THE MANUFACTURE OF STANDARD SCREWS FOR MACHINE-MADE WATCHES.

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In the whole range of mechanics as applied to the particular industry of Watch-making there is probably no subject of more general interest to mechanical engineers than that of the apparently trivial Screw. In addition to its general interest, there is no subject of greater mechanical importance in this industry, as economy in production has gradually made more and more demands upon the machine-designer and toolmaker; and the number of screws used in each watch, when multiplied by the total product of a watch factory, has justified expensive and elaborate machinery for their manufacture.

Defective Screws.—The fit and finish of the screw-heads make or mar the appearance of the watch; and the fit and shape of the thread have such an effect on its durability, that many watches, otherwise of good quality, come to an untimely end through failure of the screws to perform their allotted task. There are few watch-repairers who have not experienced the sudden transition from satisfaction at the successful termination of a conscientious piece of work, to disgust upon finding the balance-bridge screw over-turn, in consequence of which the work thought to be complete has to be gone through once more. If the repairer happens to be impatient or unscrupulous, he treats the unfortunate watch with a roughness varying only in degree of barbarity. Instead of taking the watch to pieces again, re-tapping the hole, and fitting a new screw, he tries to find one that will do; but the quest is not easy, considering that until recently no recognised standard for threads existed. The natural result is a botched job; and each successive watch-repairer

treats it as derelict, and it quickly finds its way to an unhonoured scrap-heap. In the watch trade it is customary to lay the blame on the repairer, when a case such as this occurs; but the source of trouble ought to be sought much further afield. The recent advances effected in machinery for watch-making have rendered it quite practicable to make watches with screws that will not over-turn with any reasonable usage.

Principal Defects.—The defects principally met with in hand-made screws were drunken and cross-winding threads, and variable diameters. To these should be added the irregularities which hand work necessarily entails. These defects came mostly from the absence of good mechanical methods for originating and maintaining the standards. In the ordinary practice of watch-making by hand methods, it was usual in commencing screw-making to buy a screw-plate, from which taps were made; these taps were then used to make the actual working screw-plates, and the latter generally contained thirty or forty holes. Out of these holes those were chosen which produced screws most pleasing to the eye. Other master-taps were often taken from these working plates, and used for making other working plates: no thought being given to the fact that these successive stages evolved a standard quite different in size and pitch from that started with. It will readily be seen that the only way by which even a moderate degree of accuracy could be obtained was by fitting each series of screws into holes in which they finally remained, all interchange being prohibited. Under the system of watch-making then in vogue, the result was not so disastrous as may now appear, because the movement-maker fitted the screws in the rough, and no large stocks of screws and movements were necessary: thus an account could be kept of each series of screws, and they could be fitted according to the necessities of the case. These screws were hardened and polished separately by the finisher, who put them back into their respective places: so that no great difficulty arose through want of interchangeability, until the watch got into the repairer's hands. Moreover the change from the standard screw was so gradual that it could not be detected by the

means of measurement then used; nor had the variation become so great as to cause practical inconvenience enough to condemn the plan.

Factory system for Screws.—With the advent of the factory system however, the old methods became impossible. The finished screws could not be fitted to the watch in the early stages of manufacture, because the later operations would spoil the polish; nor could they be economically fitted in the rough and be afterwards polished by the finisher, because the essence of the factory system is economy of skilled labour. Large stocks of material in each department are also necessary in the factory system, because a slight derangement of one department brings the whole organisation to a stand-still unless there be sufficient stock to fall back upon. Thus screws made today may be fitted into holes tapped months previously or months later. To meet all these contingencies, nothing would suffice except so making and finishing the screws that any screw should go into any watch after gilding, without any previous fitting. In effecting this change, the adoption of a standard thread had first to be considered; and secondly, methods had to be evolved for retaining this standard, so that watches made today might if necessary be supplied with new screws made twenty years hence.

Standard Screws.—The standard recommended by the committee of the British Association* appointed for the purpose is the one adopted by the Lancashire Watch Co., Prescott, with which the writer is connected; and all information with respect to the standard may be obtained from Professor M. Thury's "*Système des Vis Horlogères.*" It is a V thread of $47\frac{1}{2}^\circ$, rounded top and bottom with a radius equal to 2-11ths of the pitch, Fig. 16, Plate 116; and the pitch P is directly related to the diameter D by the formula $D = 6 P^{\frac{2}{3}}$. This formula will of course give an unlimited number of sizes; and in order to formulate a standard series it was decided to adopt the successive powers of 0.9 mm. for the

* Report 1882, pages 311-14; and 1884, pages 287-93.

pitch. The index of the power is used as a convenient designating number for the screws: thus the pitch of No. 6 screw is got by raising 0.9 mm. to the sixth power, the pitch being therefore 0.53 mm. and the diameter 2.8 mm. From the figures so obtained in decimals of a millimetre a series is got in decimals of an inch. Some of the screws so determined are illustrated in Fig. 5, Plate 111, magnified ten times full size.

Master Taps.—In order to originate and retain the standard, two sets of master taps are made: one set is used for making screw-dies, and the other is reserved for producing dies for making working-taps; both sets are in duplicate, one set of each being kept for reference only. The master taps are made on a small screw-cutting lathe specially designed for the work, having a corrected screw which can be depended upon for accuracy within practicable limits. The master taps for screw-dies are made to the exact standard; but those for tap dies are left sharper on the top, thus leaving them nominally larger in diameter than the standard. When the diameters are measured from the sides of the thread, both sets correspond with the standard; but the tap being larger than the screw, a space is left between the top of the screw-thread and that of the hole: that is to say, the female thread is deeper than the male thread. This space forms a convenient receptacle for any burr that may be present, but does not interfere with the fit of the screw in the hole. While in the soft, all the master taps are left slightly large, and without grooves. By hardening they become more or less distorted; this defect is corrected by grinding the threads by means of a soft steel lap charged with diamond dust; after which operation the longitudinal grooves are ground in. The grinding of the screw-threads is effected in the same lathe that cuts the thread. Instead of the cutting tool, a small and accurately made grinder is inserted in the tool-box of the lathe, and driven by a band through idler pulleys. A disc of soft steel, turned to the thread section and charged with diamond dust, is mounted on the end of the grinder spindle, and traverses along the screw in exactly the same way as the cutting tool. The longitudinal grooves are ground in by the

same arrangement, but of course the lap is of the proper section and runs vertically. An index on the lathe spindle gives the position and number of the grooves.

Dies.—The taps having been got as perfect as may be possible, the next step is to make the dies. These, as is well known, are inherently defective, as they stretch the metal and thus alter the pitch; but as yet no practicable substitute for them has been devised; all therefore that can be hoped to be done is to minimise their defects. Many attempts have been made to get nearer to cutting the thread, instead of squeezing it; but all such operations, when subjected to the inevitable wear and tear of daily use, have been found to result in more irregularity than the simple tapped hole, in consequence of the abrasion of the cutting faces of the dies, and their gradual loss of cutting power. These remarks of course apply to watch screws only, which do not exceed 0.050 inch diameter with a minimum of 0.010 inch. The die most in use therefore is simply a tapped hole, which for convenience is usually made in the centre of a small thin disc of steel. The disc is made small and thin, because the less metal there is surrounding the hole, the less is the distortion produced by hardening; and in addition, although the die is not split, yet the pressure exerted by the die-holder is sufficient to produce a slight modification in the diameter of the screw, provided the die is small enough; and it may be made small enough, because the die-holder is so designed as to prevent the die from bursting. This adjustment of the die in the die-holder is utilized to correct the alteration of size caused by hardening the die. After hardening, the dies usually open; so that they would leave the screws too large in diameter. The die-holder, which is a form of step-chuck, squeezes the die sufficiently to make up for this enlargement. When tapping the die, it is found best to mount it in a true step-chuck, and bore the hole true. A step-chuck is a chuck in which a recess or "step" has been turned in the face, of any required diameter. The chuck is then split longitudinally in three sections, and after being spring-tempered it is ground true. A conical portion behind the face corresponds

with the conical mouth of the lathe spindle; and the chuck closes when drawn into the spindle from the back, thus securing any article placed in the step or recess. The tail stock of the lathe carries the tap, and is provided with a traversing spindle, on which is fitted a feed-screw of the same pitch as the tap. When the tail-stock spindle is revolved, the tap is thereby fed into the die, and so leaves a more perfect thread than if the pitch of the tap itself were allowed to provide the feed. The tap dies are made in the same way; and both are used in the screw-making machines.

Screwing Machines.—Of these machines there are now many varieties, some purely automatic, others partially so, and others actuated by hand. As to the relative merits of each, now that the factory system of manufacturing large quantities of one sort of watch is in vogue, the purely automatic machines have the advantage. Of these there are many varieties, improvements being constantly made; and designs which a few years back would have been considered impracticable, owing to the difficulty of working to them, are now in daily use, as advances in the art of tool-making applied to watch machinery have been most rapid during the last few years.

Slitting.—A much debated point is the advisability of including the slitting of the screw-head in the operations performed by the screw-making machines. The addition of slitting mechanism certainly increases the liability of the machine to stoppage, as anything happening to the slitting mechanism necessarily stops the whole machine, and thus reduces the total number of hours per week that the machine would run without the slitting attachment. On the other hand the expense is entailed of picking up separately each individual screw, and putting it into a slitting machine; but upon so simple a job the youngest girls in the factory may be employed, and with a good slitting machine each girl can get through the product of three screw-making machines. Thus the advantage of doing the slitting in the screwing machine itself is at the best only slight; but however slight it may be, it cannot be despised.

Description of Screwing Machine.—In Plates 108 to 115 is shown a screw-making machine designed by the writer, which embodies most of the modern methods, and includes a slitting attachment. A description of this machine will therefore cover the principal features common to automatic watch-screw machines. Fig. 1, Plate 108, is a face view or front elevation of the machine, drawn one quarter full size; Fig. 3, Plate 109, is a plan; and Fig. 4, Plate 110, is a longitudinal section from front to back.

All screws are cut from the solid rod or wire. Four rods of any desired length are inserted in the hollow spindles S, Fig. 1, Plate 108, which are horizontal and parallel to one another; and the machine being then started works unattended until it has cut up the rods into screws, complete with slits, when it automatically stops, until four fresh rods are inserted; and the operation is repeated. The use of four rods, which is the distinguishing feature of the machine, renders it possible to have all the four tools in operation simultaneously. It is plain that turning down the shank by the first tool and screwing it by the second cannot be done together, where only one screw at a time is being operated upon; nor can the burr from screwing be removed by the third tool, and the parting cut be made by the fourth, until the screwing is finished. Therefore in machines working upon only one rod, three at least of the tools must be idle, while the fourth only is at work.

Lathe Spindles, Headstock, and Turret.—There are four hollow revolving lathe-spindles S, Fig. 1, Plate 108, carried horizontally in the main frame or headstock, which is a box casting. As shown full size in Fig. 6, Plate 111, each of these spindles runs in hardened and ground bearings, and is provided with friction driving-cones F, and automatic chuck. This combination allows of the rotation of the spindle being stopped at will, and also of the rod or wire being released when required, for feeding forward. The four spindles are driven by a belt which passes continuously round the driving pulley on each spindle in succession, Fig. 1, Plate 108. They are placed at equal distances apart, and concentric with a horizontal revolving turret T, upon which are mounted the four operating tools. This turret has a step by step rotation in the

direction of the arrow, through a quarter of a revolution at each step, thereby bringing the tools round into such a position that each tool acts successively upon each screw. In the position shown in Fig. 1, the first tool is turning down the shank of the screw in the lathe at the right-hand top corner; the second tool carrying the screwing die is cutting the thread on the screw in the right-hand bottom lathe; the third tool is removing the burr from the thread of the screw in the left-hand bottom lathe; the fourth tool has just given the parting cut to the screw in the left-hand top lathe; and in the centre of the turret this same screw is now having the slit cut in its head by the slitting saw, to which it has been brought by the quadrantal carrier Q.

Through the centre of the turret runs the cam shaft, Fig. 4, Plate 110, from which all the four tools are actuated; it is driven at a uniform speed by a worm and worm-wheel at the back end. One revolution of the cam shaft completes a screw; and the following quarter revolution is occupied in carrying the turret round through the next quadrant, when the operations of the four tools are repeated. Thus five revolutions of the cam shaft make four screws, a quarter revolution of the turret being utilized to open the chuck, Fig. 6, and feed the wire forward for the next screw. The opening of the chuck is effected by the cams CC, Fig. 1, carried on the turret, which strike in turn each of the four levers L pivoted on the main frame. These levers act upon other levers, which in turn are in contact with the face of the male friction-cone F, Fig. 6, driving the hollow spindle. A slight motion of the levers suffices to throw the friction cones out of action, and stops the lathe; and a still further motion of the levers pushes the friction cone against the spring-disc D, thereby releasing the grip of the chuck on the wire or rod. The arrangement which stops the machine when the rod or wire is used up is also actuated by the motion of the turret, as will be described later on.

Turning and Screwing.—The three turning tools are made in the form of circular discs, as shown in Fig. 1, Plate 108, turned on the periphery to the section required, so that they may be ground economically without spoiling their shape; circular cutters also go

back into the machine exactly, no resetting being required. These three cutters are carried on straight slides mounted radially on the face of the turret, and receive their feed directly from the three cams A, Fig. 4, through adjustable connections J, Fig. 1, which supply the means for setting the cutters so as to turn to the correct diameter. The screwing arrangement is connected with a cam B, Fig. 4, at the back of the machine, by means of a horizontal shaft running through the turret: in Fig. 7, Plate 112, drawn half full size, in which the turret is supposed to be transparent, it is seen that the cam is so shaped as to give a reciprocating motion to a pivoted quadrant, which is geared into a pinion on the shaft in the turret, and so gives a reciprocating rotary motion to the shaft; the latter is in turn geared to the die spindle E, as shown full size in Fig. 8, which thus receives a forward motion for running the die on to the screw, and a backward motion for running it off. The die spindle is also mounted in a sliding head H, which slides in a direction parallel to the axis of the screw. This sliding motion is controlled by a leading screw which is geared to the die spindle through a series of change gears, much the same as in an ordinary screw-cutting lathe. Thus the reciprocating motion of the quadrant not only imparts circular motion to the die, but through the change wheels and leading screw gives also a longitudinal motion corresponding with the pitch required.

Slitting Saw.—The slitting saw is carried in a frame G, Figs. 1 and 4, Plates 108 and 110, secured on one end of a rocking shaft which runs through the turret horizontally, parallel to the main shaft. On the back end of the rocking shaft is an arm carrying a roller, which engages with the slitting cam, as shown half full size in Figs. 9 and 11, Plate 113. The cam is so shaped as to give a slow forward rocking motion to the slitting frame, and a quick return. At the moment that the saw is cutting the slit, the saw spindle is approximately concentric with the turret; this arrangement is made in order that the driving cord shall not be affected by the revolution of the turret.

Screw Carrier.—The quadrantal carrier Q, Figs. 1 and 4, Plates 108 and 110, which conveys the screw from the parting tool to the slitting saw, has five distinct motions. It carries a split chuck, tapped to correspond with the screw. Normally the chuck is held closed by a spring I, Fig. 9, Plate 113, drawing it into a taper hole. When thus closed it runs on to the revolving screw, which has previously been nearly parted from the rod by the fourth tool. When the shoulder of the screw jams against the face of the chuck, it twists the screw off, and leaves it in the carrier, which is in the outer position shown in Fig. 9. The carrier then has a short horizontal longitudinal motion away from the lathe spindle, and a transverse quadrantal motion towards the slitting saw, assuming the inner position shown dotted in Fig. 9. After the short longitudinal movement is completed, and before the quadrantal movement commences, the carrier chuck makes a quarter turn on its arm, which brings it at right angles to the lathe spindle, and therefore ready for the slitting saw to act. After the slitting is completed, the motions are reversed; the carrier chuck first resumes its position parallel to the lathe spindle, and then returns for the next screw. During the return motion the chuck levers engage with a fixed cam K on the turret, thus opening the chuck, and thrusting the complete screw out of the chuck into a recess made for the purpose. All the movements of the carrier are got from two cams M and N, also at the back of the machine. The first cam M is a face cam, Fig. 4, which through a lever connection gives the short longitudinal forward movement; and the second cam N, Fig. 12, Plate 114, through a quadrant and pinion gives the turning and quadrantal movements. The turning of the carrier chuck, from a position parallel to the lathe spindle to one at right angles to it, is got from the rocking movement of the longitudinal shaft P in the turret. The carrier chuck is carried on the end of a second shaft Q, Fig. 9, parallel to the face of the turret, and mounted in a frame; this frame is carried on the end of the longitudinal rocking shaft P, and is free to revolve about the latter, while the carrier-chuck shaft Q is also free to revolve in the frame. The two shafts are connected by a pair of

mitre wheels. It is thus plain that any circular motion given to the longitudinal rocking shaft P must either rotate the carrier-chuck shaft Q or revolve the whole arrangement. In order to obtain each of these two motions in succession, two springs are planted on the turret so as to engage with the carrier frame. One of these at first holds the carrier frame, so as to prevent it from revolving; the longitudinal shaft P then revolves independent of it, and through the mitre wheels rotates the carrier chuck Q. When the chuck has made the necessary quarter turn, a stop R, Fig. 10, prevents any further rotation of the chuck shaft Q; and the pressure continuing, the holding spring is overcome, and the quadrantal movement travels the chuck inwards to the slitting saw.

Feed.—After each screw is taken from the wire or rod, the latter has to be fed forward through the lathe chuck through a sufficient distance for making another screw. The mechanism for effecting this consists of a hollow feed-chuck, Fig. 6, Plate 111, which passes into the lathe spindle from the back. The front end of this feed chuck has three longitudinal slots, extending about $2\frac{1}{2}$ inches in length, thus forming three spring-fingers closed in at the nose so as to grip the rod lightly. When the main chuck is gripping the rod more tightly, the feed chuck is pulled backwards by a cam and lever U, Fig. 4, and slips along the rod. As soon as the main chuck opens, the feed chuck springs forward, carrying the rod with it. The opening of the main chuck takes place during the quarter revolution of the turret; and the wire springing forward abuts against an adjustable stop W, Fig. 1, carried on the turret. This stop is planted in such a position on the turret as to continue opposite the end of the lathe spindle all the time that the chuck is open. When the feed stop W has passed over the end of the lathe spindle, the wire projecting from the face of the chuck engages with the tail of a click V, and so prevents the click from catching in a loose concentric ring Y, Fig. 12, Plate 114, immediately at the back of the turret. This loose ring is connected by levers to the striking gear of the countershaft. If the click V were not held away from the loose ring, it would engage in one of four slots or notches cut across the inner rim of the ring, and so would carry the ring round with the turret, thereby throwing

the strap upon the loose pulley. When the rod is all used up, no wire is fed forward; the click V being therefore not held away engages in the loose ring Y, and the machine stops.

Rotation of Turret.—The means by which the step by step rotation is given to the turret, through a quarter of a revolution at each step, is shown one-third full size in Figs. 13 to 15, Plate 115. The locking slide S, carried in a radial recess in the body of the turret, has a V shaped notch in its outer end, for engaging successively with each of the four radial taper stops T in the headstock, towards which it is pressed outwards by a spring at the back. In each revolution of the main driving shaft the cam C strikes the lug L on the inner end of the slide, and draws the slide inwards, clear of the stop T, Fig. 14. In this position it is held back by the nose of the side click K, against the outward pressure of the spring, after the tip of the cam C has cleared the lug L. The opposite cam D now comes against the lug G, and carries the slide and turret round through a quarter of a revolution to the next stop T. Just before reaching this position, the tail of the click K, Fig. 15, striking against the stop, releases the slide, which is immediately thrown into action by the spring, and again locks the turret in its new position, while the main driving shaft makes another complete revolution.

Slit.—The width and shape of the slit in the screw head are not unimportant matters. Until recently it was usual simply to run a saw through the screw heads, thereby forming a slit with parallel sides; whilst for the better classes of work the external corners of the slit were filed off during polishing, in order to retain the good appearance of the screw, because otherwise the screw-driver bore against the sharp edges and threw up a burr. It is now customary to make the slits of a width proportional to the diameter of the thread, and to use a cutter whose sides are inclined to the centre line at an angle of about 5° , or 10° over all.

Screw-driver.—It was also found necessary to wage war against the "handy" screw-driver, which was mostly made from the first piece of steel picked up; and a pair of flats were then filed on it in the

usual hurry. Screw-drivers are now made with standard taper holes and loose tapers, the latter being made economically in large quantities to the same taper as the slit. If a screw-driver breaks down, a new taper is at once inserted; a frequent cause of botching is thus removed. The screw-drivers are designed so that no more power can be used than is just enough to drive the screw home; and the narrowness of the slit prevents a large and powerful screw-driver from being used on a small screw.

Polishing.—The methods of polishing are various, and depend largely upon the style and quality of the watch for which the screws are intended. If flat heads are required, two or three hundred screws at a time are mounted in a series of holes in a plate, and are ground and polished on a vertical grinding mill, which in appearance is much like an ordinary drill-press; but the bottom table revolves and is placed eccentrically to the top spindle. The latter is weighted so as to exert a downward pressure on the bottom table; and carries an arm fitted with a male centre, which is put into a corresponding female centre in the back of the plate of screws, thus pressing the screw-heads down upon the bottom table, which is supplied with polishing material. The motions of the arm and table are always in opposite directions; and the two spindles are so arranged that each part of the whole surface of the bottom table has contact with the screws in turn. Where round heads are required, the screws are put into holes drilled radially into a half sphere on the nose of a lathe spindle, and are then ground and polished, which gives them a spherical contour. Many machines are also in use for doing the screw-heads separately; these undoubtedly give the best results, because any burrs left from the slitting are more effectually removed. When screw-heads of slightly conical shape are required, they are economically formed by polishing three together. Each screw is mounted in a separate spindle, three of which are arranged in the form of a triangle; then by throwing the spindles out of parallel, or by varying their length, and by using a polishing disc which adjusts itself on all three, the desired conical head is obtained.

Conclusion.—For introducing so many small details into this paper the writer's excuse must be that these seeming trivialities have an obstinate habit of taking up a most uncompromising attitude, and blocking the road which leads to success. The modern watch-factory is indeed the result, not so much of a brilliant effort of genius, as of the perseverance of many minds persistently bent on carrying their ideas to a successful issue.

Discussion.

Mr. HEWITT pointed out that in the drawings of the machine the four spindles were placed in the corners of a square, of which the sides were horizontal and vertical; but in the machine now shown that arrangement had been altered by shifting the spindles through 45° , so that they were here placed in the corners of a square of which the diagonals were horizontal and vertical. The object of the change was to suit the driving tackle, which in a watch factory was nearly always placed overhead; and this machine had to be driven from overhead. The design shown in the drawings had been got out for the machine to be driven from underneath. The alteration did not involve any change at all in principle, being simply a matter of detail. Another alteration was that, instead of the turret receiving its quarter revolution through the cam shaft, as described in the paper and shown in the drawings, an additional worm and wheel were introduced with the object of revolving the turret independently of the cam shaft. This wormwheel was cut on the periphery of the turret, and was actuated by a worm fixed upon a shaft which was driven by a round band in a grooved pulley. When the turret was locked at rest, the band slipped on the pulley; and when the unlocking cam released the turret slide, the turret revolved at a slightly slower rate than the cam shaft. This difference of speed gave the unlocking cam time to get out of gear with the lug

on the slide, thereby allowing the slide to engage with the next stop, which locked the turret securely until the cam shaft had made a complete revolution and had again released the locking slide. The object of this alteration was to relieve the excessive strain that was put upon the cam shaft and its worm and wheel in releasing the chucks during the revolution of the turret.

The PRESIDENT observed that the subject of the paper raised a considerable variety of questions, connected not only with the highly ingenious and elaborate machine now exhibited, but also more generally with the standardizing of very small screws.

Mr. THOMAS BUCKNEY, having had the honour of serving on the screw-gauge committee of the British Association in 1882-4, congratulated the author on having adopted the British Association threads, which he believed he had himself been the first manufacturer to use. The present threads had been originated at the instigation of Mr. Preece, who had been the president of the committee; and he believed it was in order to supply the wants of the Post Office that the committee had been appointed. The Post-Office authorities had experienced great inconvenience in their telegraphic instruments from the multiplicity of the pitches of the screws, and they thought it would be highly desirable to have a uniform gauge. Although he had himself been in the minority in not agreeing altogether with the decision arrived at by the committee, he had loyally accepted their decision. He should much have preferred the adoption of the Whitworth form of thread, and the British inch as the unit of measure. The committee however had adopted the metric system, and there was nothing to do but to bow to their decision. He had used these screw-threads for a number of years, and was perfectly satisfied with them. The series was an exceedingly good one. The screws were strong, useful, and readily made; and as far as he knew they were better than any that had preceded them. The screws he was using had been originated he believed at the expense of the Post Office, and had been made by Mr. Lehmann, who at one time had been foreman or works manager to Mr. Stroh. In

(Mr. Thomas Buckney.)

originating these threads Mr. Lehmann had been extremely careful and painstaking, and had certainly produced a very good series of threads. He had not been aware that any other screw manufacturer had originated these threads independently, until he learned from the paper that the author had done so. It would be exceedingly interesting he thought to compare the two sets of screws thus worked out independently, and to see whether the pitches and sizes were identical; the size was of course much more easily measured than the pitch. The system of screws adopted by the British Association committee he believed was practically that arranged by Professor Thury of Geneva; for the gauge at present in use, known as the British Association gauge, was almost identical with the gauge which had been introduced by a Swiss committee presided over by Professor Thury. The latter gentleman had followed the same course that Sir Joseph Whitworth did: he had collected a great number of screws from the best makers, and had established a gauge based on the screws most generally used, so far as regarded the pitches for the various sizes of screws. The British Association committee had practically adopted his system, making only a small difference in the shape of the thread. In Professor Thury's thread the bottom of the thread of the tap was rounded out with a smaller curve than the top, the object being to give the thread of the nut additional strength. As a matter of fact, in the small instruments for which those screws were designed and were in use, there was practically no nut. The screws themselves were generally tapped into some plate of the instrument itself. The so-called nuts or holes therefore could not be replaced; and it was consequently thought desirable to give the base of the thread that larger rounded form, with greater strength than in the screw, so as to resist wear longer, because a new screw could be put in much more easily than a new plate. The British Association committee had adopted a rounding which was equal at the top and the bottom of the thread; that was the only difference they had made, he believed. The pitch was referred to the diameter by the same formula; the angle of inclination of the thread was the same; and beyond the alteration in the rounding of the thread he himself saw

no difference. In the Whitworth thread the angle of inclination was 55° , and in the Swiss thread and the British Association thread $47\frac{1}{2}^\circ$. In the Whitworth thread one-third of the height was rounded off from the triangle which would be formed by the thread, namely one-sixth at the top and one-sixth at the bottom, leaving the depth of the thread about two-thirds of the pitch. In the Swiss thread the depth was three-fifths of the pitch; the top was rounded off with a radius of one-sixth of the pitch, and the bottom with a radius of one-fifth of the pitch. In the British Association thread both the top and the bottom were rounded off with a radius equal to two-elevenths of the pitch.

The taper slitting of the screw heads he thought was a decided improvement (page 484). He had himself slit screws with a parallel saw, and used a screw-driver, which was not exactly a taper, but was slightly hollowed out on each face so as to get the part almost parallel that went into the screw slit. The taper slitting of the screw heads seemed to him to be an improvement of great importance. There appeared to be an immense amount of ingenuity in the machine described in the paper, and he had no doubt that it performed its work well, otherwise it would not have been now exhibited for examination.

The grinding of the screw-threads, or the polishing of the threads of the tap, was stated in the paper (page 476) to be effected in the same lathe that cut the thread; but instead of the cutting tool a small and accurately made grinder was inserted in the tool-box of the lathe, and driven by a band. The edge of such a revolving grinder must of course have some inclination depending upon the pitch of the thread; and it appeared to him that by its revolution it must distort the thread to some extent. It would indeed move forward according to the pitch of the screw; but the inclination or angle of the pitch at the bottom of the thread was different from that at the top of the thread. If a mean were adopted by taking the inclination at the middle of the thread as the angle of inclination for the grinder, there would be a slight error at the top and bottom of the thread; and he should like to know how that difficulty had been overcome.

MR. JAMES E. DARBISHIRE asked whether any of the screws were tempered or hardened after cutting, and if so whether the thread was distorted thereby. He did not know whether it was the practice in watch-making to harden the screws; and if it were, it would be interesting to learn to what extent the thread would be altered in the process.

MR. BRYAN DONKIN thought it would be interesting to know the number of revolutions made by the machine per minute, the output per minute for certain sizes of screws, the average speed for the different sizes, and how many machines were at work.

MR. WILLIAM TAYLOR said his interest in screw-making had been in connection with larger screws than those with which the manufacture of watches was concerned. As a member of the standards committee of the Photographic Society of Great Britain he had been interested in securing amongst makers of photographic lenses the adoption of common standard screws for the attachment of their lenses to cameras; and as a manufacturer of lenses at his firm's works in Leicester he had taken an active part in developing appliances for securing free interchangeability, real and effective, of the screws made for that purpose. For photographic lenses, as in the case of the smaller screws for watches, it was necessary that the screws should always go together without the need of applying extra force. The problems involved in securing such free interchangeability of screws were really complex; but the condition upon which the free interchangeability of screws depended was simple. There was indeed one condition alone: namely that every male screw should be at least as small as the standard, and every female screw at least as large as the standard. The title of the paper had led him to hope that the author would have said a good deal more about his methods of originating these forms of thread, and of measuring them; because on a real and true understanding of the methods of originating and measuring forms of thread would depend the success realised in securing free interchangeability of screws. Electrical and optical instrument

makers, a large and important body of manufacturers who had adopted the British Association screws, well knew from experience the great difficulty of getting really interchangeable screws. So far as he had heard, they generally complained that the screws varied in size sufficiently to introduce the difficulty that, when a hole which might fairly be considered a standard hole had been tapped in a piece of metal, nominally standard screws might be met with, which required extra forcing into that hole. The system which he had developed at his firm's works at Leicester of securing free interchangeability amongst screws depended on the principle just defined, that every male screw should be at least as small as the normal size, and every female screw at least as large as the normal. For better illustrating the way in which this was done, he had brought one of the standard screws for lens fittings, nominally two inches full diameter, which was cut in the way that all the screws were cut at Leicester, to fit the flat calliper gauge exhibited. This was seen to be a double calliper gauge, as shown full size in Fig. 19, Plate 116; after it had been hardened, the space between the jaws FF on one side had been ground out accurately to two inches, and the space between the jaws SS on the other side to exactly one-thousandth of an inch less than two inches. The workman who cut the screws had to make each pass through the gauge on the side F that measured two inches, without any jamming whatever; and it must not pass through the other side S. In that way all the screws were made correct to one-thousandth of an inch, on a principle which secured free interchangeability, provided sufficient care had been taken to ensure that the form of the thread was correct. With this sort of calliper gauge the diameter of the screw was measured only on the crests of its thread; and if steps were taken, as could be done, to ensure that the form of the thread should be correct, or at any rate that the thread should be slightly too thin rather than slightly too thick, a screw was attained which was perfectly and truly interchangeable with other standard screws similarly made. As a proof that this system of working was satisfactory, it might be mentioned that his firm had had it in use about three years, and had made in this way thousands of screws,

(Mr. William Taylor.)

which when fitted together must have formed many millions of combinations; and never once had a case been reported of two screws failing to come together freely, and never had there been an amount of shake exceeding two-thousandths of an inch. Apart from such minute work as standard screws for machine-made watches, or even the larger screws he had mentioned for photographic apparatus, it appeared to him that, if in common bolts and nuts perfect interchangeability were ever going to be attained, this could be done only by working on the principle he had defined. Having attended the recent summer meeting of the Institution in Manchester, he had had the good fortune to be one of the visitors to Prescott who were shown round that highly interesting factory by the author of the paper; and he could bear his testimony to the wonderful skill displayed in designing not only the machine now described and exhibited, but also a large variety of other tools almost as complicated. How such a vast amount of work had been done he could not understand; and he should much like to know something of the way in which the author had managed to get through it all.

The PRESIDENT asked what were approximately the pitches and other dimensions of the threads in the photographic screws, in order that these might be compared with those in the watch screws.

MR. TAYLOR replied that the series of screws originated by the standards committee of the Photographic Society were based on the English inch, with the Whitworth form of thread, and varied in diameter from one inch, which was the smallest, up to any size. The diameter advanced from 1 inch by quarters of an inch up to $2\frac{1}{2}$ inches, then by half an inch up to 4 inches, and onward from that diameter by inches. The pitch of the screws in all the sizes smaller than $3\frac{1}{2}$ inches diameter was constant, namely twenty-four threads to the inch; for $3\frac{1}{2}$ inches and all larger diameters the pitch was twelve threads to the inch.

About the degree of accuracy obtained in forming the screw taps, not much had been said in the paper; and from his own experience he considered it was not at all a simple matter to originate a screw

thread correctly in respect to its form. In forming the chasers with which his screws were cut, he was content if the chaser was correct to one ten-thousandth of an inch. This was for work however which was comparatively coarse; and for watch screws he presumed that greater accuracy was obtained. This was a highly important matter; because, although it was comparatively simple to make screws interchangeable in any one factory, it was a different thing to make screws interchangeable in different factories when the only means of comparison lay in original standards of length, and there was no means of comparing the taps and the other actual embodiments of those standards.

Sir FREDERICK BRAMWELL, Bart., Past-President, had no doubt the practice of making female screws to the full size and male screws to the bare size would always ensure interchangeability (page 490); but he should be glad to know whether it would ensure tightness in the screw. Would a screw so made be a good fitting screw?

Mr. TAYLOR explained that, in speaking of the principle on which free interchangeability of screws was to be secured, he had intended to lay stress on the adjective "free." What was wanted with such screws as those used for photographic lenses was, that they should never require forcing together with wrenches or tongs; and in order therefore to secure free interchangeability it was provided that every male screw should be at least as small as the standard and every female screw at least as large. On the other hand, in order to limit the objectionable shake which would occur if every male screw were made much too small, a limiting gauge was used. The male screw was never made more than one-thousandth of an inch too small in diameter, and the female never more than one-thousandth of an inch too large: so that when the two screws were put together, the utmost shake that resulted would not under the most unfavourable circumstances be more than about two thousandths of an inch.

Sir FREDERICK BRAMWELL feared he had hardly appreciated the fact that the screws referred to were to be made of large diameter for

(Sir Frederick Bramwell, Bart.)

the purpose of lenses. He had been thinking rather of the use of screws for the purpose of holding work together.

Mr. S. ZACHARY LLOYD asked if the author had had any difficulty in securing exact accuracy in the number of threads per inch, in cutting them with a die. In Messrs. Nettlefolds' screw works he had found that in cutting fine threads for taps, if they were cut with a die, there was a liability to putting a slight strain upon the threads, causing a slight variation in the number of threads per inch. Even the reversing of the die, it was supposed, would occasionally affect the thread to some extent. On this account it had been found necessary to cut the threads with a single cutter, in preference to cutting them with a die. It would be interesting to know whether the same difficulty arose with an automatic machine like that now exhibited; or whether the automatic action was so accurate that the difficulty did not arise. He had not had much practical experience of screws of so small a size as those for which this machine was designed; in fact this machine began where the sizes in Messrs. Nettlefolds' works left off. In those works the British Association thread was now being adopted for all sizes below 1-8th inch diameter; and for 1-8th inch and upwards the Whitworth thread was used. So far this plan had been found to answer well for dealing with the different sizes. The machine now exhibited however was an entirely different class of machine from those used by his firm; the latter were used solely for cutting screws from blanks previously headed, which of course was an altogether different system from cutting them entire from straight wire in a turret lathe of the kind here shown.

Mr. DAVID JOY thought the machine now described was perhaps one of the most beautiful and elaborate that had ever been brought before the Institution; and he imagined that its construction would require the utmost exactness and certainty. Some of the motions, at any rate the return motions, he noticed were produced by helical springs, and not by direct or positive action. In his own experience with steam machinery, he had had little to do with such springs, and

had rarely seen any work done by them, except in the safety-valves of steam engines. He should be glad to know whether the helical springs used by the author were found to answer best in compression or in extension; and how far they could be relied upon for keeping in perfect and accurate action. In steam machinery it was not customary to place any trust in helical springs, except for safety-valves, for which that kind of spring proved a splendid servant.

Mr. C. FREWEN JENKIN asked what arrangement there was in this machine for taking up the slack which invariably arose after a machine had been working for a length of time. In other turret lathes that he had seen the great difficulty in the way of obtaining accurate work had been to provide for taking up the wear of the machine itself. In the drawings there did not seem to be any indications of how this was done.

Mr. JAMES STABLER asked what number of screws per minute could be turned out perfect by the machine exhibited.

Mr. HEWITT understood that the angle of 55° in the Whitworth thread, Fig. 18, Plate 116, would have been preferred by Mr. Buckney (page 487), instead of the angle of $47\frac{1}{2}^\circ$ adopted by the British Association, Fig. 16. With that preference he did not himself quite agree; for he thought that the thread of $47\frac{1}{2}^\circ$, having the top and bottom rounded with a radius equal to two-elevenths of the pitch, thereby leaving a strong top and bottom to the thread, was more suitable for watch-making purposes.

In the grinding of the thread (page 476) it was not pretended that the result of the operation was perfection. The best that could be done was not perfect, and it was necessary to submit to something which was far short of what he should like it to be. As pointed out by Mr. Buckney (page 489), the method of grinding the thread was theoretically incorrect; but it corrected difficulties which were greater than it created, and therefore it was used.

In regard to limiting gauges (page 493) and the preservation of the standard for taps, a system of limit gauges was adopted, not only

(Mr. Hewitt.)

for screws, but all through the Prescott factory, for cutting toothed wheels and pinions, and for diameters and everything else. Although absolute perfection could not be obtained, the limit of inaccuracy was only about 1-2,500th of an inch. It would be going too far to attempt to get absolute perfection in watch-making, because the product had to be considered from an economical point of view. The best that could be done was an approach to within about the above limit, that is, four ten-thousandths of an inch; and this had been adopted right through the factory as a standard of accuracy, applying to screws as well as to everything else. This inaccuracy was kept a minus quantity, that is the screws when not correct were 1-2,500th of an inch less than the standard; but even when the error was on the plus side, that is when the screws were 1-2,500th of an inch too large, they would still enter the holes, owing to the fact that the female thread was deeper than the male. This forcing of the screw into the hole was of course undesirable; therefore the error was kept on the small side.

The number of screws the machine would make (page 495) depended somewhat upon their size; it was designed to make an average of 6,000 screws per day of ten hours. The machine could be run more quickly than that, but it was not advisable.

As to the helical springs (page 495), with the exception of the chuck springs they were always used for return motions only, and were not intended to do any driving work, but only to return the slides, racks, and pinions to their original positions. It would be noticed that this principle had been adhered to in the design of the machine exhibited. Helical springs were always used wherever possible; and when practicable were used in compression in preference to in extension. When they were used in compression they were always put in a hole, and a steel pin with a projecting head was inserted along the centre of the spring to hold it in position. The chuck springs, as shown in Fig. 6, Plate 111, were instances of springs in compression, and were the sole exceptions to the statement that the springs did only return-work. These springs closed the chuck direct; and the requisite power was got by multiplying the number of the springs, in preference to increasing the thickness of a single spring.

The difficulty referred to by Mr. Lloyd (page 494), of keeping the threads to the exact pitch when using a die, was a serious difficulty if the die was not guided; but if there was a mechanical method of guiding the die on the screw, the defect was minimised. The difficulty could not be altogether got rid of, and there was a considerable amount of inaccuracy even in those screwing machines in which the die was guided on the screw. In the machine exhibited the die was geared to a traversing or leading screw, much in the same manner as in a screw-cutting lathe. In that way the die was mechanically guided, the difficulty was minimised, and the screws were better cut in that fashion than in any other. The net result of this error was that the length of the holes had to be kept within reasonable limits. For instance holes that were $1\frac{1}{2}$ diameters long would receive the large proportion of screws; but occasionally a lot would come round, which caused trouble. The latter was no doubt due to the variation in the quality of the metal from which the screws were made. When the holes did not exceed one diameter long, no difficulty was ever experienced.

Mr. JOHN PHILLIPS asked whether the screws were cut dry, or whether any lubricant was used. Also whether there was any heating arising from the cutting.

Mr. HEWITT replied that oil was pumped freely upon the cutting tools during the whole time that the machine was at work. Heating was a slight matter in such small work, and was largely eliminated by the oil used so liberally.

Mr. JAMES HASWELL enquired whether the American watch factories also used the British Association standard screw-thread.

Mr. HEWITT was not certain, but believed they did not.

The screws were hardened after cutting (page 490), and the distortion from hardening was so slight in such a small length of screw that it was never appreciated.

(Mr. Hewitt.)

With regard to taking up the slack in the machine after lengthened working (page 495), no provision of that sort had been made in this machine, because all the bearing surfaces were hardened as hard as fire and water could make them, and were then ground, and afterwards stoned, so as to get the grinding marks out of them and give them a perfect surface. One of the spindles had been taken out of the machine and was shown separately, in order that it might be handled by any one who desired to see the way in which the bearings were got up. When so prepared the spindles could be run for a considerable time without any apparent wear ; and therefore no arrangement for taking up the slack was needed.

The machine as arranged made only one size of screw, on which it was kept at work ; and it was not supposed to be changed to another size. The machine exhibited was fitted up for making balance screws of 0·017 inch diameter and 231 threads per inch. It could be fitted to cut any size up to 0·070 inch diameter, which was the maximum watch-screw ; and with more extensive arrangements it could be fitted for cutting screws up to $\frac{1}{4}$ inch diameter and $\frac{1}{2}$ inch long. For any larger size a larger machine would be required.

Mr. Lehmann's origination of the standard taps and screws for the British Association had been mentioned by Mr. Buckney (page 488) ; and having brought with him a set of taps which had been made at the Prescot Watch Factory, as described in the paper, he should be happy to hand them over for comparison with the taps made by Mr. Lehmann, in order to see how nearly they might be found to agree.

The PRESIDENT said such a comparison would be extremely interesting, and he hoped the result would afterwards be communicated for the information of the members. If two English manufacturers had independently managed to originate separate sets of taps for screws from one hundredth of an inch diameter upwards, and those taps made interchangeable screws, he thought it would be one of the finest things that English manufacturers had ever done.

Mr. ARTHUR LE NEVE FOSTER, having been a member of the British Association committee, mentioned that the British Association

thread had been originated by most of the principal electrical firms; and the firm of screw manufacturers with which he was connected had originated all their own standards. Having had the opportunity of comparing a number of these standards, he had found that they agreed fairly well. Both the Post Office and the War Office he believed could say the same.

The PRESIDENT was sure the members would join in giving Mr. Hewitt a most hearty vote of thanks for his admirable paper. It was not only a record of extremely careful work, but also a most detailed record of the manner of working what appeared to him to be one of the most ingenious and complete machines for doing complicated work that had been brought before the Institution. From the study of the paper and of the elaborate drawings by which it was illustrated, he had no doubt the members might imagine how great must have been the difficulty of actually arranging the details of the machine itself.

Mr. H. W. JONES, Manager of the torpedo factory, Woolwich, wrote that, although the paper dealt only with the limited range of screws pertaining to the particular industry of watch-making, much of what was therein advanced was applicable to the wider scope in which was contemplated the establishment if possible of one uniform standard for all forms of binding screws. When commencing operations at the Lancashire Watch Works it may well be imagined that some difficulty may have been experienced in selecting the special class of screw suitable for this manufacture, owing to the absence in this country of any generally accepted standard for small sizes of screws; and it will probably be admitted that the adoption of the modified Swiss standard recommended by the committee of the British Association in 1884 was a wise course. The author is to be congratulated upon the fact that he had a free hand in this direction at the initiation of the manufacture; and was thus enabled

(Mr. H. W. Jones.)

to select the particular kind of screws required, without being trammelled by outside conditions. As an illustration of the inconvenience entailed where such conditions are imposed, it may be mentioned that, when it was decided some twenty-one years ago to adopt the automobile torpedo, a sample weapon was ordered and supplied from the foreign factory at Fiume, the only source from which these torpedoes could then be obtained ; and it was discovered that the pattern torpedo contained a variety of sizes of small screws, all more or less of a bastard character, not conforming with any recognised standard. Nevertheless the reception and approval of this pattern torpedo necessitated the adoption of these objectionable screws for all future supplies ; and when the manufacture of torpedoes of different designs and patterns was commenced at Woolwich, these illegitimate screws were notwithstanding continued, in order to avoid multiplying patterns and sending out into the navy screws of the same diameters but with different pitches. Indeed even in the present manufacture of torpedoes the adoption of any standard for screws, with a view of its becoming recognised as universal, would be precluded for the same reason. The torpedo of twenty years ago was a primitive machine compared with what it is at present. During this period it has developed into an extremely beautiful and refined piece of mechanism, involving in each weapon a large number of small screws. In the 18-inch torpedo there are about 600 screws, ranging in diameter from 0·078 inch up to 0·314 inch, all of which have to be perfectly interchangeable with others at remote stations in every quarter of the globe. No margin is allowed for looseness in fit, but it is necessary that each screw should fit its nut or seat without any shake or play whatever ; otherwise, owing to the vibrations set up in the torpedo when running at high speed, the screws would shake out, and the result would be a lost shot. The smallest of the torpedo screws exceeds in diameter the largest mentioned in the paper (page 477) ; and even if it were possible now to start afresh from the very commencement, it would be difficult to find a uniform standard for the range of torpedo screws, owing to the non-existence at present of any satisfactory standard ranging between 0·236 inch diameter, which is the maximum of the Swiss scale,

and the half-inch diameter in the Whitworth code of engineers' screw-threads. While the latter system is generally satisfactory for diameters above half an inch, the writer believes it is decidedly the reverse for screws below that size; and he thinks it would be highly desirable to originate a new standard for all screws between 0.236 inch and 0.500 inch diameter.

However satisfactory the four-spindle screwing machine may prove in the author's works, the increase in number of parts, in prime cost, and in wear and tear, together with the constant adjustments likely to be needed, leads the writer to fear that not much superiority may ultimately be found over the single-spindle machines. The screwing machines preferred at Woolwich, which have given the most complete satisfaction there, are those of the Hartford Machine Screw Co., made by the Pratt and Whitney Co., U.S.A. These machines are extremely simple, and cheap in first cost; while with ordinary attention to dies and cutters their production is everything that can be desired, so far as the screws required for torpedo manufacture are concerned.

Mr. HEWITT considered Mr. Jones' communication most interesting (page 499), as showing how universally mechanics are confronted with the screw problem, and what difficulties attend any change of standard. At the Lancashire Watch Works the adoption of the British Association standard, Fig. 16, Plate 116, was found to be by no means an easy matter. On the formation of the works the existing watch-movement manufacturers were amalgamated, with the intention of carrying on their existing businesses and gradually merging them into one establishment for complete watch-making. As the movements of Messrs. Wycherley Hewitt and Co. had become the recognized standards, these were adopted, and the other movements were brought into line with them. The manufacture of these movements proceeded for some time, until in fact many thousands had been made and sold, before the necessity for a revision of the screw standard was forced upon the author's firm. Thus the same difficulty as that experienced at Woolwich was felt by themselves; nor does the author think they could ever have adopted the

(Mr. Hewitt.)

British Association standard except for the fact of its having been based upon the screws most generally in use in the watch manufacture. This enabled them to choose screws so nearly corresponding with those hitherto used that the new series could be utilized for jobbing purposes.

Curiously enough the Woolwich experience of screws ranging from $\frac{1}{2}$ inch to $\frac{1}{4}$ inch diameter is exactly the same as that of the author's firm. The latter have been forced to the conclusion that the Whitworth pitches below $\frac{1}{2}$ inch diameter are too coarse; and for tool-making purposes they have in consequence adopted a standard which better suits their requirements. The accompanying table (page 503) gives the dimensions of this series. The diameters are all in hundredths of an inch, which gives the advantages of the decimal system and a convenient and sensible designating number. The shape of the thread is a V of 60 degrees, sharp both at top and at bottom. The pitch of this series is all that could be desired; but the form of the thread is not altogether approved by the author's firm. They would have preferred to use the British Association thread for all their screws, had the committee recommended the adoption of the negative or ascending series, Fig. 17, Plate 116, in which the pitch is expressed by the same constant 0.9 mm. raised to the powers of -1 , -2 , -3 , &c., and the diameters by the same formula * as in the paper, namely $D = 6 P^{\frac{1}{6}}$. The thread is triangular with a vertical angle of $53^{\circ} 8'$, which gives a triangle whose perpendicular is equal to its base. The top and bottom are truncated through one-eighth of the height with a radius equal to 0.1011 of the pitch. In this series the pitch corresponds closely with those generally approved, such as the Whitworth, Fig. 18; but owing to the fact of its being founded upon a rational theoretical basis, there are none of the irregularities and inconsistencies that are met with in other series. This series of screws therefore is suitable for watches, clocks, and electrical apparatus, as well as for machine building and the largest engineering work. The great objection to its adoption is the fact of its being based upon the millimetre, which is an insuperable obstacle,

* That is, the diameter is equal to the product of six multiplied by the sixth power of the fifth root of the pitch.

unless the inch be abandoned and metric measurements adopted. Theoretically millimètres can be converted into inches; but the measurements then become so fractional as to entail much loss of

Dimensions of Standard Screws with Flat Heads.

Diameter at Top of Thread.	Number of Threads per inch.	Diameter at Bottom of Thread.	Diameter of Drill for Cast- iron.	Head of Screw.		
				Diameter.	Length.	Width of Slot.
Inch.	No.	Inch.	Inch.	Inch.	Inch.	Inch.
0·04	160	0·0292	0·033	0·06	0·04	0·006
0·06	112	0·0446	0·050	0·09	0·06	0·010
0·08	84	0·0594	0·067	0·12	0·08	0·013
0·10	68	0·0745	0·083	0·15	0·10	0·016
0·12	56	0·0891	0·100	0·18	0·12	0·020
0·14	48	0·1040	0·117	0·21	0·14	0·023
0·16	42	0·1188	0·133	0·24	0·16	0·026
0·18	40	0·1368	0·150	0·27	0·18	0·030
0·20	36	0·1519	0·167	0·30	0·20	0·033
0·22	32	0·1659	0·183	0·33	0·22	0·036
0·25	28	0·1882	0·208	0·375	0·25	0·041
0·30	24	0·2279	0·250	0·450	0·30	0·050
0·35	22	0·2713	0·292	0·525	0·35	0·058
0·40	20	0·3136	0·333	0·600	0·40	0·066
0·45	18	0·3538	0·375	0·675	0·45	0·075
0·50	14	0·3763	0·417	0·750	0·50	0·083
0·55	13	0·4168	0·458	0·825	0·55	0·091
0·60	13	0·4668	0·500	0·900	0·60	0·100
0·65	12	0·5058	0·542	0·975	0·65	0·108
0·70	11	0·5426	0·583	1·050	0·70	0·116
0·75	10	0·5768	0·625	1·125	0·75	0·125

The dimensions given in the last five lines are added only for occasional use; screws slotted for screw-drivers are rarely required larger than 0·50 inch diameter.

2 x 2

(Mr. Hewitt.)

time both in the drawing office and right through the works. Considering that the British weights and measures are little better than a relic of barbarism, and must sooner or later give way to some decimal system, and that the metric system is now well established and is perhaps as good as any other decimal system which might be evolved, the author's firm would most assuredly have adopted the British Association series, making all measurements in millimètres, if the committee had seen fit to recommend it. As it was, they preferred to wait the development of events.

Having had the good fortune of inspecting Messrs. Pratt and Whitney's works in Hartford, Connecticut, and having also many of their machines in the tool room of the Lancashire Watch Works, the author can fully endorse the Woolwich experience as to the merits of their screw-making machinery. The machine described in the paper he is confident will pass unscathed through the ordeal, only too trying, of lengthened experience: firstly, because up to the present time it has justified all his expectations; and secondly, because many turret-machines, constructed much on the same lines for kindred purposes, have already been in daily use for some years, and have proved most advantageous. As explained in a paper read before the British Association on 15th September 1893 by Mr. Thomas P. Hewitt, the objections offered by Mr. Jones to a four-spindle screwing machine have been anticipated by so designing the turret rest as to render the accuracy of the work almost independent of ordinary wear and tear. In fact before the improvements now effected were introduced, the turret rest could be used only as a roughing-out machine; but already some dozens of them are doing the most accurate work possible, and doing it most speedily.

While fully recognizing the advisability of simplicity in all machinery, the author would remark that simplicity is only a relative term and may become misleading. For instance in the Prescott factory there are six single-spindle screwing-machines making together an average of 80,000 screws per week, inclusive of stoppages for re-setting &c. When these machines were introduced they were considered so complicated that they were in danger of

being condemned untried. But subsequent experience with still more elaborate machinery has now made these earlier machines appear not merely simple in comparison, but also quite behind the times, as indeed they are. Thus complication today may be looked upon as simplicity tomorrow; and the author's experience leads him to conclude that no machinery is so good that nothing better can be desired.

WATCH SCREWS.

Plate 108.

Automatic Screw - making Machine.

Fig. 1. *Front Elevation.*

Fig. 2. *Face View of Racks and Levers.*

Scale $\frac{1}{4}$ th

Mechanical Engineers 1894.

Plate 108.

*Automatic Screw-making Machine.*Fig 3. *Plan.* *Scale 1/4" = 1"*

Automatic Screw-making Machine.

Fig. 4. Longitudinal Section.

WATCH SCREWS.

Plate 110.

Scale $\frac{1}{3}rd$

WATCH SCREWS.

Plate III.

Fig. 5. *Standard Watch Screws, enlarged to ten times full size.*

Nº 13.

Nº 15.

Nº 18.

Nº 22.

Fig. 6. *Longitudinal Section of hollow Lathe - Spindle, full size.*

*Mechanical
Engineers 1894.*

Plate III.

Fig. 7. *Cam and Quadrant.*

Half full size.

WATCH SCREWS.

Screwing Arrangement.

Fig. 8. *Screwing Gear.*

Full size.

Plate II2.

Plate II2.

WATCH SCREWS.

Plate 113.

*Slitting - Saw
and
Quadrantal
Carrier.*

Fig. 9.

Fig. 11.

Fig. 10.

Full size.

Half full size.

Mechanical Engineers 1894.

Plate 113.

WATCH SCREWS.

Plate 114.

Fig. 12. *Carrier Turning and Automatic*

and Quadrantal Motion, Stopping.

Half full size.

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Mechanical Engineers 1894.

Fig. 13.

Rotation and Locking of Turret.

Scale $\frac{1}{3}^{\text{rd}}$

Fig. 14.

Fig. 15.

Fig. 16. *Section of British Association Thread.* Fig. 17. *Modified Section of British Association Thread, ascending series.* Fig. 18. *Section of Whitworth Thread.* *Double Calliper Gauge for Screws of lens fittings.*