

Designing and Constructing a Clock*

A Simple Mechanism That Functions as Well as An Expensive Regulator

By Guy H. Gardner

THE accompanying illustrations show how a machinist, with scant knowledge of horology, designed and constructed a timepiece whose running compares favorably with that of "regulators" costing \$100 or more. The construction is ordinary lathe work, but the designing called for some knowledge of escapements and compensating pendulums, which were supplied by a friendly watchmaker. As the machinist had no gear-cutting facilities, he was obliged to use stock gears, the pitch of which is coarser than that used in most high-grade clock trains, and the performance of the clock has led him to suspect that undue importance is sometimes attached to fineness of pitch. The high cost of brass led to the use of sheet steel for the plates, bushings of phosphor-bronze being inserted for the pivots to run in. The bushing holes were reamed with what the watchmaker calls a "broach"—a five-sided reamer—and finished with a similar round tool used with oil.

In Fig. 1, *S* denotes sprocket wheels. The large wheel *A* has 240 teeth; the center wheel *B*, 120 teeth; the center pinion *C*, 20 teeth; the third wheel *D*, 72 teeth; the third pinion *E*, 12 teeth; and the escape pinion *F*, 12 teeth. All these are 48-pitch brass gears.—The sprocket marked *S*₄ has its arbor squared on the front end for a key. The arbor carries a ratchet wheel, and a pawl prevents backward rotation; it winds right-handed. The motion work, or "back-gears," shown in Fig. 2, consists of the cannon *A* for the hour hand; the hour wheel *B*, which has 60 teeth of 32 pitch; the minute pinion *C*, which has 20 teeth of 32 pitch; the minute wheel *D*, which has 96 teeth of 48 pitch; the cannon pinion *E*, which has 24 teeth of 48 pitch; and the center staff *F*.

For both ends of the center staff and the escape-wheel staff, which carry the minute and the second hand, respectively, the bushings have a simple straight hole, with a countersink to hold oil, and are without caps. For all other pivots, the bushings are made as in Fig. 3 and are capped with thin disks of hardened steel; this form of bushing causes the oil to be held by capillary attraction about the end of the pivot. These pivots are coned on the end, and are allowed about 0.020 or 0.025 inch end shake. This arrangement makes it possible for the clock to run at least two years before requiring cleaning and fresh oil. The disk *S* is tool steel, hardened and surfaced bright. It is held by fillister-head screws, not shown, the heads of which overlap the disk.

The escapement presents no difficulties after its underlying principles are comprehended. As Fig. 4 shows, the center distance between the escape staff and the pallet arbor is readily determined, either by calculation or by lay-out, as it depends solely on the outside diameter of the escape wheel and the number of its teeth embraced by the pallets. As is usual in clocks beating seconds, this wheel has 30 teeth, of which the pallet embraces 10. As lines *AB* and *AC* are tangent to the circumference of the wheel, it is easy to determine the center distance *AO* and the radii for laying out the locking "planes." The "lift lines"—the beveled edges of the pallet—are at an angle of 30 degrees to the tangents *AB* and *AC*. The so-called locking planes of the pallet are not planes, but, as in all "Graham" escapements, are curved surfaces that have the same axis as the pallet arbor. The pallet is of tool steel, hardened, and the locking surfaces are lapped in the lathe, the pallet being mounted for this purpose on a stud carried by the tool-block.

In all high-grade clocks there has to be some device to keep the movement running during the winding, as otherwise several seconds will be lost each week. For this purpose a spring-driven "maintaining power" is usually employed, but in the present design this is unnecessary, as the drive is by an endless sprocket chain, and the act of winding the clock does not interfere with its operation. The clock was designed to be wound by a key and to run eight days. However, the builder has attached an electric device whereby a small motor winds the clock at the end of every hour for another hour's running, but this is not an essential part of the design. It was added, the owner says, "just to make the clock complete." If the motor or the battery should fail to perform its function, the clock will continue to run until the end of the week.

The pendulum rod is well-seasoned, straight-grained, white pine, and is thoroughly shellacked. It is of elliptic cross-section, except for about 14 inches at the bottom, where it fits a square brass tube running through the

center of the bob. The adjusting screw below the bob is cut 36 threads per inch, and the nut has 30 graduations to facilitate regulation; one graduation corresponds nearly to one second in 24 hours.

The bob is of 1 3/4-inch brass tubing, about 12 3/4 inches long, and is filled nearly to the top with shot; the exact quantity must be determined by experiment, as will be explained later. The weight and also the dummy weight on the opposite loop of the chain are of the same tubing. This dummy is added solely for appearance's sake, and both weights, like the pendulum bob, are plated with nickel. The driving weight contains about two pounds

number of days showed that the compensation was inadequate, as the clock ran more slowly in the warm room. More shot was accordingly added to the bob and the trials in cold and heated rooms repeated. This tedious process was continued until satisfactory compensation was attained, after which the regulation by the nut at the bottom of the bob finished the job.

Screw Gages

IN the course of some notes on screw gages, presented before the Institution of Automobile Engineers, Colonel R. E. B. Crompton pointed out that, though the difficulty of obtaining gages which was experienced at the beginning of the war has been remedied to a certain extent by much hard work at Woolwich, the National Physical Laboratory, and elsewhere, there is no doubt that, had a more satisfactory system been in use and the gages been so designed that they could have been cheaply and rapidly produced in quantity, the country would have been saved many thousands of pounds and much delay in the turning out of shells. The paper on tests on screw gages issued by the National Physical Laboratory showed what extraordinarily fine work is necessary in the screw gages to make them capable of passing the screwed parts of shells sufficiently accurately to allow those parts to be assembled.

With threads of angular form, the fit on the slopes—in other words, the tolerance on effective diameter—is the principal matter to be considered. If this dimension is kept within reasonable limits clearances can be given on both crest and root so that, the fit at these points being unimportant, the tolerances may be large and the parts will still assemble and be a sufficiently good fit on the slopes. Small tolerances on effective diameter lead to increased cost of manufacture, but too large tolerances, generally accompanied by reduction of core diameter, may in some cases reduce the strength of the bolt and nut as a means of holding parts together, though a slack fit is always undesirable wherever bolt and nut are subject to alternating strain or vibration. Tests recently carried out by the National Physical Laboratory to ascertain the effect of excessive tolerance on the strength of the nut and bolt to resist end pressure yielded the expected result, that large tolerances do not appear to have a material effect on the strength until they reach something in excess of 20 per cent of the thread depth.

If high-crested taps having a core diameter somewhat above the nominal are used for all nuts, the high crests will insure triangular clearances at the crests of the male threads, and the increased core diameter will reamer away the inner salients of the nuts, so that the threaded surfaces of bolts and nuts will come in contact only on the slopes. Their good fit is, therefore, a question of the tolerances on effective diameter; the full diameter and core diameter of the bolts may take care of themselves, and if specified at all very wide tolerances may be allowed upon them. If a good fit is secured by tolerances graduated according to the requirements of the work on effective diameter, the gaging question can be greatly simplified by practically confining it to the gaging of the male screws by means of an adjustable split nut, accurately made as to pitch and thread form and chased in such a manner that it bears only on the slopes of the threads that are to be tested, and therefore tests the effective diameter only.

The real gage for nuts is the tap, and nothing will improve screw interchangeability so much as improvement in tap manufacture. Errors in pitch introduced in the process of hardening taps must be minimized, and a system of cutting the taps directly and accurately out of hardened blanks should be encouraged. Taps never have a long life; in nine cases out of ten they are thrown aside from breakage before they are appreciably worn, so that if they are correct when new, all the female screwed work formed by them will also be reasonably correct and will hardly require gaging. But if an inspector has to use a gage for the nuts it should be a male plug gage of accurate effective diameter, but with lowered crest and correct core diameter. With the taps proposed, the work should never bear on this form of inspector's gage at these points, and the wear on his gage would be confined to the slopes. Inspectors would always be able to compare this tap testing gage with their reference standard gage by testing it in their adjustable female gages, the latter having been previously checked and adjusted to the reference standard male gage.—Engineering Supplement of the *London Times*.

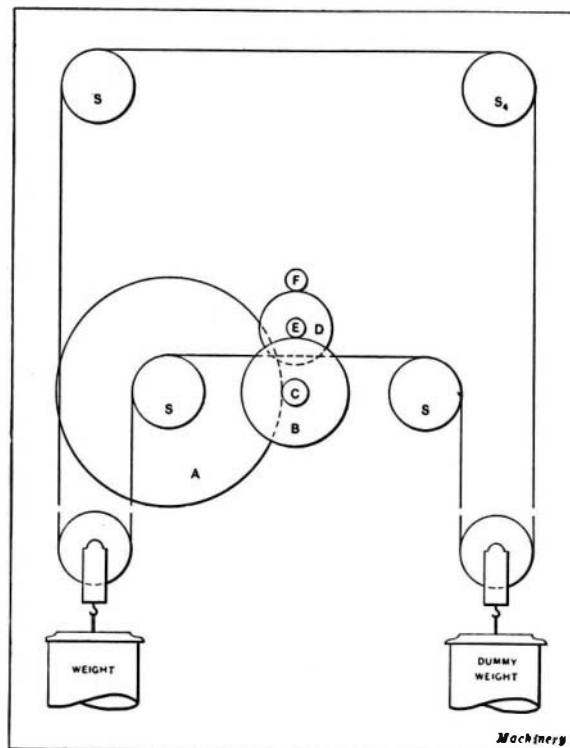
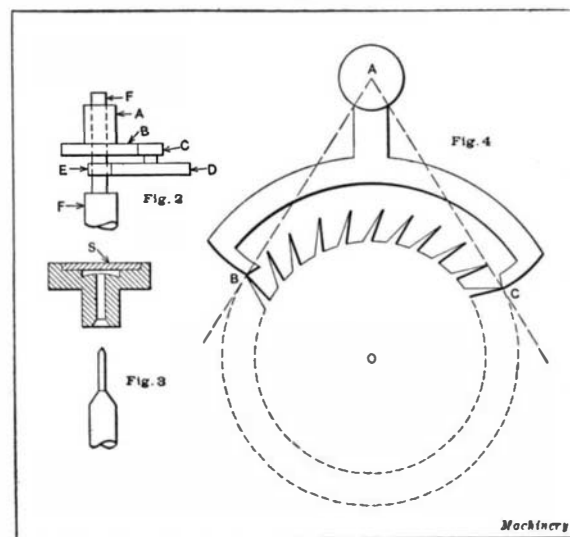


Fig. 1. Arrangement of weights in clock

of lead. As all the staffs are of drill rod, the pivots ground after hardening, and the whole train carefully constructed, a much smaller weight will drive the clock, but it was thought best to allow an ample margin.

The case is made of birch, finished to resemble mahogany; it is of unusual strength and solidity. The back is of hard wood, 1 1/2 inch thick, with two strips of 1/2- by 1 1/2-inch steel set into gains to prevent warping. These strips carry the studs to which the movement is held by a "three-point" fastening, while the piece that carries the suspension spring of the pendulum is bolted



Figs. 2 to 4. Important details in clock construction

to the upper one. The axis of the pallet arbor, produced, would pass through the under surface of the "chocks" holding the pendulum suspension. The dial is 12 inches in diameter.

The compensating property of the pendulum depends on the fact that lead has a higher coefficient of expansion than wood, and its adjustment was effected in the following manner: When the clock was otherwise completed, the pendulum bob was filled with shot to a depth of 11 1/2 inches and the clock run for several days in a room open to the winter air. Its rate having been found and recorded, the room was warmed and a run of an equal

*Courtesy of *Machinery*.