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Manufactures of the United
States
at the
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MANUFACTURES OF INTERCHANGEABLE MECHANISM.

V.-THE MANUFACTURE OF WATCHES. (Charles H. Fitch)

The constituent material in watch-making comprises a small portion of the cost and a small cost also relative to that of the factory supplies and materials used, which are of great variety. The jewels, mostly garnets and rubies, with some sapphires, are of no great value when in the rough, most of their value in the works of a watch being due to the labor of making and setting. The brass, steel, and copper punchings are the most essential materials. These are largely furnished, even for remote sections, by the brass-works of Waterbury, Connecticut, being punched from dies furnished by the watch manufacturers and sold by weight. For hair-springs the best imported steel wire is used. The range of work in factories usually extends to every part except the largest punchings. In some cases also the mainsprings, and in others the jewels, are bought, since in the making of jewels the improvement in mechanical facilities has not been as marked as in some other portions of the work. In order to insure purity, the diamond dust is sometimes ground, and other material is prepared at the watch factory. The diamond dust is ground from the "bort", or outside cuttings of the stone, in hard steel mortars, and grinds about eight times its weight of steel dust from the mortars, being afterward separated from the steel. Of course the higher the grade of the watch the smaller out of all proportion is the relative cost of the material used, which, inclusive of mill supplies, may be commonly rated at about a third of the value of the product; but it must be said that the census returns of material relative to product or number of operatives are no indication of the grade of watches made, but indicate rather a discrepancy of views among manufacturers as to what constitutes material and may properly be reported as such.

The manufacture of watches is conducted under conditions which admit of the fullest development of systematic detail, but these conditions, in opposition to much prejudice, have themselves been developed by the ingenuity and the administrative talent of American enterprise. The manufacture of watches by machinery on the uniform system was first attempted by and at the instance of Aaron L. Dennison, of Boston, in 1848, and was first made a commercial success by the American Watch Company, of Waltham, Massachusetts. This company, as it was thus the pioneer, has also been the standard-bearer of the American system of watch-making in the competitive displays and trials at all the world's fairs since 1876, with such brilliant success as to stimulate the most strenuous efforts of foreign watch-makers to equal its results. The essential features of a system so successful and so widely published can scarcely fail of ultimate adoption in other countries.

In the American system the watches are made with parts practically interchangeable, except at a few points, upon which can be concentrated as great a nicety of adjustment as may be necessary to secure the highest accuracy; but by accurate machining the liabilities to error and the expense and necessity of skillful adjustment and rectification are eliminated from the greater part of the work. In the quality of a watch the American system, properly conducted, furnishes the most substantial foundation for accuracy.

The same mechanism which secures interchangeability increases the product, the interchangeability itself facilitating the work of assembling, finishing, and adjusting, and the division of labor resulting therefrom enables skill to be made perfect by practice upon a single kind of work. The establishment of standard forms and sizes of the component parts secures the closest attention to their best proportionment and the development of the most precise mechanical facilities for producing them. There has thus been a continuous improvement, the delicacy of the work and the rapidity with which the pieces are produced being advanced step by step.

The facility in repairs insured is also a great and obvious merit of this method of fabricating watches.

The manufacture of certain classes of large machinery may involve comparatively little system. There may be a foundry, a machine-shop, a blacksmith-shop, and an assembling-shop, but the work is only so rudely classified that attention is not concentrated upon details closely enough to stimulate their improvement. But in watch-making the system resolves the smallest items of the work into separate problems, and, as it were, puts them beneath a magnifying glass, so that under the eyes of skillful managers there is the closest pursuit of every advantage assured or promised in the existing knowledge of mechanical possibilities.

But comparison is suggested, not between two phases of the American system, the same now as ever in principle, though now with greater perfection of detail, but with a system of

manufacture which has never existed to any appreciable extent in this country. This European system consisted in making watches by scattered labor, the manufacturing being technically only the assembling of the parts made by different artisans at different places. It was a system of farming-out work, which has no present analogy in American manufactures (except possibly in such work as the manufacture of gloves at Johnstown and Gloversville, New York). The number of skilled trades required for making a watch by this method is usually stated at about fifty, some of the work being done at the homes of the operatives, as gun components were once similarly made, a man having a bench or a foot-lathe, or even a little forge, under the roof of his cottage. To such methods the factory system comes like a clearing-house, saving trade by consolidating the interests of small buyers, relieving the manufacturer of onerous duties as a dealer in a vast variety of small and unreliable components, preventing wastage of material, diminishing the number of pieces rejected upon inspection, and bringing in the exact operations of machinery to swell the product for the same expenditure of labor, both by more rapid action and by the saving in fitting and finishing.

Leaving out of account the superiority of the product resulting from the precise machine methods of the American system, a comparison by number is afforded in the statement of M. Edouard Favre-Perret, that where 40,000 workmen in Switzerland make on an average each 40 watches per annum, in the United States the average is 150 watches. "Therefore," he adds, "the machine produces three and a half to four times more than the workman."

Under this uniform system the greater proportion of the operatives are paid by the piece. At the works of the American Watch Company, at Waltham, monthly cards are prepared by the superintendent for each foreman, stating the number and kind of watches to be made. Each foreman makes a daily report of work done and of the transfers of work between the several departments, and to facilitate this each foreman has a book-keeper, who is responsible to the superintendent.

The custom generally prevails of starting watches in large lots, say 1,000 of one kind or grade, 1,000 of another grade being started when these are out of the way, and so on. But the watches are not finished in the same order, the partly-finished portions being kept in store and given out in job lots of ten for assembling. In the process of assembling these parts are kept temporarily in trays with suitable compartments, but in stock they are kept in glass jars. Thus, while one lot of a thousand watches remains in the works, many subsequent lots may be completed. It is stated at some factories that the usual average time of completion is about five months, including the testing; it being obvious that no such time is required in the simple fabrication of the movement.

The watch parts to which interchangeability does not extend are the jewelry pivots, which are selected to fit the jewels, and the balances and hair-springs, which are adjusted or selected of weight and strength to correspond; but records of these parts are carefully preserved for every watch, so that they may still be replaced with accuracy.

The quality of interchangeability is specially utilized in some styles of stem-winding watches made by the Elgin National Watch Company, which, by the transfer of a single bevel gear, are made to wind either at the figure 3 or at the figure 12, so as to permit the movement to be conveniently fitted to an open-face or a hunting-case watch.

Owing to the more complex and detailed organism necessary in conducting the manufacture, the capital investment required in making watches upon a large scale is much greater relative to the product than in clock-making. The machinery is a very heavy item of expense, and the more so, as most of it is of private design, made in machine-shops of considerable size connected with the factories, and made as the finest job-work, without regard to the expense. The number of machinists in these shops is usually 6 or 7 per cent, of the whole number of operatives. As neatness and order are matters of the highest consideration, the factories themselves are handsomely laid out, built, and equipped, and require a heavier investment in real estate than is necessary for most other classes of manufacture.

We now come to the consideration of the labor, its division in the work, and its efficiency in all, and, so far as may be stated, in the several departments; but as these departments and the requirements put upon them differ somewhat in the various factories, they cannot in some cases be more than vaguely defined. Apart from the machine-shop work and the case-making, there is the press-work, from which the plates, bridges, and so on, go to the frame-making, and thence to the stoning, gilding, and engraving; the wheels and similar parts to the train-making or the pinion roughing and finishing, and then to the stoning and gilding; the dials to the enameling and painting, and the stem-winding, balance, and escapement parts to their special departments. The jewel making and the jewel-setting, the flat steel work and the tempering, the nickel-finishing, the spring-making, and the springing and the screw-making are departments naturally separated by the character of the work. The assembling - both in the gray, that is, before gilding, and finally - and the finishing and adjustment complete the enumeration of all the usual departments. All these involve essentially different classes of work; and as each embraces work upon a variety of pieces, it is easy to see where more than 50 skilled trades might be required in the manufacture of a watch. The work of several of these enumerated departments

may be executed under one foreman, or the work of one of them may be divided among two or more foremen, such divisions being termed "jobs" or "ends" of the work, the subdivision in this respect being, as might be expected, more minute in the larger factories.

The percentage of the numbers of persons occupied in the various duties of watch-making is here given roundly in an average of the practice at several factories, viz: The springing and finishing, including the train-finishing, 17 1/2 per cent.; the pinion roughing and finishing, 15 1/2 per cent.; the screw, flat steel, and escapement work, 12 1/2 per cent.; the jewel-making, 7 per cent.; the jewelery, 7 1/2 per cent.; the plate work and engraving, 7 1/2 per cent.; the balance-making, etc., 7 per cent.; the machine-shop work, 6 1/2 per cent.; the dial work, 6 per cent.; the carpenter and blacksmith work, clerical work, watching, and time-keeping, 6 per cent.; the stoning and gilding, 3 1/2 per cent.; the mainspring making, 1 1/2 per cent.; the nickel-finishing, 1 per cent.

The percentage of female operatives to the whole number ranges as follows in those parts of the work upon which females are employed: In pinion roughing and finishing, 70 to 80 per cent.; in screw-making and flat steel and escapement work, 30 to 64 per cent.; in gilding, 36 to 50 per cent.; in jewel-making, about 50 per cent.; in balance making, 44 per cent.; in springing and finishing, 21 to 43 per cent.; in plate work, 20 to 39 per cent.; in dial-making, 17 to 37 per cent.; in jewelery, 30 to 35 per cent.; in nickel-finishing, etc., 10 to 33 per cent.; and for the whole work, from about 33 to over 40 per cent. Relative to the employment of female labor, we may quote from the report on horology by Professor James C. Watson, at the international exhibition of 1876, as to the practice of the American Watch Company:

There are many important operations in the manufacture of watches by this method where the delicate manipulation of female hands is of the highest consequence, and it ought to be mentioned here that for this labor the amount of wages paid by the company is determined by the skill and experience required, not by the sex of the operative.

Upon much of the work either sex might be employed, but it may be of interest to note some of the items of work upon which women are usually engaged, viz, the cutting and setting of pillars, the drilling of pin- and screw holes in plates, the cutting of the teeth of wheels and pinions, the leaf-polishing, the gilding, the making of hairsprings, the setting of springs, the making of pivot jewels and balance screws, the putting of movements together, and the fitting in of roller jewels and jewel pins. Beside the machine-shop and general work and superintendence, some items of work usually performed by men are the punching and press work, the brazing, enameling, firing, and lettering of dials, the plate-turning, fitting, and engraving, the fitting of wheels and pinions, the uprighting and end shaking, the stoning and oxidizing prior to gilding, the rosette-turning, cutting of scape wheels, milling of pallets, balance-making and handling, and the final work of finishing and adjusting.

From the minute division of the work it will be seen that it is almost entirely specialized, and that the labor required is skilled. In a few cases, such, for example, as the cutting of pinions, the machinery may be so far automatic or conveniently arranged that the operations of attendance are simple and easily performed; but even here the smallness and delicacy of the work and mechanism and the rapidity of action demand much more careful oversight than in a similar duty in the manufacture of coarser work. We can scarcely indicate one of the numerous departments mentioned where trained intelligence and skillful manipulation are not required in a high degree by the nature of the operations. The operatives are for the most part of American birth, and although some are young, none can be classed as boys or girls or unskilled laborers; and despite the many instances of manual skill which may be witnessed by a person in passing through a watch factory, he may, on the whole, be no more impressed by the dexterity of the fingers than by the high intelligence of the faces of the operatives.

The number of watches produced (correct time-keepers of a good medium grade) may be rated at over 150 per operative per annum for all hands employed, the number at some factories ranging higher for an average of all grades produced, all being fine full-jeweled watches. At some factories the productive capacity per operative has within the decade been more than doubled - an advantage attendant upon an increase of the gross capacity of the factories no less than upon the introduction of labor-saving methods.

The power required may be rated at about one-tenth horse-power per operative and one-fifth horse-power per power machine, and although watch-making machinery is in most cases very light, it is very rapid running, and rapid movement consumes great power at a small stress. In fabricating the movements from six to eight hundred processes are estimated to be employed, there being upward of 100 and sometimes more than 150 pieces in a watch, over a fourth of which are usually screws.

The manufacture of watch movements usually commences with the punching, but in case-making the material is first rolled into sheets. The old style of sets of rolls for rolling silver plate had the driving spurs of the same size as the rolls, so that large rolls had to be used to get pinions large enough to resist breakage. The spacing of the rollers was effected by a loose square coupling, involving knocking and lost motion. A form of rolls has been devised by Mr. Charles V. Woerd, in which the rolls carry large spurs, driven by smaller pinions and movable in a vertical

slide, the pinions turning upon spindles in set positions. The space between the rolls can thus be considerably varied without sensibly affecting the engagement of the gears, which, nevertheless, have epicycloidal teeth.

The heaviest press used in this country in watch-making is at Waltham, and has a capacity of 2,700 tons. The frame weighs 9 tons, and is cast of gun-iron, which may be reckoned at double the strength of ordinary cast-iron. The uprights of the frame are two solid 12-by-12 inch pillars, and the moving die is forced up by an eccentric upon a shaft below. This press is used for silver cases, but for the heaviest plates, bridges, and the like, the metal is rolled and punched at Waterbury, Connecticut, the punchings being one of the products of brass and one of the materials of watch manufacture. The smaller punchings are pressed out at the watch factories by comparatively small presses. One man with a 20-ton punch will blank out 10,000 watch wheels a day.

In the die-presses used by the American Watch Company the blanks as they are formed are forced up into the upper member of the press, passing into a cavity opening outward and with a sloping top, so that in the process of the work there is a column of blanks being continuously pushed up and out.

In punching the dials one stroke cuts the blank from the copper strip, punches the holes for hour and second hands, turns up the edge of the plate so as to retain the coating of enamel afterward put on, and makes the impressions into which the dial feet are brazed. Three men will do the work of punching and brazing dials for 200 movements in a day.

The plate work may be considered to include the following principal operations: The turning or facing-off of the pillar plates (which is done in lathes, the plates being set in revolving heads and the tool being brought up on a slide-rest by a lever); the drilling of holes for screws and steady pins, which is done in jigs of hardened steel; the countersinking of the holes to remove the burrs left after drilling; the cutting of threads in a tapping lathe; sundry finishing operations on bridges, potences, and the like; the numbering of the parts by stamps; the screwing of steady pins into the plates; the finish-turning of steady pins; the milling of steady pins; the fitting of plate parts together; the turning of plates to fit cases; the uprighting of jewel holes, and the drilling of pivot holes. Over one-fourth of the labor is in the turning of the plates. The eight last-named operations are briefly executed, one man doing the work of each operation for from 100 to 200 movements a day. There are considered to be some 275 operations of turning, beside about 100 other operations upon the plate work. In drilling holes the plate is put into a jig. In one instance 26 holes are drilled by one operative, using five different sizes of drills before the removal of the plate. A variety of raised circles, part circles, rim cuts, and grooves have to be made on both sides of the plate. At the outset the bottom plate is a disk one-sixteenth of an inch thick, half the weight being afterward machined away. The largest hole drilled is usually one-sixteenth of an inch in diameter. The countersinking of the holes is done upon lathes by cutters running at a high speed. This lathe is the most essential piece of mechanism used in watch-making, and the vast majority of the whole number of machines are lathes more or less fitted with appliances for special work. In cutting and setting case pillars one operative, with the Elgin pillar cutter and setter, cuts 2,000 pillars a day; by hand-work one man would cut and set only 30 in a day. In cutting threads upon pins they are run into a little die which finishes the thread. The finest pitch cut is about 250 to the inch, and in drilling pivot holes the finest drills are near the size of a human hair. In one instance the pivot containing the drilled hole and the wire polishing the same are revolved at high speed in opposite directions, making an aggregate relative revolution of 14,000 turns a minute. After completion, the watch parts are distributed in trays of ten compartments each, ten watch plates to a tray. The device most commonly employed for holding the plate, case, and other work is a simple chuck with three jaws, so characteristic of the manufacture as to be sometimes called the first element in watch machinery. Machines in which cutters work to formers are used in cutting bridges of irregular outline. These are simply neat little profiling-machines. The power is communicated from a horizontal drum at the back of the machine to a pulley on the vertical cutter-spindle, which is carried by a frame with a transverse traverse and vertical adjustment by a handle in a universal pivot, while the bed carrying the former and the work holder (against which the guide-pin and the cutter respectively bear) has a horizontal traverse perpendicular to that of the frame.

In some factories there is a single department comprising the plate work, pinion roughing and finishing, and train work, under the style of train, plate, and motion department.

In the pinion room are usually made the balance and center staves, the center, minute, third and fourth wheels and pinions, the scape, cannon, and winding pinions, the barrel, the barrel-head, the barrel and pallet arbors, the intermediate and stem-winding wheels, the dial feet, and the hair-spring collets, beside the handling of other parts. The stem-wind work sometimes constitutes a separate department. In one factory thirty different parts are made in the pinion roughing room; and in general it may be said that pinion roughing comprises the cutting of teeth and some operations of threading and turning to size from brass and steel wires and brass blanks. The brass and steel wires are usually received in three-foot lengths. A cutting-off machine, operated by one person, is capable of cutting 6,000 pieces an hour. Turning to length

and size is done upon lathes. In cutting teeth, one operative, with machine, will cut 60 piles of 20 eighty-leaf watch wheels (1,200 wheels, 96,000 teeth) a day. In pinion cutting, the finishing cuts, which give a fine epicycloidal shape to the finest leaves, are sometimes made by an index pinion cutter, the index regulating the turning of the blank so as to admit of cutting variable numbers of leaves, there being a three-mill rotary tool-stock, the pinion blanks reciprocating for the traverse and the pinion holder shifting for every leaf, and stopping the motion when all are cut with one mill. The tool-stock then turns, and a second cutter repeats the operation, the work being finished by a third. Another form of automatic pinion cutter has a horizontal chuck for holding the pinions, and a three-cutter horizontal tool-stock perpendicular to and above it, with a feed motion of the cutters and a pivoted lift to bring them clear of the work for the return movement. The term chucking is applied to the intermittent turning of the pinion blank so as to bring tooth after tooth under the cutter. Strictly speaking, chucking is the placing, centering, or adjusting of work in a chuck, although a chucking-machine is sometimes understood to signify a machine in which the tool remains stationary while the work revolves, being held in a chuck.

In cutting the wheels they are piled together and a large number are cut at once, the process being the same as in pinion cutting. Some machines for cutting wheels with long sleeve-bearings cut only one wheel at a time, a cutter with a horizontal axis moving vertically, while the wheel being cut chucks about a vertical axis. All of these machines are exceedingly prolific in output. Even with hand machines the output is large. The cutting mills usually make about 7,000 revolutions a minute. In the hand machines the mills are given a reciprocating motion from a lever operated by hand. The indexing or chucking is also done by a hand-click, the attendant operating the index wheel with the left and the reciprocating feed of the cutter with the right hand, the mills, of course, being driven by power.

The mechanical requirements for wheel and pinion cutting may be briefly recapitulated. The work, if wheels, must be carried on an arbor and held fast; if pinions on staves, they must be held fast in a centering chuck. The work must automatically or manually turn and stop as many times in a revolution as there are leaves to be cut. This is usually accomplished by a click and ratchet-wheel or some other arrangement of intermittent link work. If it is desired to make the machine adjustable for cutting different numbers of leaves, an index ratchet-wheel is used, with an arrangement for regulating the stop so as to pass a given number of teeth in the ratchet-wheel, either by varying the throw of the click or introducing change wheels in the train. In automatic machines, after the leaves have been cut all around, the machine must stop itself. This is effected by a disengagement in the train, sometimes by the pushing out of a catch, allowing a bearing to drop, or removing a half-nut from the screw thread in which it works. The cutter must of course be upon a power spindle; and if there are several of them, they must chuck or turn and stop to work successively upon the pinion, each in turn engaging with a driving spindle. Either the work or the cutter must move longitudinally to furnish the feed. If the work moves longitudinally, the return movement may be utilized to turn the work into position for a new cut. In case the cutter with its carriage moves longitudinally, its power motion has to be continued by means of a drum and belting, as in profiling machinery.

An automatic pinion cutter of fine design, used at the works of the Hampden Watch Company, is stated to have cost \$4,000, and to be capable of cutting pinions for fully 100 watches a day.

In one instance the output of pieces from the pinion-roughing department was 160 per operative per day. The finest piece made is the pallet arbor, a pivotal bolt, which for a small size of watch has a thread of 260 to the inch, weighs 1/130000 of a pound, and undergoes twenty-five operations, costing 2.27 cents for all. Measurements are gauged to 1/25000 of an inch, sometimes called a degree.

Pinion finishing comprises leaf-polishing, which is done with fine crocus in reciprocating apparatus, sometimes called "wig-wags" (the pinion being turned and the polishing piece passing over each tooth space in succession); facing or polishing the ends of leaves; burring and turning under (sometimes done by hand with a graver), and staff polishing by reciprocating machinery.

The train work, in the practice of one factory, comprises the finishing of the brass barrel, the end-shaking, the truing and inspection of the wheels, and operations of fitting, such as fitting the cannon pinion to the hour wheel, the arbor to the barrel, and the staves to the wheels. In this case about a fourth of the operatives engaged in the train work are occupied in fitting staves to wheels, and nearly as many in end-shaking. End-shaking is usually gauged to 1/10000 and side-shaking to 1/25000 of an inch. These measurements are effected by dial gauges, with trains of gears for multiplying the discrepancy. These gauges are sometimes furnished with a screw adjustment of the height of the table, with a set screw, so as to take up wear and adjust the pointer to the zero of the dial. The end-shaking machinery is sometimes made to measure from each actual arbor to determine the depth of bearing to be drilled. The drill is driven by a belt, and is pushed down to the required depth by a handle with a pin, which arrests the motion by striking a stop upon a fixed frame. The rod of the handle is divided below the pin, the separate ends being held in place by a yoke. Between these ends the arbor is inserted, and by its length determines the height of the pin above the stop and the consequent depth of the hole drilled.

The manufacture of dials is in all its details a special and interesting process. At the works of the American Watch Company the muffle furnaces are of a specially ingenious construction, designed by Mr. Woerd, being built of interchangeable fire-brick blocks (which can be quickly replaced), and so arranged as to insure a vastly greater endurance of the muffles and a considerable saving of fuel.

The enamel is ground with pestles in Wedgewood mortars. In the form of paste it is spread upon the copper dials, being retained in place by the raised rim. The dials are then heated to about 1,100° F. in the muffles; are removed for surfacing, fired, reheated in the muffles, and then the figures and lettering are put on in black enamel, there being in all four operations of firing. The most expeditious method of putting on the hour figures is found to be by covering the figure ring with black and ruling out and scraping off all but the hues of the figures. But the fine lettering is done by skilled hand-work with brushes.

Dial sinking is the process of cutting out the seconds and other circles of the dial and cementing in circles at lower levels, to give an ornamental appearance to the face of the watch.

Stoning and gilding are usually done in the same room, stoning being the smoothing of the surfaces of the brass parts of the train and plate work preparatory to gilding. It consists in rubbing the pieces upon Ayr-water stone, the pieces being sometimes set in cork. After stoning, the pieces are strung upon wires, immersed in a hot alkali, and then in an acid bath, and are then "oxidized", which consists in brushing the pieces in brass-wire brushing machines, the brushes revolving in a bath of beer. This gives them a frosted surface. Then follow, in succession, gilding with a galvanic battery, wire-brushing, regilding, drying (after an alcohol bath) in boxwood sawdust, and wrapping in tissue paper ready for the finishing department. In gilding, a cold solution is sometimes used with the best results, thus avoiding the poisonous fumes of the cyanide of potassium. Sixteen operatives will stone and double gild the work for about 240 watches in a day.

For the ordinary work of engraving, the impressions of names, lettering, and ornamentation are stamped, and afterward finished with a graver. Hand-stamps are commonly used, but elaborate presses are sometimes employed, in which the position of the work is nicely adjusted by verniers.

In jewel-making the jewels are first sawed into slabs one five-hundredths of an inch thick. These slabs are shellacked to plates, in which are concentric rings or grooves, so that the slab may be better trued to the plate. They are then surfaced upon one side with an ivory lap, and that side, being in turn shellacked to the plate, the other is similarly surfaced. From these slabs the separate jewels are obtained by sawing or by marking out and breaking. In making the pivot bearings the jewel is fastened by shellac to the end of a spindle, which during the working the operative heats at intervals by a small lamp. Thus held, it is in position to be worked on one side. The jewel is, in form, similar to a plano-convex lens with rounded edges. It is also drilled through the center, and there is a depression or cavity in the center of the convex side for an oil-cup. The cutters are diamond points carried by a holder, which first moves the cutter upon a long radius for surfacing the face of the lens, and is then unshipped and brought up on one side of the spindle to round the back-edge. Diamond dust is also used for polishing, and sticks of pith for cleaning the jewels. The jewel, prepared for its bearing, will weigh about an eighty-thousandth of a pound troy. In turning the oil-cup side and edge of the jewel one operative does from 200 to 300 a day, the fiat side not taking as long. On the average, one operative finishes over 150 a day.

The jewel is put into a setting, and the setting is then trued, so as to bring the jewel hole exactly in the center. The holes are opened to the required size with diamond dust. After washing, they are gauged on a needle gauge and distributed in boxes according to size. The pivot holes are also gauged, and records of these measurements are preserved. The jewels are then fitted into pivots of corresponding size, and all are fitted into the plates.

A machine has been devised by Mr. C. V. Woerd for the side-shaking of jewels, by which each pivot setting is bored to correspond with its jewel. In this the tool is carried upon a rocking-frame, and at double the distance from its center is the measuring device, an edge upon the rocking-frame approaching a fixed edge, so that the jewel or arbor placed between them will throw the boring tool half the diameter of the jewel off center, causing the tool to bore a hole to fit the diameter of the jewel.

The jewel bearings are polished by a wire with diamond dust, and afterward by a pointed splint of wood. In the straight gauge for measuring the holes in jewels the jewel is run upon a fine graduated wire point as far as it will go. The point is then pushed back against a spring, the jewel acting as a stop and determining the movement of a pointer along a scale, one of whose divisions is equivalent to the twenty-five thousandth of an inch in the diameter of the jewel hole.

Machines in which cutters work to formers are used in nickel-finishing, and also in cutting rosette work upon the watch-case. The rosette-cutting machines have a spindle for holding the work, pivoted below upon parallel bearings. The formers are scalloped or fluted wheels upon this swinging spindle. In its revolution these bear upon a guide which moves the spindle relatively, to the cutting tool, causing these wavy lines to be reproduced upon the watch-case to a diminished scale. Very beautiful ornamentation is executed upon the nickel work of watch plates,

a great variety of curious forms being produced by the movement of an ivory style or steel point over the nickel surface, the movement of the style being obtained by elliptic gearing, escalloped wheels acting as formers, or other aggregations of cam motions, to vary the position of the style as the rotation progresses. This is called nickel-finishing.

The stem-winding movement usually comprises some twenty-five or more additional pieces, the most characteristic being bevel gears, requiring bevel-gear cutters and angle grinders and polishers. The movement usually consists of a train with bevel gears for stem-winding, and another train for stem-setting, which engages upon pressing a button or pulling out the stem itself, so that the hands are also moved as the winding proceeds.

In the common screw-machine for watch screws the wire is first stopped and shouldered; the die is then carried over it, and the motion is reversed, running the die off, when the screw is run into a screw plate and the wire is cut off; leaving the head. A screw plate full of screws with plain heads is thus obtained, which is placed under a mill for slotting the heads. In this way one man can make 1,200 screws a day, not including the slotting. When more than one operation is performed on the wire blank before cutting off a pivoted tool-stock is used. Such tool-stocks for this and for other work in watch-making, instead of being like ordinary turret lathes, are often centered back of the work, so that the cutting tools converge toward instead of diverging from a center.

The unslotted screws are sometimes run into a cylindrical holder, so that they may all be slotted by one operation of turning. Automatic screw machinery, which is very prolific in output, is used by the American Watch Company, having been designed by Mr. Woerd in 1872. With the same attendance it will turn out fine watch screws about as rapidly as the most prolific automatic screw machines used in sewing-machine work will turn out the smallest sewing-machine screws. Most of the movements in these screw machines are derived from cams on a side shaft. Such a cam causes a chuck to feed the wire forward and gives it a rotation by means of fast and loose friction pulleys; another cam moves a toothed sector, which by a pinion actuates the chaser-screw spindle, which drives the die spindle by a pair of adjustable gears; another cam operates, after the wire has been threaded by the die, to throw over an arm pivoted upon another spindle, which arm carries a small gripping chuck, or holder, and on coming into line with the die (which is drawn back by a cam) is allowed to spring forward and take the screw just as the head is formed by cutting off with a straight automatic tool. Finally, another cam operates to lift and lower upon a pivot the frame carrying the mill, which is driven by pulleys with round leather bands, and slots the screw head after it has been brought into position by the return of the pivoted arm, which successively transfers the pieces from the die spindle after they have been threaded and cut off. The smallest watch screws weigh only about $\frac{1}{122400}$ of a pound. In polishing the heads of screws they are inserted in a metal disk, and are then passed over a glass and emery surface, being given an eccentric rotary motion, moving from the center toward the circumference.

The scape-wheel has 15 teeth. They are cut in piles of ten or more by a machine with eight sapphire cutters. With this one man in a day can cut 3,000 wheels, and, delicate as is the work, with the wheels once set the operative might turn the handles with his eyes shut.

The hair-spring studs go through sixteen operations. In grinding and polishing these studs one man will do 250 a day. The watch pallet is first punched from sheet-steel in the press-room, and is then slotted and milled on lathes fitted with suitable chucks and holders. Slips of jewel are inserted to form the acting surfaces and to take the wear. The pallet is often made in curious forms merely for ornamentation. The pallet jewels are sawed in strips with diamond saws, are polished by fine diamond laps, and in ten hours one man will complete 300 of these jewels, one of them weighing of a pound. Roller jewels are made from long bits of jewel, which are fastened in a revolving spindle ground and polished to size. One man will make 200 a day, and one will weigh $\frac{1}{256320}$ of a pound.

An apparatus called a horizontal bar and pole is sometimes used for surfacing steel work, the pieces, by means of it, being brushed over a stone - that is, held and imbedded in a brush, which is swept over the stone. The tempering of the steel work and the hair-springs requires experienced judgment, but is only a small item of labor.

In balance-making the steel blanks are first pressed out and brass rims are fused or brazed upon them. The blanks are then repunched, and the sections, leaving the single arm, are also punched out. This cross-piece, or arm, is sometimes formed by four milling cuts, and the rest of the steel disk is turned out, excepting a narrow rim of steel within the brass. Screws of gold or brass are placed in the rims. Two machines, one operative attending each, turn out 400 balance screws a day, 1 pound of brass being enough to make 2,000, and 1 pennyweight of gold 50 screws. One operative can drill upward of 2,200 screw holes for the balance-wheels in a day. There are 80 operations upon a balance-wheel, 66 of them being drilling, threading, and countersinking holes. The drills revolve at 4,800 turns a minute. The balance, which at first is a steel disk rimmed with brass, weighs 72 grains, but after machining weighs only 7 grains, and, fitted with 16 gold screws, 7.20 grains. The hands are punched in two operations, the finished weight being one-fifth of the original weight of the blank.

The final operation of assembling is called the gilt training, in distinction from the assembling before gilding or in the gray, and the finishing and adjustment of the balances is commonly called the balance handling. In the finishing one operative will in a day set 90 mainsprings and fit them into the movements. The mainsprings are cut from rolled sheet, the remaining operations being tempering, polishing, and winding. The temper is very neatly drawn by bench apparatus with burners. The polishing and working are usually done by hand, the tools being drawn to and fro over the springs, which are extended flat and fastened in vises at the ends.

The hair-springs are made from spools of fine wire. These wires are polished by drawing them between diamond points, and are cut to length, coiled, hardened, and tempered. The coiling of the hair-springs is a very simple operation. The ends of two or more, generally of three, springs are inserted in holes in a small arbor, which is placed in a small cylindrical box and turned until the springs wind themselves within the box, the thickness of one or two springs being the space thus determined between the coils of a single spring. These boxes, with tops wired on, are bunched together, and the springs, after tempering, retain their form. Hair-springs are sometimes made of gold, and this is the case in the movements for the Yale time-locks for vaults, as steel is specially subject to corrosion from the dampness and condensation of moisture.

In common watches the fast and slow regulation of the hair-spring is effected by moving a lever on which are pins, which clasp the spring and extend or shorten its vibrating length by a little, causing the vibration to be slower or quicker. The inner end of the hair-spring is fastened by running it through a hole in the collet of the balance pin, where it is clinched by pushing in a tiny brass pin, made long enough to be driven from outside the spring and then nipped off close to the collet. The point at which the outer end of the hair-spring is held, in respect to the position of insertion of the inner end in the collet, having been once properly fixed, cannot be greatly varied without impairing the isochronism of the movement of the balance. In watches of the finest time-keeping qualities the balance is therefore carefully selected to accord with the strength of the spring, so that the least possible adjustment may be necessary in shortening or lengthening the spring. The balances are weighed to the fourteen hundredth part of a grain, and the strength of the spring is gauged relatively by winding and unwinding against a given spring. The time-keeping of a watch is perfected by a trial, so as to adapt it to a wide range of circumstances, and is subjected to high and low temperatures, and made to run with 6 up, 12 up, 3 up, 9 up, face down, and so on. The adjustments resorted to in consequence of the results of these experiments are such as seem justified by a long course of experience, and are of a nature and nicety which cannot well be explained.

The foregoing illustrations of the processes of watch-making outline more or less superficially the character of the work. The examples cited have been drawn from observation of the practice at all of the larger factories, and acknowledgments are due to the officers of the American Watch Company, of Waltham, Massachusetts; the Elgin National Watch Company, of Elgin; the Illinois Watch Company, of Springfield, Illinois, and the Hampden Watch Company, of Springfield, Massachusetts, for courtesies kindly extended.

MANUFACTURES OF INTERCHANGEABLE MECHANISM.

VI.-THE MANUFACTURE OF CLOCKS. (Charles H. Fitch)

The manufacture of clocks exhibits a much more rapid growth during the past ten years than in any preceding decade, there having been, in 1850, 82 per cent. as many operatives as in 1860; in 1860, 73 per cent. as many as in 1870; and in 1870, 47 per cent. as many as in 1880. At the same time the reported value of material handled and of product per operative is less than in 1870; against 47 per cent. as many operatives in 1870 as in 1880, there being a return of about 77 per cent. as great a value in the product. There thus appears a change in the character as well as in the extent of the industry. The value of material formerly trebled is now little more than doubled in the process of manufacture. At the same time it may be said that a smaller proportion of the labor is now devoted to the clock movement, more being expended upon the manufacture of ornamental cases in great variety, bronzes, and the like.

It is obvious that much less labor is expended upon the same weight or even upon the same value of material in clock- than in watch-making. A greater value of material is therefore handled by the same number of operatives, and the relative value of constituent materials for movements is three or four times as great, and the aggregate value of all materials is for the same number of operatives greater in clock than in watch manufacture.

Clock materials are almost entirely domestic, except a small proportion of foreign woods used in casing. Copper and zinc, the chief constituents of sheet-brass, are obtained in this country in unsurpassed purity and excellence; the steel and iron wire are also commonly American, and native black walnut is the wood in most general use for cases.

Clock-making was one of the earliest outgrowths of Connecticut ingenuity, and clock parts being coarse as compared with watch parts, practical uniformity has followed more in consequence of wholesale manufacture and the necessity of correct gearing for uniform velocity ratios than as an end deliberately sought or utilized for the interchanging of parts. The work upon the common clock movement is for the most part of two kinds: plate work and wire work. Dies for punching the plate parts determine their uniformity, and the wire gauge determines that of the arbors, pillars, and trundles. Even the wires are not formed into complicated shapes, and in common clocks screws are not used, the plates being riveted like lock-plates.

But clock-making, having been so long practiced (and the primitive processes being susceptible of such great improvement), exhibits perhaps more forcibly than any other manufacture of mechanism the great strides that have been made. The successful manufacture and general use of many kinds of mechanism has been consequent upon the prior existence of manufacturing mechanism, but from the single-handed manufacture of wooden toys clock-making has gradually come to be conducted in large establishments, having all the advantages of labor-saving machinery. Some of these produce an average above two clocks per working minute.

The departments of the work are principally two, devoted respectively to the manufacture of movements and of cases, of which the latter often requires the greater space and the greater number of operatives, although the material for the movements usually costs more than that for the cases. Metallic cases also are made for many styles of clocks, involving both metal working and foundry facilities in their manufacture.

The capital required is notably smaller in clock than in watch manufacture. The returns for the United States in 1880 show an average of \$1,236 per operative for watch and \$756 per operative for clock manufacture, the total products in the two cases being nearly equal, the total capital being twice as great in watch as in clock manufacture, and the average number of hands being about four-fifths as great in the latter as in the former.

In the earliest work of wood clock-making in Connecticut it took a man upward of a week, sometimes several weeks, to make a clock; but by 1820 the average time was about three and a half days.

In 1820 thirty hands made 2,500 wooden clocks in four different styles in the course of a year, or 83 clocks per operative per annum. These clocks were made with cherry wheels and laurel pinions, the teeth being set in. But in 1880, though the number of different styles made in a single establishment is fifteen or twenty times more, and many of them are of an elaborate ornamental character, an average of over 520 brass clocks per operative per annum is attained, and for the cheaper styles the output would of course be considerably greater. It may be said roundly that one operative will upon an average in a given time perform the work upon four times as many ordinary clocks, including casing, as upon ordinary watch movements. Of large calendar clocks, more than 125 are turned out per operative per annum, and since 1870 an

improvement of as much as three or four fold is stated in some instances, the advantage being due to improved machinery and to the practice of manufacturing clocks of the same kind in very much larger lots at a time than before.

A large proportion of the labor in clock-making is unskilled, about 10 per cent. of all the hands being children and youths, while practically no children or youths are employed in watch-making. In clock-making, about 12 1/2 per cent. of the operatives are females, in contrast with 36 per cent. in watch-making. Of the operatives, we may consider roundly that about one-third of them are machine-tenders, and the remaining two-thirds bench-workers, varnishers, packers, and so on. The number of power machines ranges from as many to half as many as the number of operatives, but many of the machines are not in continuous operation.

In clock as compared with watch manufacture the machine processes are generally similar, but without the same degree of refinement. The large proportion of wood-case work is also peculiar to clock-making.

In 1807 Eli Terry, of Plymouth, Connecticut, commenced using machinery in making wooden clocks. Clock gears were then marked out and sawed by hand, a much slower and more laborious work even than fret-sawing. Such movements were sold at \$25 each, but by 1840 the cost of a wood movement had been reduced to \$5, and at this time the manufacture was fairly revolutionized by Chauncey Jerome, who introduced the one-day brass clock, the movement for which can now be made for less than 50 cents, three men being able to level the sheets and punch out wheels for 500 such clocks in a day. Mr. Jerome sent his first consignment of clocks as a venture to England in 1842, and the export business thus commenced has grown to such an extent that some American manufacturers have their catalogues printed in French, German, Spanish, Italian, Swedish, and Portuguese. Not only is the civilized world supplied, but American clocks are found to have preceded the American traveler in semi-barbarous lands.

The labor on a handsome wood clock-case often costs a surprisingly small sum, and the common zinc faces are cut, painted, and lettered at 3 or 4 cents apiece. In the case-making the processes are of great variety. Knobs and ornaments are turned and carved; stencils are used in laying out patterns to be carved; and curved, round, and half-round cases are formed by deeply scoring the wood at intervals upon the inner side and bending it to shape. Some of the most elaborate ornamentation is executed by pressing compositions of glue and sawdust, which, when finished, appear like fine wood carvings. Ornaments in glass are etched by acids. Wheels covered with sand-paper are used in smoothing wood work, the wheels for finishing moldings being molded to correspond to the work. Planing, sawing out, drilling, mitering, gluing, varnishing, bronzing, painting, and polishing comprise the balance of the work on ordinary cases.

Most of the work upon ordinary clock movements is done by those machine methods well known to be of the greatest rapidity, viz: Press work, turning pins and arbors from wire, and cutting small gears in piles. The making of main-springs and the riveting and other kinds of bench work are also rapidly performed.

Index gear and pinion cutters are commonly used, these being sometimes automatic. Among other instances, automatic machines are used for placing pinion blanks upon arbors. The blanks and arbors are held in proper feed receptacles, the blanks being allowed to drop successively into grooves, when the arbors are thrust through them. The arbors with the pinion blanks exactly placed are then thrown out ready for the pinion cutter. The little staves in the lantern pinions are placed by girls. There is much work of turning, and the turning tools are commonly set upon arbors, which rest in sockets parallel with the lathe spindles, the tools being brought against the work by handles set in the arbors, which will accommodate a number of tools placed radially in various positions.

It is, however, obvious that between the fine and the heavy, the plain and the fanciful, a great range of work is involved in clock-making. No mechanism is too exact for the manufacture of fine astronomical clocks, and tower clocks are large and heavy machines, involving nice work, and being sometimes built by special contract. The other extreme is in the manufacture of small alarm and other cheap clocks, upon which, however, the exactness of machine methods in wholesale manufacture enables a very excellent quality of work to be done at a low cost.

The power required in clock manufacture may usually be rated at from two-fifths to one-half horse-power per operative, of which the greater part is commonly consumed in the case-making.