses, the reverse process can be followed, closing the regulator pins a little for a small alteration, and shortening the hairspring for a larger one.

Before making any such alteration, see if the clock is clean and oiled properly, as a dirty clock or sticky oil will cause all sorts of errors. If a clock cannot be made to go slow enough, even when the regulator pins are opened out and all the hairspring let out, weighting the balance by tinning it with lead solder will be effective. But after this it must be well washed in plenty of water to remove the acid, and the hairspring should be removed during the process. Or three holes may be drilled at equal distances through the balance rim, and pins or screws fitted to make it heavier.

The parts requiring oil are the balance pivots and escape wheel and lever pivots, the pallet faces, and just a trace on the impulse pin. The regulator pins must be perfectly clean and dry; also the hairspring where it passes between them, or else they will become sticky, giving the spring a jerky action and causing the clock to gain.

Different varieties of this escapement are met with.

Some have pin pallets, like Fig. 53 (p. 46), and the description there given applies to them equally in all respects. Others have differently shaped lever forks or impulse pins of other forms; but the principle of all is the same, and if the action of the common form of escapement is mastered, no difficulty will be found with its varieties as seen in clocks by different makers.

The escapements of cylinder drum clocks, French lever carriage clocks, etc., come under the head of watchwork, and need an expert watchmaker to clean and repair them properly. As already stated, a drum clock with lever escapement and balance is really a big and comparatively coarsely made watch.

CHAPTER XIII

Cleaning Regulator Clocks

A REGULATOR is understood to be a clock made especially to show the closest rate of timekeeping—a watchmaker's clock on which he relies to regulate his watches and clocks. It should be furnished with a weight as motive power, also a one-second pendulum, a seconds hand, a dead-beat or other escapement with similar accuracies, and acting surfaces made to reduce friction to its minimum. There is no law to prevent any person from making or selling any timekeeper marked "regulator," any more than there is of selling a watch stamped "accurate" or "perfect timekeeper." A perfect timekeeper has not yet been produced, and a "regulator" is an acknowledged standard quality.

Next to an English one-second pendulum regulator, the Vienna regulator is the best timekeeper to be had. Its great advantage lies in the possession of a long and fairly heavy pendulum and a carefully made dead-beat escapement. It is driven by a weight, which is superior to a spring, in that the power does not vary when wound up fully or nearly run down, but is always the same.

Figs. 73 and 74 show the movement. On an earlier page, the special form of pallets used in the dead-beat escapement is illustrated and described, and the adjustment of the escapement explained. The resting surfaces of the pallets, or their "locking faces," as clockmakers would say, are struck from the pallet pivots as a centre, and consequently the escape-wheel teeth, when resting upon them, neither advance nor recoil, but only move when they give impulse across the faces of the pallets. This form of escapement, invented by Graham, is admitted to be the best yet introduced for ordinary clocks; its only superior is the "Gravity," used in turret clocks and sometimes in the best regulators. As already pointed out, Vienna regulators are generally well made, have light wheels and small pivots, and are driven by a comparatively light weight; thus, as there is no excessive driving force, they need to be kept clean and well oiled.

"**Maintaining Work.**"—It will be observed that there is "maintaining work" to keep the clock going while it is being wound. In a spring clock this is unnecessary, but in a weight clock, unless some such arrangement were provided, the act of winding would not only stop the clock for the minute or so occupied in winding, but would cause the escape wheel to travel backwards and double the error. A careful examination of the barrel and main wheel will amply repay the worker. It will be seen that a ratchet and curved spring are interposed, and it is through this spring that the driving power reaches the clock. A pawl, or "detent," as it is called, falls by its own weight into the ratchet teeth, and, when the clock is being wound, prevents the ratchet and curved spring from being carried backwards; the curved spring in

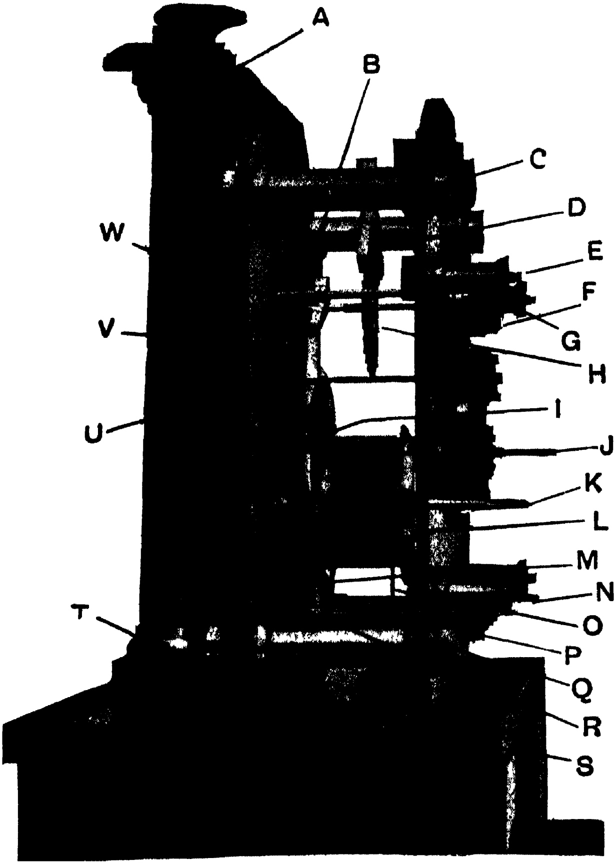


Fig. 73.—Regulator Clock Movement

A, pendulum suspension; B, escape pinion; C, verge arbor; D, pallets; E, dial feet; F, bridge; G, escape pivot for seconds hand; H, escape wheel; I, barrel ratchet; K, winding square; L, stop work; M, click; N, hour-hand pivot; O, line; P, barrel; Q, maintaining ratchet; R, main wheel; S, bed plate; T, hold-fast; U, pinion; V, third wheel; W, maintaining detent.

the meantime keeps the clock going until winding is completed.

Removing Movement.—To remove the movement of a Vienna regulator, undo the two set-screws just underneath the clock and draw the movement forwards. The pendulum will be left in the case and need not be disturbed. Hands and dial come off as usual. The plates and wheels, etc., must be polished with rottenstone and cleaned in the ordinary way. Repairs of any kind are seldom needed. The gut line, if broken, is easily replaced with a violin "A" string, purchased at a music-seller's, the method of replacing being self-evident.

Setting Up.—To set up a Vienna regulator, proceed as follows: first hang it upon a stout picture-nail, and adjust for upright by means of the pendulum and the enamelled scale at the bottom of the case, the pendulum when at rest just indicating zero on the scale. Then screw the two steadying screws, one each side of the bottom of the case, firmly into the wall. Finally, set in beat by means of the adjusting screw on the crutch, which can be easily manipulated without disturbing anything. In most clocks of this type, the seconds hand revolves once in about forty seconds.

Vienna Regulator Gaining.—If the hands move too easily, it will account for serious irregularities. Or if the escape-wheel teeth do not lock properly on the pallets the clock will gain. To test this, take out the movement and, having "set up" the maintaining work, move the crutch slowly across so as to allow a tooth to "drop" on to one of the pallets. Observe

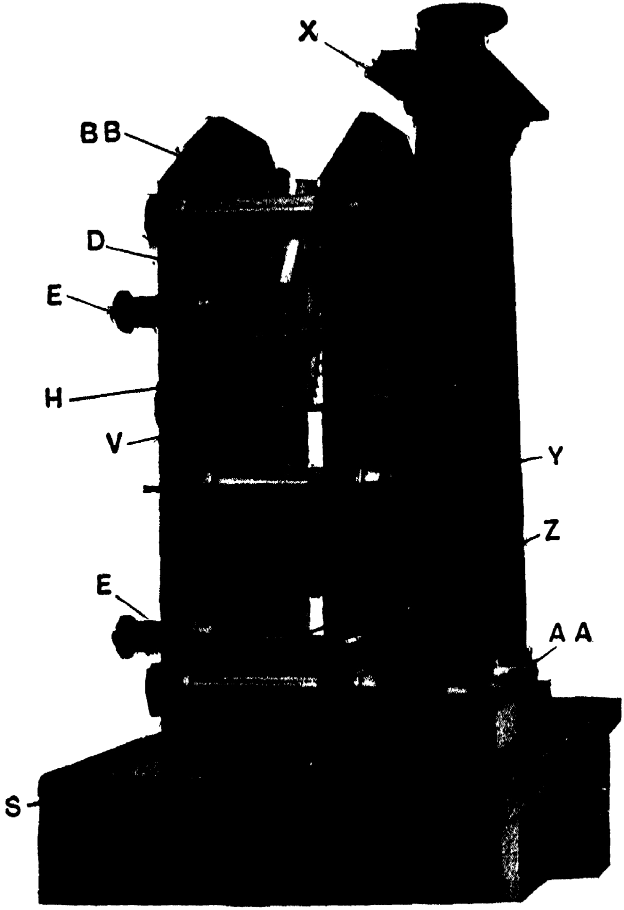


Fig. 74.—Another View of Regulator Clock Movement

D, pallets; E, dial feet; H, escape wheel; S, bed plate; V, third wheel arbor; X, pendulum bracket; Y, centre wheel; Z, 24-hour wheel; A A, pillars carrying pendulum; B B, verge cock or bridge.

the pallet carefully, and see that the tooth point falls on the circular locking face, close to the pallet corner. If it falls beyond the corner and on to the inclined face direct, the pallet must be advanced until correct. The teeth should fall on the locking faces as near to the corner as possible; the merest hairbreadth is sufficient margin. Too much will stop the clock. The writer has known a fine spider's web spun from the pendulum rod to the case back behind the movement cause one of these clocks to gain many minutes in the course of each day.

Regulator Striking Clock.—Many forms of clock are marked "regulator," and some are of cheap manufacture. Generally a regulator is a non-striker of the highest-class manufacture made to record very close time. However, some regulators are met with that have rack striking work, resembling that of a grandfather clock, and on this principle most others are made. In Fig. 75 the wheels between the plates are represented by plain circles to show their positions. The gut lines are wound up on barrels, fitted with winding ratchets and clicks and click springs to prevent running back. The main wheels are driven by the barrels, and are mounted upon the barrel arbors. Around the pin wheel are arranged the lifting pins, which lift the gong hammer. The pallet wheel arbor carries the gathering pallet, which gathers up the rack teeth during striking. The snail, mounted upon the star wheel, determines the number of blows to be struck at each hour. This system of wheels is known as the rack striking work, and is used in a great many

French clocks and in nearly all English grandfather and bracket clocks (compare Fig. 75 with Fig. 69). The letter references are as follows: A is the striking main wheel, B pin wheel, C pallet wheel, D warning wheel, E fly, F going main wheel, G minute wheels, H centre wheel, I third wheel, J 'scape wheel, K pallets, L minute wheel cock, M warning lever, N lifting piece of warning lever, O rack hook, P gathering pallet,

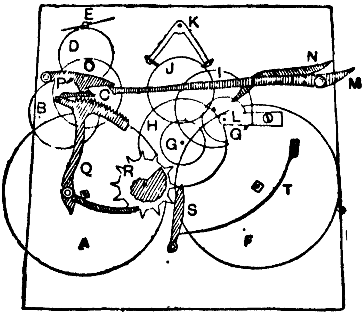


Fig. 75.—Vienna Regulator Striking Movement

Q rack, R star wheel and snail, S flirt, and T the flirt spring.

Move the minute hand slowly to the hour to test the warning and striking, and make a note of any part that requires correcting or repairing, as the clock is taken to pieces. A clock that stops in the going is seldom wrong in the striking work. The striking part should be examined before taking the plates apart. Fig. 76 shows a detail of the most important part, the principle being the same as in Figs. 69 and 75, although the small details vary. Move the pin A (Fig.

76) round slowly until it engages the lifting piece B, and notice the action of the latter with its contact to the rack hook C and warning piece. As soon as the rack hook is lifted,* the rack D should fall immediately on the snail, and the warning pin in the striking train fall on the warning piece E. Space will not permit of dealing with the number of faults to be found in the striking work. The most common are: clock strikes on the warning; this will not give the rack sufficient time to fall on the snail; obviously the wrong number struck. Rack spring too weak gives the same result. In the former the warning piece can easily be bent, or the pin. The rack spring will usually bend to throw stronger. When the power is gone a new one is advisable. A loose rack tail F is tightened with a few taps from the pene of a hammer. Refrain from filing a piece unless certain the alteration will cure a fault. Should the clock strike one at five minutes to the hour, and one short at the hour, the wheel that carries the pins for lifting the hammer must be shifted a tooth or so forward in the pinion with which it gears. It will be found that in its faulty condition, when the clock finishes striking at the hour, it raises the hammer to such a position that it drops off when the clock warns five minutes before the hour, thus giving the one blow mentioned. It then gathers up one tooth of the striking rack, leaving it one blow short at the hour when the clock strikes. Should the clock, immediately after striking, make a clattering noise, it will probably be due to the hammer chattering on the stop pin or spring, and the noise can be lessened by slipping a

rubber tube on the pin. Bicycle valve tube is sometimes handy for this purpose in clocks.

The striking work having been examined, it may be removed and the plates taken apart for general cleaning and overhauling. On re-assembling, place the going and striking trains in the frame and pin the top plate on. Put the lifting piece on its stud, the rack, the rack hook, the gathering pallet and minute

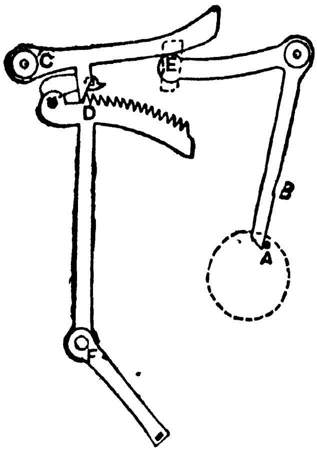


Fig. 76.—Rack, Rack Hook and Warning Piece

wheel, as shown in Fig. 76, and try the warning. The warning pin, which is in the wheel between the plates, should have half a turn before it falls on the pallet E. To correct this, lift the top plate, move the wheel round a tooth, and replace it in the hole.

CHAPTER XIV

Cuckoo Clocks: Mechanism and Cleaning

In cuckoo clocks the cuckoo is mounted upon a wire arm, which, as the clock begins to strike, swings forward and pushes open the little door, the bird just projecting. The door is linked to the wire-carrying arm by a length of wire, and on the completion of striking the arm draws the door shut again. A projecting wire upon the top of one of the little bellows at each blow raises the cuckoo's tail, making the bird "bow" to the audience, and by little internal wires, to which the wings and beak are jointed, the "bowing" simultaneously opens the wings and beak.

A cuckoo clock is a most difficult clock to clean properly; indeed, valuable cuckoo clocks have been entirely spoiled by having been tampered with by inexperienced persons. Start by drawing out the pin and then unscrew the brass nut that holds the hands; remove these, then the four pins that hold the dial in place, and the two doors, and draw out the wire nails holding the back to the movement. This will then be clear, and the small door opened and closed by the bird being removed, the works should be well studied. Note how the bird is sent out and how the tilting motion is given to cause its mouth to open and its wings to spread. The slender wire fixed to the left-hand bellows does this, and a lever near the bottom of the rod on which the bird is fixed causes it to go out, calling "cuc" "koo," and then allows it to return. A rough sketch of the various parts will help in putting the whole together, because, unless the five lever bars at the left-hand side are in their proper places, it will all be out of order. The lowest bar has a wire upright which lifts the right-hand bellows, the next lifts the other bellows, and the bar above is the hammer to strike the gong which accompanies the bird's calls. Another lever counts on the count wheel the number to be called, etc. The difficulty lies in this mechanism, but after study it may be managed. Use a thin piece of card to clean out the dust which will have accumulated in the cap part opposite the lips of the pipes.

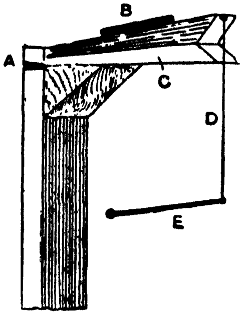


Fig. 77.—Pipes and Bellows of Cuckoo Clock

The going part is like that of all other clocks, and so need cause no trouble. Replace the chains, then fix on the back with the gong attached and the dial, making the hands agree with the hour struck, and replace the small door on the front part with wire attached to the pedestal of the bird. Oil all the pivot holes, giving a drop to each and to the tips of the bars and each pallet, and one drop to the clutch where the pendulum works in the loop.

Should a cuckoo clock, after going a short time, begin to strike in advance of the right hour, it may be that the stopping mechanism is defective. Observe carefully the thin bent wire that dips into the slots of the count wheel and regulates the number of blows struck. See that it falls clear and well into the slots, and that when it does so the inner part of the same arm locks the striking train properly. When the parts are running fast it is difficult to see just what happens, but by placing a finger on the fly and only letting it turn half a turn at a time, the action can be watched.

In a case in which a clock regularly strikes one hour in advance, proceed as follows: If the hour hand is capable of being turned to a fresh position, simply turn it until it points to the hour struck. It not, lift the striking hook at the back of the clock, or open one side and raise the warning lever. In this way the clock may be struck round without moving the hands until the hour struck and the hands correspond.

Making "Cuckoo" Mechanism.—This mechanism may be bought of material dealers; or the reader may attempt to make it for himself. Two pipes are required, these being in reality small organ pipes, placed with the mouth up, not, as in an organ, one at each side of the case. An opening is cut in the side of the clockcase to improve the clearness of the note. The pipes may be made of cigar-box wood, but the tone is better if white pine is used. Dress a board up to the thickness of a cigar-box lid, about 1 ft. square. Make it perfectly smooth and true; then cut it into four lengths 1 in. wide and four lengths ¾ in. wide, four being 6½ in. long and four 7 in. long. The 6½-in. set is for the pipe to call "cuc," and the 7-in. set to call "koo." Then proceed to make the lips. Take two of the broad pieces and mark, exactly $\frac{1}{2}$ in. from their ends, a cross-line, and $\frac{1}{4}$ in. from that mark another cross-line. With a sharp chisel cut out the space between the lines, leaving uncut at each side the thickness of the side-pieces, which will be glued to it. Now carefully cut the lip—that is, the part that has to speak—of each one. Begin by making a sloping cut $\frac{3}{8}$ in. above this opening, dressing it down carefully to a uniform thickness at the opening, and reducing it to the thickness of an ordinary thin postcard. To the other give a little longer slope, this being for the large 7-in. pipe.

Make up the pipes by placing the two wide pieces that are uncut on the bench, and glue two of the narrow pieces on the edges, placing them edgewise upon the bottom pieces. Then place the two pieces with the lips cut, and glue the edges; clamp both up square, or place weights upon them. When dry, run thin glue down inside each seam, so that there will be no air-holes, or the pipes will have a poor sound. Cut the blocks to fit the ends where the lips have been cut, no longer than is necessary to reach the opening facing the lip. Before gluing it in position, shave a thin piece off the upper part of the wind passage, taking a little more off at the entrance where the bellows are to be placed; or cut away the lower portion of the piece that was cut for the lip, and fix a small partly hollowed piece for the cap, thus leaving the blocks flush with the side pieces; the opening between this block and the cap should be made so as to admit a piece of thin postcard. This amount of wind is quite sufficient. Fix the small bellows to the small pipe, and the larger bellows to the other. The air passage is at the thin end of the bellows and down the open space at the blocked end of the pipe. Glue triangular pieces from the pipe under the bellows to support them, and place a thin piece of lead upon the top right weight to sound the "cuc" "koo" quickly. The top lid of each bellows has a small eyelet in front, to which should be fixed an S-shaped wire to lift them alternately. One wire is ¾ in. longer, to be clear of the other when rising. Attach the other ends to the two levers, which are lifted by the pin-wheel of the clock. The bellows are 2½ in. by 1½ in., and are of kid. Try the pipes with the bellows before gluing to the case. The large bellows is placed on the going side of the clock, the smaller on the striking side. Be sure that the small one lifts first, to call "cuc." In Fig. 77, A represents the mouth of the lip, B the lead weight, C the bellows, and D the wire connecting the lever E to the bellows.

CHAPTER XV

Adding Quarter-Chimes to Grandfather Clock

MANY people who possess grandfather striking clocks wish to add chimes to them. Given a clock the wheels and pinions of which are sound and not badly worn, and which has a good case, there is no reason why this should not be done; and there are many amateurs capable of carrying out the necessary alterations when aided by proper directions.

To undertake the job with any chance of success, a small good lathe, or a large pair of clock turns or clockmaker's "throw," a bench, vice, numerous small files, drills, broaches, etc., will be wanted; and, above all, the ability to work fairly well in metal. As none but fairly good mechanics will attempt such work, it is not necessary that very elementary details relating to the working of the clock or the execution of small mechanical operations of the ordinary kind should be minutely described.

Making New Frame.—In Fig. 78 is shown a general view of a grandfather striking-clock movement. To convert it to a chime clock, it will be necessary to add a third barrel and train of wheels on the right-hand side, very similar to the striking train of wheels on the left. It is obvious at a glance that there is no room in the frame for this addition; therefore the best and only really practical way is to discard the old plates and make a new frame. This doubtless appears to be a formidable undertaking, but is not so in reality. In some cases the old pillars can be saved and used again, especially if they are large in diameter and strong; but generally it will be found advisable to turn four new ones. As movements differ somewhat in size and general proportions, exact dimensions of any part cannot be given; each worker must, according to his own special case, work them out for himself. The new plates should, as a rule, be a trifle higher than the old ones—say ½ in. to 1 in.—and 3 in. wider, which usually makes the movement about 8½ in. square. For the plates, procure two pieces of the required dimensions and from ⅛ in. to 3/16 in. thick, the latter thickness being best. All the metal, etc., may be procured from material dealers, and there are certain firms who will, for a trifling sum, also planish the brass for the plates—that is, hammer it flat and true, and polish the surfaces until they are almost like glass; this will save an immense amount of labour, and produce a finish that no amateur could hope to attain.

Castings should not be used for the pillars; the metal will be too soft. They should be cut from a length of ⅝-in. round brass rod, and turned. In making a clock frame, the object to be steadily kept in view is to produce a firm, rigid frame, true and squarely built up. Fancy pillars, polished plates, etc., are not necessary, and in many cases may tend to weaken the parts; so that, unless time is no object, the pillars can be used as they leave the lathe, and the plates will not require any more polishing than the file or emery-buff has given them. The letter references in Fig. 78 are as follow: A the striking barrel, B the going barrel, C the pin wheel, D the pallet wheel, E the warning wheel, F the fly, G the centre wheel, H the third wheel, I the 'scape wheel, J the pallets, K the snail, L the rack, M the rack hook or detent, N the gathering pallet, O the

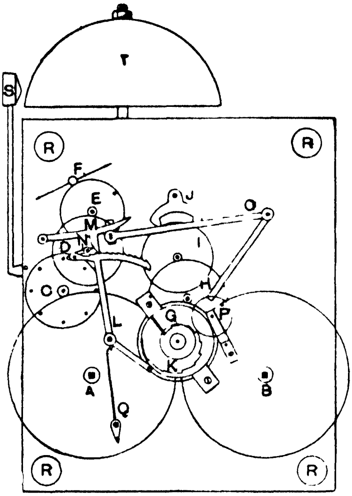


FIG. 78

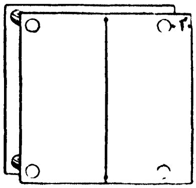


FIG. 79

Fig. 79.—The Frame

Fig. 78.—Movement of Grandfather Striking Clock

warning or discharging lever, P the minute wheel, Q the rack spring, R the pillars, S the hammer, and T the bell.

In Fig. 79 is shown the new frame on a smaller scale. First take the two plates, and draw a centre line down each. Clamp the plates together, and on the centre line, close to each end, drill them both right through with a drill about $\frac{1}{16}$ in. wide. Rivet them together lightly with brass rivets, and file up square and true on the edges. Mark and drill the pillar holes, $\frac{5}{16}$ in. in diameter, right through both. Note that the top right-hand hole is placed 1 in. in from the side. This is to clear the hammer rack for the chime bells. The plates can then be separated by knocking out the rivets. These rivet-holes will be found useful when drilling pivot-holes, etc., for after drilling the holes in one plate the plates can be lightly pinned together, and the back plate drilled through the front one. The rivet-holes can be left, as they will do no harm. The pillars can be screwed into the back plate up to a shoulder, or a screw can be driven into them through the plate, or they can be riveted like the old ones. Perhaps this latter is the better and easier way. The pillars should come through the front plate and be pinned, as in the old frame.

"Pitching" the Going and Striking Trains.—The frame having been made, the going and striking trains can be "pitched in." Fig. 80 shows the position of wheels, etc., and the letter references are thus explained: A the hour snail, B the hour rack, C the hour-rack hook, D the hour warning lever, E the quarter snail, F the quarter rack, G the quarter-rack hook, H the quarter lifting and warning lever, I the pin in the quarter rack, J the lifting-pin in the warning lever, K the chime-hammer rack, L the chime-hammer springs, M the chime bells, N the chime hammers, and O the chime barrel or drum and pins.

The going train must be pitched all on the centre line. The positions of the pivot-holes can be obtained by measurement from the old plates, or they may be transferred direct by marking through the old holes. After drilling, the plates may be pinned together and the holes drilled in the back plates. The holes should be carefully opened out by broaches, so that they fit

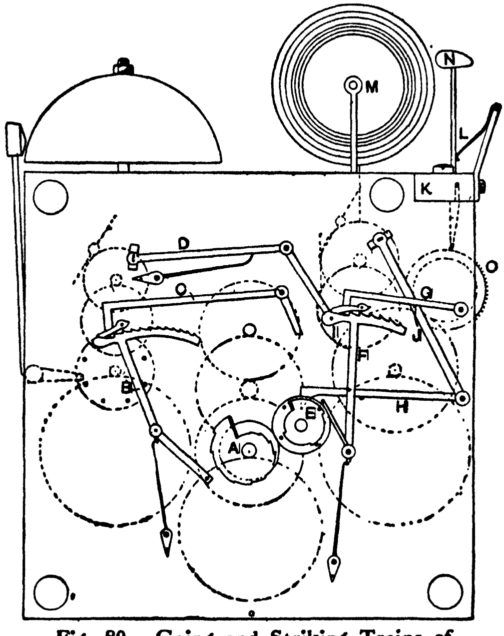


Fig. 80.—Going and Striking Trains of Grandfather Clock

the pivots easily, but without shake. Always oil broaches when using them. If the depths are not quite right when run in, the imperfect holes must be opened out by broaching them larger, plugged with brass, and re-drilled.

In pitching the striking train, note that the pallet-wheel holes must be at exactly the same distance from the centre-wheel holes of the going train as in the old movement, or the striking rack will not be correct. This distance must be most carefully made exactly the same as before, and may necessitate the pin-wheel being placed in a different position from that shown in either Fig. 78 or Fig. 80. The position of the pallet-wheel pivot-hole must be first determined, and the pin-wheel then planted in such a position as to run properly with both main-wheel and pallet-wheel pinion. The back plate will require cutting to admit of the pallets being taken out, and the back cock or pendulum suspension cock must be screwed on in its proper place. In pitching the going train, the barrel must be placed as low as possible without fouling the wooden seat board. The hour hammer and its check spring, etc., can be re-planted in the new frame as in the old one. Possibly, the hammer may want a longer stem, on account of the increased height of the frame.

Motion Work.—The motion work can be made as before, the cannon pinion put on, the "bridge" screwed and steady-pinned on, and the hour-wheel mounted. If the old snail was on the hour-wheel, the rack stud can be screwed in again, its position being carefully located by compasses, making it bear exactly the same relationship to the hour-wheel and pallet-wheel as before. Its spring can be planted and the rack put on. Try the rack all round the hours very carefully, and, if necessary, alter the tail and pin, and make a new one to suit the new pitching. Here the worker's skill is required in order to determine the amount and direction of the alterations necessary to restore the rack action to its previous accuracy. The warning lever, which engages the pin in the warning wheel, can be planted as shown in Fig. 80, a new tail made to it, and the necessary slot cut in the front plate. But the old rack hook will be discarded for one of a different shape. Its stud, however, can be used again in a new position.

Minute-wheel.—The minute-wheel may be planted in the same position as before. If it has a steel pinion and is held by a cock and screw, plant in the cock in an upright position, with the screw downwards. If it has a brass pinion and works on a stud, it will be better to turn a new pinion and mount in a cock screwed to the plate. If the hour rack works on a separate star-wheel with jumper and spring, plant all exactly as before, taking care to run nothing too close to the winding square of the striking barrel, and to leave room for the key to be placed on it.

Chiming Train.—The train of wheels for the chiming side should now be taken in hand. When purchasing, ask for a rough barrel of ordinary size for the chime side of a grandfather quarter clock, a main wheel of 100 teeth, second wheel of 80, pallet wheel of 63, warning wheel of 56, and chime nut of 40. Pinions can be purchased ready almost for riveting on the wheels, and pivot or pinion wire may be bought in lengths, and will require turning down, hardening, tempering, etc. If the latter plan is adopted (and it is the best), order with the wheels half a length of pinion wire of eight leaves to suit the main wheel, half a length of eight leaves to suit the 80 wheel, and a length of seven leaves to suit the 63 and 56 wheels. The pinions on which the 80 and 63 wheels are mounted have eight leaves; the pinion of the 56 wheel and the "fly" pinion are of seven leaves. Procure also a piece of 1¼-in. brass tube, 2 in. long, for the chime barrel in which the pins are to be fixed.

Large Barrel.—The large barrel will be found to be mounted on a rough arbor, turned roughly, with the spiral groove for the line cut, and the ratchet cast on and cut. Place this in the lathe, and smooth up the ends and all surfaces; turn the arbor down true, and also the pivots and groove for the "key" which fastens the wheel. The striking or going barrel can be taken as a pattern, so no illustration is necessary.

Fig. 81 shows the relative positions of barrel, wheels and pinions, and "fly," A being the pipe of fly, B the curved or bow-spring, and C the pin to hold the pipe and spring.

The barrel pivots must be turned as smooth as possible, and finished with a very smooth file. After this they are polished by means of a brass, bell-metal, or steel polisher, which is filed smooth, and has oil-stone dust and oil spread on it. Use the polisher as a file with light pressure while the arbor runs in the lathe. When this has taken out all file marks, clean the polisher thoroughly, re-file it, and charge again with "red-stuff" and oil, which will bring up a good polish in a few minutes, especially if the speed is fairly high. The polisher and the red-stuff should be kept quite clean and covered up from dust.

Main Wheel.—The main wheel must be turned true in the centre, as must all the wheels, before opening it out with a broach to fit the arbor of the barrel. It is important that it should fit without shake. It is necessary that the centres of all the wheels should be turned true, because when the wheels are cut they are only approximately true to their centres; consequently

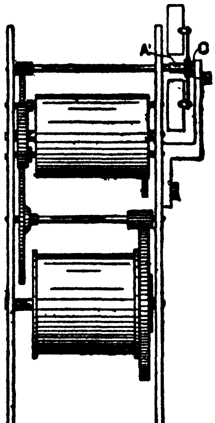


Fig. 81.—Arrangement of Chiming Train

Fig. 82.—Pinion Wire Centred for Turning

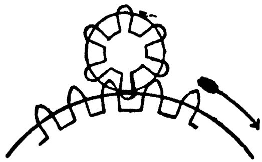


Fig. 83.—Pinion and Part of Wheel

there is no guarantee that the centre hole is the true centre of the circle of teeth. The centres of all the wheels may as well be turned true at once in the same chuck to save time and trouble. To do this, mount a piece of wood on the face-plate of the lathe, and face it true and flat. Then with a sharp chisel and at high speed make in it a shallow depression, into which the smallest wheel can be just pushed friction tight to the bottom. The wheel thus held by the points of the teeth must run quite truly. While thus held turn out the centre hole true, after which it can be opened out by means of broaches for fitting; then enlarge the depression in the wood for the next wheel, and so on until all are done. The fitting and fastening on of the main wheel to the barrel and the making of the "click" and its spring can all be copied directly from the other barrels.

Pinions.—Pinion turning will not be found so easy an operation as barrel turning; but with a fine pair of female turning-centres, and a running centre which is perfectly true, it can be accomplished in any ordinary small lathe. It is quite impossible to turn pinions between ordinary or male centres. Start on the pinion for the 80 wheel, as that is the stoutest. Cut off the required length, and centre it to run quite truly. The centres will have to be filed up. When centred it will present the appearance shown in Fig. 82. Turn two nicks, marking out the portion of the leaves it is desired to leave on, and, removing it from the lathe, proceed to file off the useless part of the leaves, and leave only the centre core. Then turn the pinion true throughout, and it is ready for hardening and tempering.

To harden the pinion, heat it to a full and even red from end to end, and plunge it end-on into cold water and stir it round; or the water may be stirred up and the pinion plunged in and held quite still. Brighten with emery-cloth, and very carefully re-heat over a clean flame, like a Bunsen burner or a spirit lamp, until the pinion takes a deep blue colour from end to end, after which the centre portion may be let down still more to a pale blue. This will facilitate straightening should it happen to have gone out of truth in the hardening. Place the pinion in the lathe again and test for truth; bend it until the pinion portion runs quite truly; the other part does not matter, as it can be reduced until true by turning. It can then be turned, pivoted, and the pivots polished as before described.

Wheel Mounting.—The 80 wheel is mounted on a brass collet. To make this, drill up a piece of brass rod in the lathe, and roughly turn it to shape; then solder it on to the pinion and turn true, taking great care with the seating for the wheel. Rivet the wheel on well with a punch, having previously notched the hole in the wheel to prevent turning round. A wheel mounted thus should go on quite truly. The pinion for the 63 wheel must have a rather large front pivot, and come through the front plate in the same manner as the corresponding wheel of the striking train.

Other Pinions.—The warning-wheel pinion needs no special directions, except that, as it is slender, only its ends need be hardened. The same remark applies to the fly pinion, which, it will be seen from Fig. 81, extends through the back plate and is carried by a large brass cock.

Fly. — The "fly" is of the regulating pattern, as shown in Fig. 81. It consists of two square vanes, ½ in. by ½ in., or ⅜ in. by ⅜ in., supported on a cross-arm riveted to a central "pipe" turning loosely on the pinion. It is held friction tight by being kept pressed down to a thin curved brass spring with a central hole in it, which passes over the pinion and rests against a shoulder. The fly is held up to this spring by means of a pin through the pinion.

Chime-barrel Arbor.—The chime-barrel arbor is made of a piece of steel wire about $\frac{3}{16}$ in. thick, turned up true and pivoted and polished like the rest. Before proceeding with this, it will be necessary to decide whether single four-bell or eight-bell chimes are wanted, or both; because if both are wanted and a changing mechanism, the arbor will need to have an "end-shake" between the plates, or a "pump action" of $\frac{1}{8}$ in. to allow of the change of chimes. In Fig. 81 this is shown to be the case. Having turned the arbor, mount the 40 wheel on it so that it will gear properly with the 80 wheel in both positions of the arbor, allowing for the shifting. The chime barrel is made from the brass tube already specified. First drive on and solder brass discs to form the ends; turn them true and then solder on the tube, afterwards turning that true all over. Make it the whole available length of the arbor. The complete chime train can then be pitched between the plates, as shown in Figs. 80 and 81.

Pitching the Depths. — To pitch the depths correctly, the wheels and pinions must be carefully measured with fine-pointed compasses, and then transferred to the plates. To do this, the theory of "depths" must, to a certain extent, be understood. If the teeth of the main wheel are examined, they will be seen to consist of straight radial lines up to a certain spot called the "pitch circle," beyond which they are curved to a point. These curved portions are the parts that act on the pinion leaves. If a pinion is examined, the leaves will be found likewise to consist of radial straight lines up to the "pitch circle," beyond which they are rounded by a semicircle. It is the *straight* portions on which the curved points of the wheel teeth act; therefore, if the pinions turned from the pinion wire are not well shaped, file out the leaves deep and straight, and smooth them up carefully with emery on wood.

For a depth to run perfectly the pitch circles must roll on one another, as in Fig. 83, which shows a portion of a wheel and pinion, the "pitch circles" being drawn. Therefore to pitch a depth, the actual diameters of the wheels and pinions are not considered, but the diameters of the pitch circles only. To pitch, for example, the main wheel depth with the 80-wheel pinion, first drill the barrel arbor pivot-holes in the correct position level with the centre-wheel hole and the striking barrel. Then with fine compasses measure the full diameter of the pitch circle of the main wheel, and transfer it to a line drawn on a sheet of smooth white paper. Next measure the diameter of the pitch circle of the 80-wheel pinion, and add it to the other on the same straight line. Then, by trial with the compasses, find the exact half of the length, and transfer it to the plate as the required distance between the barrel pivot-holes and the 80-wheel pivot-holes to form a correct depth. Pitch all the depths in this way, and drill the pivot-holes in the plate, transferring them to the other plate by pinning the plates together and marking through as before.

Bells, Hammers, etc.—The set of eight chime bells, forming a complete octave, is mounted on a spindle, supported by two uprights screwed to the back and front plates respectively. Small wooden washers, $\frac{1}{8}$ in. apart, are placed between each bell and its neighbour so as to separate them, the eight bells thus ranging over $1\frac{7}{8}$ in.; if the pillars are only 2 in. long the bells must be spaced more closely. The eight hammers work in slots cut in a brass block screwed across the top corner of the frame in recesses cut for it, as shown in Fig. 80. It should be about $\frac{3}{4}$ in. wide, $\frac{3}{8}$ in. deep, and the length equal to the width of the frame.

The hammers are made of flat steel or iron, rather thin, say a little less than $\frac{1}{16}$ in. thick. They all work on one pin running from end to end of the brass block. To drill a hole for a small pin from end to end through a $2\frac{1}{2}$-in. brass block would be no easy job, so it is managed in this way. The brass block, on the underside, is cut halfway through with a saw from end to end (a tenon saw cuts brass well). A slip of brass to fill up the saw-cut, all but a small space for the wire, is then filed up and soldered in and filed off flush outside, as shown in Fig. 84. The pin should project at the ends to facilitate removal.

The hammer heads are of brass, and are driven or screwed on. The hammer springs are made from a thin piece of brass, and are like a comb with eight teeth, the whole being fixed to a support, as shown in Figs 80 and 85. The hammer stems should be bent to suit the bells, that which is to strike the smallest bell being farther forward than that which is to strike the largest bell. But the tails, which should just clear the chime barrel, must all be in a straight line. The slots in which they work should be cut to such a depth as to ensure this, or stops can be arranged for each

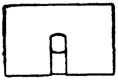


Fig. 84.—End View of Hammer Rack

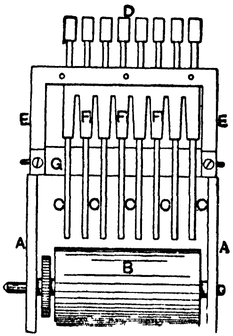


Fig. 85.—Plate with Hammer Springs

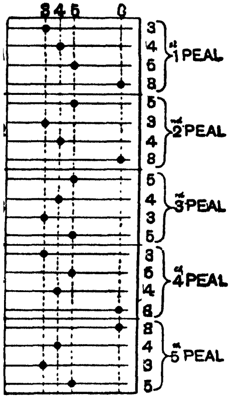


Fig. 86.—Positions of Pins for Westminster Chimes

hammer if desired. The following are the letter references in Fig. 85: A the plates, B the chime barrel, C the hammer tails, D the hammer heads, E the frame for the hammer springs, F the hammer-spring "comb," and G the hammer rack.

Motion Work.—Very precise directions cannot be given as to the rest of the mechanism, as so much depends on the size and arrangement of the movement in hand; therefore a description of the action of the motion work will now be given, which should enable the worker to complete it correctly.

As the clock approaches a quarter, one of the four pins marked on the minute wheel E in Fig. 80 advances and begins to raise the lever H. This also raises J (in one piece with it) and the quarter rack hook G. The quarter rack F then falls until its tail rests on the snail E (with four steps). The rack, in falling, releases the gathering pallet and the chiming train "warns," being stopped by the pin in the warning wheel coming in contact with the steel block in the warning lever. The train is thus held stationary until, as the minute wheel E advances, the pin finally passes the warning lever H, and the latter falls, at the same time releasing the pin in the warning wheel and allowing the rack hook G to fall, and the clock chimes the quarter. That is to say, supposing the rack F fell on the first step of the snail E, it would fall a distance equal to one tooth. Therefore, the gathering pallet would make one revolution and gather up the one tooth, coming again to rest on the pin in the rack. One revolution of the pallet wheel being equal to one-fifth of a revolution of the chiming drum, the latter would move one-fifth of a turn and chime one "peal," or one quarter, it being spaced into five divisions, each having one "peal" pinned on it.

There are thus five "peals." No. 1 is struck at fifteen minutes; Nos. 2 and 3 are struck at thirty minutes; Nos. 4, 5, and 1 at forty-five minutes; and Nos. 2, 3, 4, and 5 at the hour. The chime barrel thus makes two revolutions for each hour, chiming ten peals, one at the first quarter, two at the half-hour, and three at three-quarter hour, and four at the hour.

During all this time the striking train is locked by the gathering pallet being in contact with the pin in the hour rack B (Fig. 80). The pin I in the quarter rack goes right through and projects on both sides. The front portion locks the quarter gathering pallet, the back portion engages with the tail end of the hour warning lever, and when the rack is all gathered up, pulls this tail up, leaving the striking train free to run as far as the pin in the warning wheel is concerned. It, however, cannot run because it is locked by its gathering pallet. When the quarter rack falls, the hour warning lever rises, its tail end being released, and is in a position to intercept the pin in the hour warning wheel.

At fifteen minutes the quarter rack falls on the first step of the quarter snail E, and one "peal" is chimed, warning lever D being meanwhile released and pulled down again, effecting nothing, the striking train being locked by its gathering pallet.

At thirty minutes the quarter rack falls on the second step of the quarter snail, and two "peals" are chimed, the same process being repeated as regards the hour warning lever.

At forty-five minutes three "peals" are chimed, with the same action as before.

At the hour the quarter rack falls on the fourth and deepest step of the quarter snail, and the rack falls four teeth, the pin I coming in contact with the tail of the hour-rack hook C, which it raises, letting the hour rack

B fall. The hour gathering pallet is then released, and the hour striking train runs and "warns" until the pin in the warning wheel comes in contact with the steel projection in the hour warning lever D, which has been allowed to rise on the falling of the quarter rack F. When the hour is reached, the quarter warning lever H falls, the quarter rack is gathered up, and four peals are chimed. As the last tooth is finally gathered up, the pin I in the quarter rack pulls up the tail of the hour warning lever D and releases the hour striking train, which then runs and strikes the hour until its gathering pallet is stopped by coming again in contact with the pin in the hour rack.

The reader is advised to study this action very carefully, for until it is thoroughly understood, the mechanism cannot possibly be correctly made. The rules for putting striking clocks together must be observed throughout, namely, when the trains are "locked" by the gathering pallets, the hour hammer and quarter hammers respectively must be quite free of their lifting pins, and not the least bit "on the rise." Also, the pins in the warning wheels must have at least half a turn of run to their stop pieces.

Placing Pins in Chime Barrel.—The placing of the pins in the chime drum or barrel will now be described. As before explained, there are fi e "peals" equally spaced out on the barrel, the barrel moving one-fifth of a revolution for each tooth of the quarter-rack gathered up. Therefore No. 1 peal strikes at the first quarter, Nos. 2 and 3 at the second, Nos. 4, 5, and 1 at the third quarter, and Nos. 2, 3, 4, and 5 at the hour, making two revolutions of the chime barrel per hour. For convenience, the smallest bell will be called No. 1, and so on to the largest, No. 8. For eight-bell chimes (sometimes erroneously called Cambridge chimes, though, as a matter of fact, Cambridge and Westminster chimes are identical), the eight bells are all used, pretty much in any order the maker may desire; a selection may be made from the following very usual ones, or any others may be devised, five, of course, being chosen.

(1) 1, 2, 3, 4, 5, 6, 7, 8.
(2) 1, 3, 5, 7, 2, 4, 6, 8.
(3) 4, 3, 2, 1, 5, 6, 7, 8.
(4) 1, 4, 3, 6, 5, 7, 2, 8.
(5) 4, 6, 5, 3, 7, 2, 1, 8.

On the other hand, the Westminster chimes are invariable, and are struck on four only of the eight bells. So that if Westminster chimes alone are wanted, the set of bells should consist of four; but for eight-bell chimes, or eight and four bells with a changing mechanism, the whole eight are used, the Westminster chimes being taken on Nos. 3, 4, 5, and 8. The arrangement is as follows:—

(1) 3, 4, 5, 8.
(2) 5, 3, 4, 8.
(3) 5, 4, 3, 5.
(4) 3, 5, 4, 8.
(5) 8, 4, 3, 5.

The first thing to do is accurately to divide the barrel into five sections by straight lines from end to end. This can conveniently be done by means of the wheel of 40 teeth mounted on it. Each portion is then marked off as shown in Fig. 86, which represents the five peals with the positions of the pins marked for Westminster chimes. As shown in the figure, there is a slight pause between each peal. The circles on which the pin-holes are drilled are accurately marked beneath each hammer tail and run round in the lathe. The cross lines must be drawn at equal intervals, or the chiming will be jerky and irregular.

If a change of chimes is desired, these circles for the pin-holes must be marked with the barrel at one extreme position, and the barrel afterwards shifted to the other extreme, and eight more circles made for the eight-bell chimes. In this case, eight transverse lines must be made in each section, and the positions of pins carefully plotted out, according to the chimes chosen. Against the back plate a flat brass spring is fixed, which always keeps the chime barrel forward against the front pivot shoulder and on one set of chimes. To change it a lever is set, turning on a stud screwed into the front plate; the end is bevelled where it presses on the front pivot of the chime barrel, and so depresses it. The upper end of the lever is made accessible to the hand by a small slot cut in the edge of the dial near the top, out of sight.

CHAPTER XVI

Notes on Electric Clocks

ELECTRIC clocks may be classed in three divisions: (1) Clocks with movements so arranged as to be driven by an electric current acting through electro-magnets. (2) Secondary electric clocks, in which the movements are very simple and few in number, worked also by electro-magnets, the current being controlled by a master electric clock, or any other clock keeping good time. (3) Electrically controlled and regulated clocks, in which an electro-magnet controls the speed, such magnet being connected to a controlling device on a good timekeeper, and with a constant primary battery.

In the first and third classes a pendulum and 'scape wheel are essentials; in the second class a driving wheel like a 'scape wheel, without a pendulum, is all that is necessary, as the pendulum of the master clock regulates the movements of all the others in that series.

Fig. 87 shows diagrammatically the first class of electric clocks—that is, a master clock driven by current from a battery, and controlling by its pendulum and 'scape wheel a whole series of secondary dials. In this diagram, A is the soft-iron armature of an electro-magnet fixed with small set screws to a long brass lever pivoted at B, and having in its upper part the regulating screw C. In a position of rest this lever is held back against the contact screw D by a long spiral spring E, and is then in circuit with the electro-magnet F and the battery. As a consequence, the armature A is drawn forward, and the regulating screw C, on the top of the lever, sharply strikes the heel of the L-shaped lever pivoted at G, and causes the weight H at the other

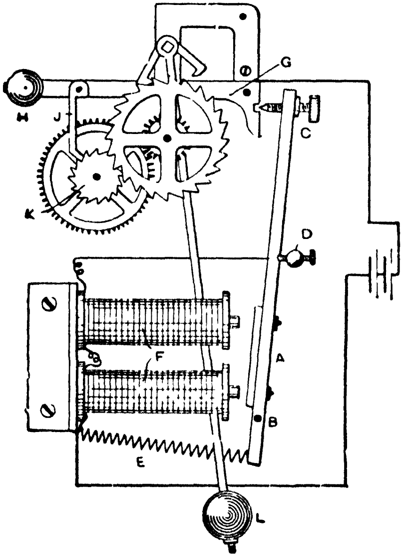


Fig. 87.—Master Electric Clock with its Electrical Connections

end to rise, at the same time drawing the pawl J up over one tooth of the driving wheel K. This causes the lever of the armature to break contact at D, when the weighted lever presses down the pawl J, and thus moves K one tooth forward. All these movements are so arranged as to synchronise with the movements of the pendulum L and the 'scape wheel.

The make-and-break action can be communicated direct to the electro-magnet of the secondary dial by a wire connected to the frame of the clock above G, and another wire connected to the insulated contact screw D. Or each swing of the pendulum may be made to close the secondary circuit by means of light springs

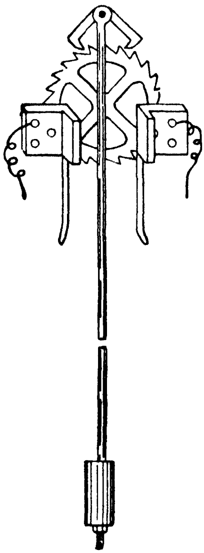


Fig. 88

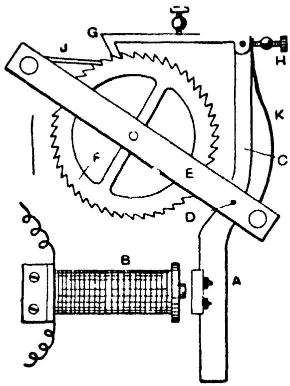


Fig. 89

Fig. 88.—Pendulum Regulator Contacts
Fig. 89.—Driving Gear of Secondary Electric Clock

mounted on insulated brass brackets, placed on each side of the pendulum near the top, as shown in Fig 88. The frame of the clock and the pendulum, in this case, form part of the electric circuit.

Figs. 89 and 90 show two slightly different plans for the construction of secondary dials, to be worked by impulses sent from a master clock, such being an electric clock similar to that described above, or any other good timekeeper. In the arrangement shown in Fig. 89, A is a soft-iron armature of the electro-magnet B, attached by set screws to the power part of the vertical lever C, this being pivoted at D to a brass bracket E, which also serves to hold the driving wheel F. When an electrical impulse from the master clock is sent through the coil on B, it attracts the armature A, giving movement to the vertical lever C and the horizontal hooked pawl G. As this pawl engages with the teeth of the driving wheel F, the wheel is pulled forward by this movement, the distance it is pulled being controlled by the space between the face of A and the core of the magnet, and by the regulating screw H. These should be so arranged as to allow the pull to be through a space equal to the width of one tooth only. When the pawl pulls the tooth forward, the little click spring J also falls into another notch and prevents recoil of the wheel when contact is broken with the electro-magnet by the master clock. At the same time the long thin steel spring K pushes the lever C and the hooked pawl G back again over another tooth, ready for the next pull forward.

In the plan shown in Fig. 90 the action is reversed. By this device the magnet A attracts the armature B attached to the bottom part of a lever C pivoted at D. It thus draws back the pawl E from one of the teeth of the driving wheel F, and when contact is broken with the coil of A, the spiral spring G pulls the armature B away, and at the same time thrusts the pawl E one tooth forward, while at the same time the small click H falls into a tooth behind, and prevents a recoil when the armature is again attracted. The forward movement of the pawl is controlled by the regulating screw J, and the tension of the thrusting spring G by a long regulating screw K. These diagrams are not drawn to scale, but are merely given to show the principles of construction; therefore, no attempt has been made to show the train of wheels required to convert the impulses into such time measures as minutes and hours,

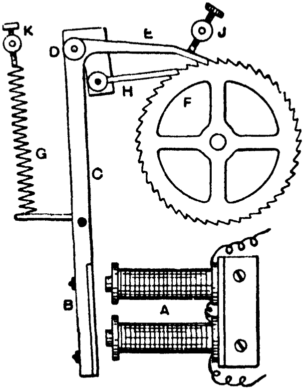


Fig. 90.—Another Method of Driving Secondary Clock

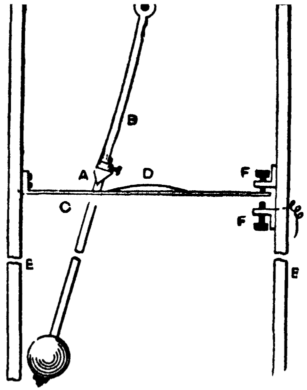


Fig. 91.—Another Method of Transmitting Electric Impulses

nor the dimensions of the several parts. The devices were patented by Mr. Hope-Jones. The pendulum must be of the proper length—39 in. from the centre of the suspension spring to the centre of the pendulum ball. The electro-magnets should have soft-iron cores 2⅜ in. long and ½ in. in diameter, the bobbins being wound with twelve or fourteen layers of No. 26 d.s.c. copper wire.

The battery must be one of a constant type. Dry cells have been used for this purpose, but they have a short life on such constant work, and are somewhat expensive to renew. The Daniell gravity cell is inexpensive in construction and renewal, and is of a good constant type; so also are the Edison-Lalande and other cupric oxide batteries. Accumulators have largely come into use for this purpose. These, like all constant batteries of the primary type, need watchful care in working to prevent exhaustion. Injury is sustained by accumulators if allowed to run down entirely, and it will be found that the clocks will go slowly as the current fails. Indicators have been devised to show when the current is failing, but practical users of these clocks find the beats of the pendulum a sufficient indicator, as these lose their tone when the battery begins to lose its power.

Primary batteries and accumulators are fully dealt with in two companion "Work" handbooks.

The third class of electric clocks consists merely of secondary dials of the types shown in Figs. 89 and 90, controlled by a master clock of the ordinary type and fitted with a special transmitting device, to transmit regular electrical impulses to those dials. Fig. 88 shows how this may be done by means of two slender platinum-faced springs attached to insulated brass brackets, fixed one on each side of the pendulum. One of the line wires leading from a battery to the electro-magnet of the secondary dial is divided here, and the two ends are fixed to the two brackets. The support of the pendulum terminates the other line wire. When the pendulum swings to the left it comes into contact with one of the springs and closes the circuit, as it also does when it swings back again and touches the other spring. Thus there is an impulse at each swing of the pendulum. This may be lessened by having only one contact spring on one side of the pendulum. The pendulum rod at the point of contact should also be protected from corrosion by electric sparks with a thin strip of platinum soldered thereto.

A better method of transmitting the electric impulses is shown in Fig. 91. Here a small V-shaped steel lug or cam A is clipped to the pendulum rod B about one-third its length down from the top. A thin steel spring C, with a hump D on its upper side, bridges two brass pillars E, fixed one on each side of the pendulum. These pillars form parts of the electrical circuit, and are therefore insulated from the rest of the clock and each other. One end of the thin steel spring is fixed to one of these pillars as shown; the other end is loose and free to play between two contact pieces F on the opposite pillar, the spring passing along in front of the pendulum and nearly touching the V-shaped cam clamped to the pendulum rod. As the pendulum swings to and fro, this cam sweeps the hump on the top of the spring, and thus causes it to break contact with the upper screw, whilst at the same time it is forced down in contact with the lower one. If the upper screw is insulated from the brass pillar, the circuit is only closed when the spring is pressed down, and this period of contact can be adjusted to a nicety by means of the cam and spring, both of which can be moved up or down, and thus into more or less long touch with each other.

Still another method of electrically controlling and regulating clocks from a master clock is effected by having a small piece of soft iron attached to the under side of the pendulum bob of the secondary clock, and an electro-magnet fixed beneath this with its poles close to the bob. Current controlled by the master clock actuates the magnet, and its influence on the soft iron above either retards or accelerates the swing of the pendulum to synchronise with that of the master clock.

The following is a brief description of the Hope-Jones "Synchronome" system of time control, which is covered by patents. Fig 92 gives an idea of the transmitter (the pendulum movement below the dial is omitted), and Fig. 93 shows the mechanism. The pendulum rod A is about 39 in. long, the bob being 15 lb. in weight, and its position is regulated by means of a nut, the lower end of A being threaded. The pendulum suspension is a piece of thin clock-spring, hung after the manner of the ordinary grandfather clock, between clamps fixed to a bracket at the top of the framing. The gravity lever C rests normally on the catch K, but is released once in every half-minute as the fifteen-toothed ratchet wheel carrying the vane rotates, by the fact of this vane engaging with the catch K. This is timed to happen exactly when the pallet is immediately under the roller R on the gravity lever, and the pendulum then derives a fresh impulse in a horizontal direction from the shaped face of C exerting a "wedging" action on it. But directly C is let down it makes contact with the upper platinum-pointed screw in the armature E. This establishes a circuit through a number of secondary dials or sub-dials, of which each receives an impulse, by means of mechanism to be described later. At the same time

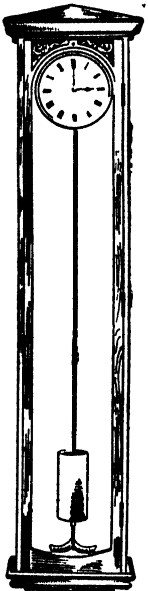


Fig. 92.—Hope-Jones Master Clock

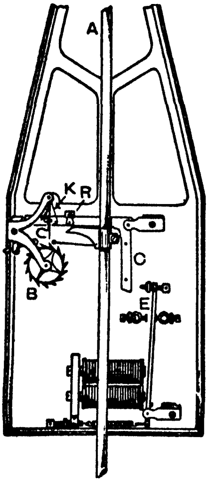


Fig. 93.—Essential Mechanism of Master Clock

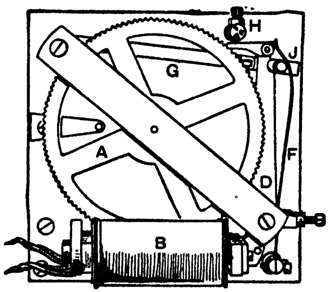


Fig. 94.—Mechanism of Secondary Clock

that this occurs, the electro-magnet at the bottom of the transmitter movement attracts the armature, and kicks up the lever C with a jerk, to rest on its catch again until the ratchet wheel and its rotating vane come into operation again for the next impulse half a minute later. The method of rotating the ratchet wheel is simply by means of a light hook B with a jewelled frictionless end, which rides over the ratchet teeth in one direction, but engages with them on the return swing of A, stepping the wheel forward one tooth at a time. On each side of the armature E are two stop screws, which limit the throw. The electro-magnets may be wound with No. 26 gauge copper wire, double-cotton-covered, and then should work with about five dry cells and control six sub-dials at the same time. Much depends, however, on the delicacy of the construction, the shaping of the pallet, and on the pivoting of the ratchet wheel.

The dial mechanism of "movement" of the secondary or receiver dials is quite simple, being just a reciprocating armature acting on a ratchet wheel by a pawl, shown in Fig. 94. The wheel A has 120 teeth of rectangular shape, and carries the minute hand on its arbor. B, an electro-magnet, attracts an armature, on which is mounted the lever D, drawing back the click momentarily every time the magnet receives current from the master clock. When circuit is broken D is released, and the click, having picked up one tooth, is impelled forward by the spring F. G is a back-stop lever, and H and J are stops, the arrangement of these being such that the wheel A is locked at every point in the cycle of operations, but can be released by raising the lever G.

CHAPTER XVII

Pendulums

Calculating Length.—A pendulum that is approximately 39 in. long takes one second to complete a single swing. From this can be calculated the length of any pendulum if the number of vibrations or beats per minute is known, as explained below, always remembering that the time occupied by a pendulum in making a swing varies as the square of the length. Thus a two-seconds pendulum is four times the length of a one-seconds pendulum.

To find the length of a pendulum for any given clock, first find the number of vibrations it is required to make in one minute, and then find the length of a pendulum making that number either from a table of lengths or by calculation. To find the required number of vibrations per minute, multiply together the numbers of the teeth in the centre wheel, third wheel, and 'scape wheel. Divide this by the numbers of the third pinion and 'scape pinion and 30 multiplied together. Thus, suppose the centre wheel is 64, third wheel 60, pinion 8, 'scape wheel 30, pinion 8, then $\frac{64 \times 60 \times 30}{8 \times 8 \times 30} = 60$ = number of vibrations per minute. To find the length of the pendulum making this number of vibrations per minute, divide 375·4 by the number and square the result. Thus $\frac{375 \cdot 4}{60} = 6 \cdot 26$; this squared = 39·18, which *is* approximately the length of the seconds pendulum in England. Or, make a proportion sum, calculating from the length of the seconds pendulum, 39 in. (about). Thus (Required number of beats)^2 : 60^2 :: 39 in. : required length. If 120 be the number of beats, then 120^2 : 60^2 :: 39 in. : required length; which, of course, equals 14,400 : 3,600 :: 39 in. : 9¾ in.

A variation of the above method of ascertaining the number of beats per minute is to count the train wheels, multiply together the numbers of the centre wheels, third, and escape wheels, and double the result. Divide this successively by the third and escape pinions, and the result is the number of beats in one hour. Divide this by 60 and it will give the number per minute. For example, centre 84, third 73, escape 32, and pinions of 7. 84 × 78 × 32 × 2 = 419,328. This divided by 7 twice = 8,558 = number of beats per hour; 8,558 ÷ 60 = 142 = number of beats per minute. Then from a table of pendulum lengths it can be seen that a pendulum to give this number of beats per minute must be 6·9 in. long, or nearly 7 in. This measurement is from the top of the suspension spring (where it bends) to centre of bob. A little extra length should always be allowed for regulating.

Grandfather clocks and clocks which beat true seconds have pendulums approximately 39 in. long. Those Vienna regulator clocks that beat three times in two seconds have pendulums 18 in. long. Half-second pendulums, as in some English dials and some American clocks, measure 10 in.; quarter-second pendulums, as in "tic-tacs," 2½ in. But pendulums of all conceivable lengths between these are frequently used.

Weights of Pendulum Bobs.—There is no rule as to the weight of a clock pendulum, but it should be said that the best clocks carry the heaviest pendulums. Weight does not affect the time of vibration; that depends solely on the length. The weights of pendulum bobs vary from 2 lb. to 5 lb. in grandfather clocks; they may be in the neighbourhood of 2 lb. in English dials and as little as 1 oz. or even less in small American and Continental clocks.

Wooden Seconds Pendulum.—For a seconds pendulum having a bob resting on a rating nut, the first consideration is to secure a piece of perfectly straight-grained, well-seasoned wood. A second-hand furniture or marine-store dealer's is a likely source. Wood rods are varnished, polished, or painted to repel the effect of atmospheric changes. The suspension spring is fitted in a slot cut in a brass cap fitted over the top of the rod, and fixed with two pins. A piece of thin brass tube is fitted on the end to receive the rating nut. A thin brass casing is fixed for the crutch engagement. Mahogany, ebony, and other woods are often employed for shorter pendulums, because deal would be unsound for the attachments in small sizes. The bob should be of lead, cased in brass if thought necessary for the sake of appearance.

Compensation Pendulums.—Clocks, like watches, have their rates affected by changes in the temperature. A rise in the temperature is accompanied by a lengthening of the pendulum rod, and the clock accordingly loses, just in the same manner as it would if the bob had been lowered by means of the regulating screw. Exactly the reverse of this occurs when the temperature falls.

The lengthening of the pendulum rod being the main cause of the loss through heat, it is evident that if a material could be found, and used in its construction, that did not expand under the action of heat, there would be no temperature error worth considering. A near approach to these conditions is found in a pendulum composed of a piece of thoroughly well-seasoned wood and a heavy round bob of no great height. Such pendulums are nearly always found in church clocks of the common kind, also in some regulators, and the results are very satisfactory.

Clocks fitted with these pendulums do lose a little on being subjected to heat, and gain in the cold. It has therefore been suggested to compensate the remaining error by fitting the plain wood rod with a lead bob in the shape of a thick tube about one-quarter or one-third of the length of the pendulum, and resting at its lower end on the regulating screw. This has been found an improvement, and in this form it can lay some claim to be termed a true compensation pendulum. The theory of the arrangement is as follows: On heating, the wood rod expands and lengthens a trifle; the lead bob also lengthens, and lead expanding more under the influence of heat than wood, its centre of gravity is raised, it being supported by its under edge. This brings back the centre of oscillation of the pendulum to where it was before, or very nearly so.

If the expansion of wood were quite regular and could always be depended upon to be the same, this kind of pendulum would give a true compensation; but it does not, and for the best results other kinds of pendulums are used.

Among these, the mercurial form is perhaps the most accurate—at all events, it is the most popular. Fig. 95 shows a mercurial pendulum of the ordinary form. The rod is of steel, and the bob consists of a glass jar filled with mercury. It acts as follows: Mercury expands under the influence of heat about sixteen times as much as steel. The effect of heat on the rod is to lengthen it, and lower the glass jar of mercury. The effect on the mercury is to expand and rise in the jar. If the quantity of mercury is properly proportioned to the length of the steel rod, an exact compensation is arrived at. The foregoing is theory. In practice, it is found that under a sudden change of temperature the thin steel rod is affected more quickly than the jar of mercury, and, as it were, the rod gets a start of the mercury and causes an error, which occurs at each change of temperature.

To avoid this there was invented a form of mercury pendulum in which the rod is a steel tube and the mercury is inside it. This ensures their being of the same temperature.

The next form of compensation is the "zinc and steel," shown in Figs. 96 and 97. It consists of a steel rod A, over which there is a zinc tube B fastened to the rod A at its lower end only. Depending from the zinc tube B is an iron or steel tube C, to the lower end of which the bob D is fixed. It will thus be seen that any lengthening of the steel rod or tube tends to lower the bob, while a lengthening of the zinc tube B raises it. Remembering that zinc expands more than twice as much as steel, the one length of zinc tube just counteracts the two lengths of steel, and a compensation is effected.

One other form of compensation pendulum is the "gridiron," and one of the earliest made. But for its ungainly appearance it would, perhaps, have been much more widely used than it is. It consists of a central steel rod and a set of vertical bars of brass and steel side by side, so arranged that while the expansion of the steel rods lowers the bob, the brass rods raise it. Brass expands more than steel, and therefore by making the total lengths of the brass rods and steel rods in inverse proportion to their rates of expansion, a compensation is effected.

However, the introduction of a special alloy for pendulum manufacture has more or less relegated the above types of pendulum to the past.

Invar.—This is a nickel-steel alloy compounded by Dr. Ch. Ed. Guillaume, of the International Weights and Measures Office at Sèvres, near Paris. Its special property is an extremely small co-efficient of expansion; that is to say, it expands or contracts only very slightly on being subjected to changes of

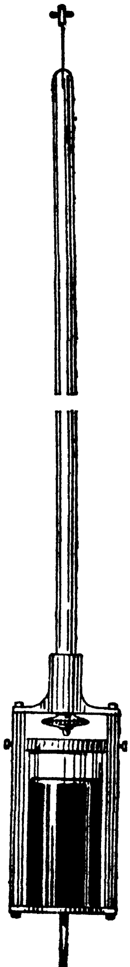


Fig. 95.—Mercurial Pendulum

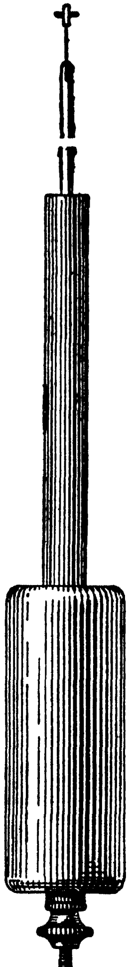


Fig. 96.—Zinc and Steel Pendulum

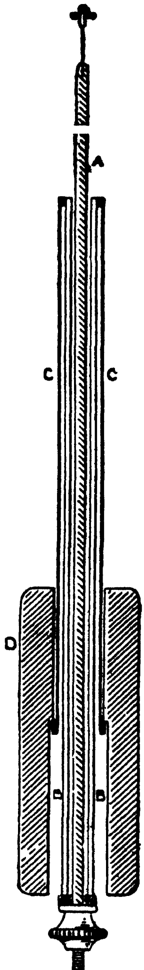


Fig. 97.—Section through Zinc and Steel Pendulum

temperature. All metals expand in length and breadth when heated, and contract when cooled. Thus a brass rod will expand in length to an extent equal to ·002 of its length when heated from the freezing point to the boiling point of water; while a steel rod under the same conditions will not expand so much, the exact extent being ·0011, or a little more than half the expansion of the brass; but a rod of first-grade invar will expand only ·00008, or about one-fourteenth the expansion of steel. Thus a clock having a pendulum rod of invar has hardly any temperature error at all, the amount being quite inappreciable in ordinary clocks, and only becoming apparent in high-class regulators.

The following calculation shows still more clearly the relative expansions of these three metals, the figures indicating the expansion per mile for an increase of 1° C.: First-grade invar, $\frac{1}{20}$ or ·05 in.; second-grade invar, $\frac{2}{20}$ or ·1 in.; third-grade invar, $\frac{3}{20}$ or ·15 in.; steel, $\frac{14}{20}$ or ·7 in.; brass, $1\frac{5}{20}$ or 1·25 in. Thus a brass wire which measures one mile in length at 20° C. will increase in length by $1\frac{1}{4}$ in. if warmed up to 21° C.; while an invar wire under the same conditions will measure only $\frac{1}{20}$ in. more.

It will be noticed that three grades of invar are mentioned, having different expansion values. The first grade expands least, and is the most costly; the second and third grades expand a little more, but are much cheaper. The metal is procurable in the form of sheet, wire, or rod. For clockmakers, pendulum rod lengths of 3 ft. 9 in. each are specially made.

Invar was tested carefully, both at Sèvres and at

Kew Observatory, and the trials confirm the inventor's claims, thus placing the accuracy of the figures beyond dispute. In face of these facts, it would be folly to make compensation pendulums of any other metal. The necessity for mercurial and zinc-and-steel compensation pendulums no longer exists. Taking first the third-grade invar—the cheapest—an almost perfect compensation will be attained by threading its lower end to take a rating nut and using a lead cylindrical bob 8 in. high, resting on the rating nut, the upward expansion of 8 in. of lead compensating for the downward expansion of the inner rod. With second-grade invar, a cast-iron cylindrical bob 1 ft. 1 in. high resting on the rating nut, or a 7-in. high lead bob would be necessary. Using first-grade invar and a 15-lb. cast-iron bob 6½ in. high, an almost perfect pendulum will be obtained.

Any of these pendulums can be adjusted, if found under- or over-compensated, by varying the height of the bob a trifle. They are all seconds pendulums measuring 3 ft. 3¼ in. from the point of suspension to the centre of the bob. For ordinary house clocks with short pendulums, the third-grade invar pendulum rod may be cut up and brass bobs fitted having a height equal to a quarter the length of the pendulum rod. Thus for an 8-in. pendulum the rod will have to be 9⅛ in. long from the point of suspension to the bottom of the bob, and the brass bob 2¼ in. high. This will give a pendulum of 8 in. acting length.

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