THE BUILDING OF A WATCH.

If we were asked to state the most important element in our rapidly approaching industrial supremacy, we would name, without any hesitation, labor-saving machinery. If we were asked where labor-saving or automatic machinery was to be found in its very highest state of development, we would direct the inquirer to visit one of the great American watch factories, which are at once the pride of the watch industry in this country and the despair of all foreign competitors.

Time was when all watches were made by hand; they are largely so made in Europe today, and the prejudice against machine-made watches, based upon the mistaken supposition that they must be necessarily rough in their construction and uncertain in their running, dies a lingering death. The credit for the scheme of applying machinery to watch manufacture belongs to this country, and is due to a Boston watchmaker, Aaron L. Dennison, whose earliest work in this direction dates from the year 1848. Mr. Dennison's theory was that the substitution of special machines for human skill would insure such uniformity of product that similar parts would be practically interchangeable. The cradle of the industry was laid by Dennison and his partners, Howard and Curtis, in a small factory which they started in Roxbury, Mass., in 1850. Four years later the concern was moved to Waltham, and out of this venture, in spite of many early disasters, has sprung the vast establishment known as the American Waltham Watch Factory, where automatic machinery is now turning out watches at the rate of 2,500 a day.

Every one is more or less familiar with the appearance of the mechanism of the watch; but to comparatively few people is given the opportunity of observing the operations of the thousand-and-one machines, most of them marvels of ingenuity, which, with metallic fingers, pick up the crude material—brass, nickel, or steel—cut it into the desired forms in a number of swiftly succeeding operations, pass it from machine to machine, from tool to tool, and finally deposit it, completely fashioned, before the attendant, whose sole duty it is to supply the raw material at one end and receive the finished articles at the other.

There is something almost human and extremely fascinating in the motions of these phenomenal tools, and there is something more than human in the absolute accuracy of the finished product, much of which before it can pass the inspector must be gaged to one ten-thousandth of an inch. The American watchmaker has proved, not only that watches can be made by machinery, but that the machine-made watch has an accuracy of movement superior to that of the average hand-made article. This demonstration was made over twenty years ago at the Centennial Exhibition, where three Waltham watches earned the highest awards for accuracy, by running for ten weeks with a mean daily variation of only twenty-three one-hundredths of a second and an average difference of only forty-four one-hundredths of a second between the first and the eleventh weeks of the trial.

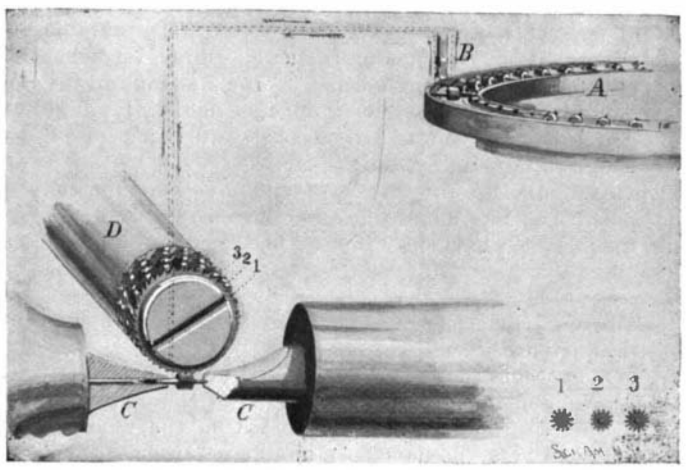
In describing the construction and adjustment of

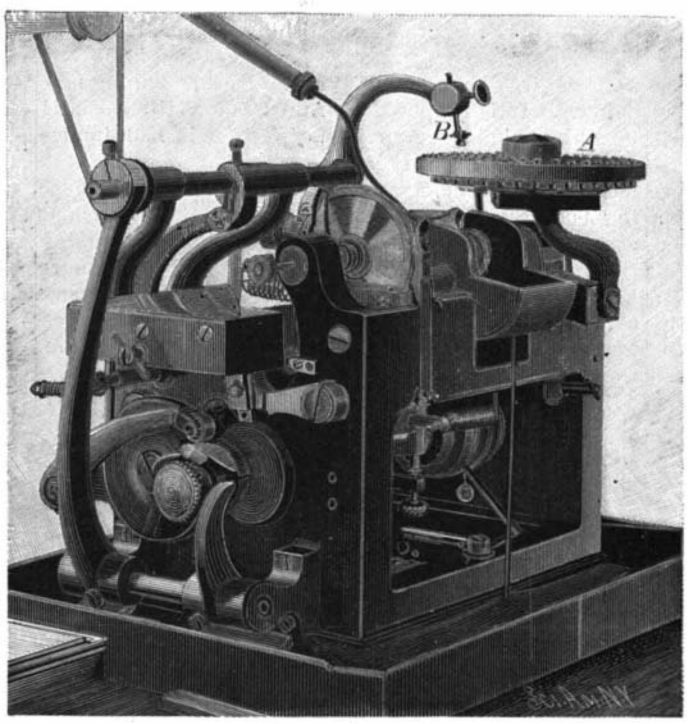
12.—Train Wheel Blanks and Cutting Arbor.

the machine-made watch, we have chosen the Waltham Watch Factory as being thoroughly representative, both in the size of the establishment, the variety and quality of its tools, and the excellence of its product, of the latest development of the watchmakers' art in this country. The factory (Fig. 3), which still occupies the original site, has been entirely rebuilt since 1876. It is a four-story brick structure with a frontage of 746 feet, and six wings which, with the main structure, would make a building nearly half a mile in length. The operatives include about 1,400 women and 800 men, and as the total output is 2,500 watches a day, it is evident that somewhat more than a watch and one-eighth is made by each operative every working day of the year.

Compare this with the work of the hand-labor watchmaker who required nearly three months to produce one high grade watch.

A visitor to the factory has not covered very much of





11.—Automatic Pinion Cutting Machine.

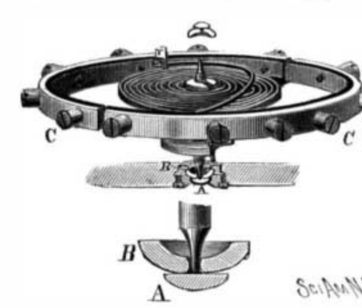
the two-mile journey which is necessary to complete the circuit of the various floors before he realizes that to describe comprehensively or in any detail the building of a watch would require a volume of no small dimensions. This will be understood when we state that an ordinary watch movement is composed of 160 separate pieces, requiring for their production 3,750 distinct operations. For it is to be understood that there is no part of the watch movement which is not made in this factory. It is the aim of the present article to present such a selection of views and as much descriptive matter as will give the reader some slight conception of the rare ingenuity, skill, and accuracy which characterize both the tools and the finished output of this modern watch factory.

A watch may be defined as a self-contained motor of the stored-energy type, whose duty it is to impart motion to a train of gearing, the speed and uniformity of which is regulated or governed by the vibrations of a small balance wheel. The energy is contained in a coiled main spring and is imparted to the balance wheel through a train of gears, which are so proportioned to each other that three of them will complete a revolution respectively in one minute, one hour, and twelve hours, while the balance wheel is vibrating at the rate of five beats to the second, or 18,000 to the hour.

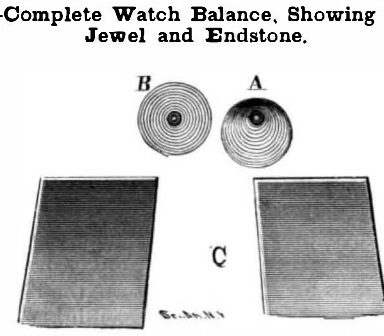
PILLAR AND TOP PLATES.—The various members of the "movement" are carried upon delicate steel axles, which have a pivotal bearing in two plates known as the "pillar plate" and the "top plate," the bearings in the better grades of movements consisting of jewels set in the plates, and with holes of such exactness that the clearance between the pivots and the jewels is only one one-thousandth of an inch.

Blank punchings for the pillar and top plates of the required form are received from the brass mills, where they are punched out of sheet brass or nickel, the latter metal being preferred for the Waltham watches. The preparatory machining is done in the ingenious machines shown in Figs. 4, 6, and 9. The plates are first faced on both sides in a fully automatic machine, of which two are shown in Fig. 9. The operations are shown by the diagram at the top of the cut. About 100 blank punchings are packed face outward in a cylindrical magazine, *A*, from which they are taken one at a time. A similar magazine, *E*, receives the finished plates at the opposite end of the machine. The facing is done by the tools, *F* and *G*. The operation is as follows: As soon as a full magazine of punchings has been put in place, a horizontally swinging arm, *C*, swings in front of *A* and lets fall a carrier, *D*, which seizes one of the plates; the arm then swings around and deposits the plate in the holder at *F*, where it is faced, as shown in the diagram. Another arm on the opposite side of the plate now swings over, picks up the plate, swings over to the next tool (meanwhile reversing the plate so as to bring its opposite face to the tool), and places it in the next holder at *G*, where it is again faced. The third arm then picks it up and carries it over and drops it in front of the receiving magazine, *E*, into which it is pushed by a plunger. The three arms always act in unison, and the motion of the machine is continuous until the magazine has been emptied. The operation is absolutely automatic, the operator merely having to supply another full magazine of plates at regular intervals. Fig. 6 shows a fully automatic machine for recessing the plates, which is even more elaborate, involving no less than seven transfers, which are made by the swing-ing arms, *C*, *C*, *C*. The problem is complicated by the fact that most of the recesses being eccentric to the plate, the latter has to be centered accordingly on the chucks, *A*, *A*, *A*, after each transfer. This is done automatically, and, as in the machine just described, the attendant has merely to feed the magazines of faced punchings at regular intervals at one end and remove the finished work at the other. When one arm moves, all move, so that a finished plate is turned out at each transfer. Most ingenious of all, however, is the automatic machine shown in Fig. 4, whose duty it is to drill with mathematical exactness as to size and position the holes in the pillar plate, numbering 39 in all. In this machine the magazines, *A* and *C*, are placed vertically, and the transfer arms swing in a horizontal plane. Five transfers are made and each of the turret heads contains six drills. As soon as the plate has been transferred to a new holder, the latter, which has a universal movement in a horizontal plane, moves the plate to the proper position, when the particular drill, corresponding to the required hole, rises from the turret head and drills a hole. The holder then shifts to a new position and the operation is continued until all of the required holes of that particular size have been drilled, then a second drill of a different size is brought into operative position and the operation is continued until about one-fifth of the holes have been drilled. The piece is then transferred by the arm, *B*, to position No. 2, where more holes are drilled, the operation being continued throughout the series.

GEARS AND PINIONS.—The gears are made from sheet brass and the pinions from steel wire. To follow the manufacture of the former, we must first pass to a room in which we see rotary cutters cutting the sheets of brass into long strips, which vary from one-fourth inch to three-fourths inch in width. These strips are then fed by an attendant to a punching machine,



13.—Complete Watch Balance, Showing Pivot Jewel and Endstone.



14.—A Non-magnetic and a Steel Hairspring, Latter Distorted by Magnet.

where the gear blanks are punched out at the rate of 25,000 per day. The little wheels thus produced, ready for the gear cutter, are very perfect, with hub, spokes, and rim complete. Just here it will be well to say that all the parts of a watch that admit of it are fabricated from punchings, and it is in this department that some of the greatest saving of labor is achieved. For such delicate work, of course, the dies have to be made with the nicest care, and so well is the work done that the punchings are wonderfully clean and true.

By far the most delicate work of this kind is done in the production of minute, hour, and second hands. In this case the metal is too fine to admit of its being punched at a single stroke of the machine. Three operations are necessary. The flat wire is first run through a machine (Fig. 7) which produces rough punchings. These are then swaged in a second machine, which leaves the form of the hand standing out in clear relief; and the superfluous stock is then removed in a third machine, which punches out the delicate hair-like little pointers to finished size. Great care is exercised in preparing the dies for this work. The die is held against a vertical file, of great fineness, which works through a table somewhat after the manner of a jig-saw. The heads of the pointers are polished by means of a hard rubber block, *A*, Fig. 15, and Vienna lime, the former having a rapid reciprocating movement above a small table, *B*, in which is a recess of the exact size and form of the pointers. In order to secure a convex face on the pointers, the table is given a lateral rocking motion.

To return to the gears: The cutting of the teeth is done in a special machine, part of which is shown in Fig. 12. Fifty or more of the punchings are assembled on a split arbor, *B*, which is placed between the centers of the machine. A fly-cutter, *A*, then begins to cut across the gears, the arbor being rotated between each cut by an amount equal to the pitch of the teeth.

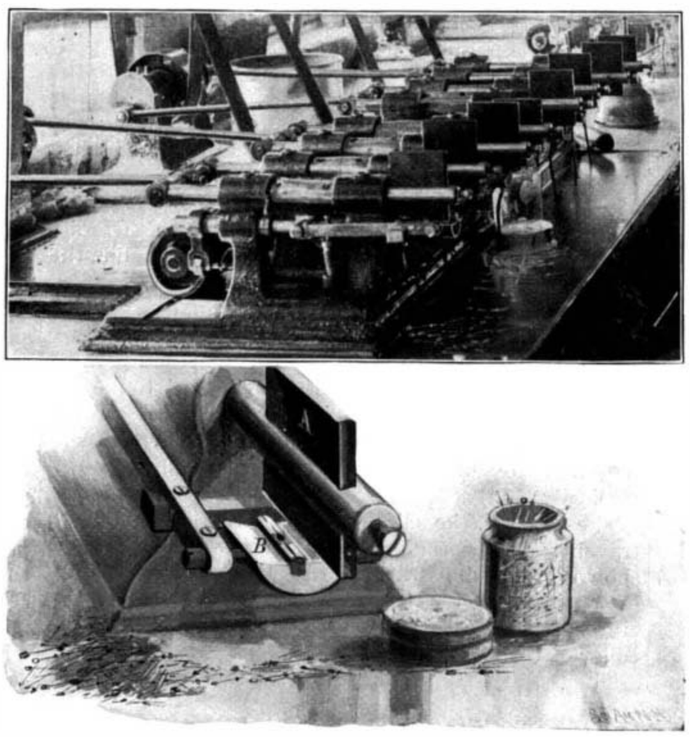
The pinions with the microscopic shafts on which they turn are made out of a special grade of steel wire. They are automatically cut to the right lengths, roughed out and pointed, and then are transferred to the machine (Fig. 11) which cuts the teeth. As it is necessary that these diminutive pieces should operate with the least possible friction, they are cut with epicycloidal teeth, and the cutting is performed by a tool carrying three milling cutters. The pinions are placed in a circular rotating magazine tray, *A*, from which they are picked up by a pair of tongs, *B*, one at a time, and placed between the centers, *C C*. The first cutter saws out the stock, the second shapes it, and the third finishes the teeth with a true epicycloidal curve. The pinions are then hardened and tempered and polished ready to go into the watch.

SCREW MAKING.—In Fig. 8 is shown a little machine which perhaps more than any other appeals to the mechanic as exhibiting the very refinement of ingenuity in automatic mechanism. At one point there is fed into the machine a length of steel wire and at another point there issues from it perfect little screws, many of which are so fine as to call for a magnifying glass to discover at which end is the head and at which the thread. The wires enter long cylindrical split chucks, 1, 2 and 3, etc., see diagram, which are arranged on a rotating head. Opposite, and on each side of the head, are two cutting tools, *A* and *B*. At point 1 the screw is pointed; the head then rotates to 2, where the stock is cut off; at 3 nippers draw the screw forward; at 4 a die, *C*, comes forward and threads it; at 5 the screw is cut off, and a plunger comes forward, seizes the screw and carries it over to 6, where the head is slotted; and finally at 7 a wire passes through the plunger and pushes out the finished screw. A stream of oil is directed constantly at each point where cutting is being done, through the curved pipes, *D, D, D*. There are in this department 41 of these really wonderful little machines, and their capacity is 175,000 finished screws per day.

TEMPERING AND BLUING.—All the parts of the watch which are made of steel are carefully tempered, and all of them are drawn to some desired color, in the case of the Waltham watches the preferred color being a dark blue. The heating is done in gas furnaces of the kind shown in Fig. 1. The articles to be tempered are placed in small cylindrical boxes, *B, B*, several of which are packed together in larger cast iron boxes, *C*, of the kind shown at the bottom of the cut, and covered with powdered charcoal, *D*, the latter being used to exclude the air. The boxes are then placed on a little revolving turntable, *A*, within the furnace and kept there until the contents have been raised to the proper heat. The hardness is then obtained by plunging into oil or water. The coloring is done in the apparatus shown in Fig. 5. It consists of a closed sheet-iron case, *A*, in the bottom of which is a set of Bunsen burners, *B*, which play upon a revolving cylinder, *C*. The articles are placed in a loose cylinder, *D*, which is placed within *C*, and rolls within the latter during the process of heating, the rolling serving to expose every piece fully to the action of the heat. The color is determined by the temperature to which the contents of the cylinder are raised.

THE ESCAPEMENT.—Limits of space forbid our giving a detailed description of that most ingenious and delicate part of the watch known as the escapement, Fig. 16. Its duty is to bring to a full stop at regular intervals every wheel of the train, and after a brief period of rest permit it to start again. It has to do this five times in every second or 18,000 times in the hour. It consists of an escape wheel, *E*, with curiously shaped teeth whose top and side edges are so formed as to impart a rocking motion through the sapphire hooks, *C*, *D*, to a lever, *B*, which rocks upon a pivot, *F*. The upper arm of the lever has at its end a slot, which engages a little sapphire pin, *G*, set in and at right angles to the face of a small disk, *A*, which is mounted on the same staff or arbor as the balance wheel. As the arm, *B*, of the lever or "pallet" rocks, it catches the pin, *G*, within the slot above mentioned, and carries it alternately to right or left, giving it an impulse which causes the balance wheel with its controlling hair spring to vibrate in unison with the escapement wheel. The horns, *C*, *D*, and the roller pin, *G*, are made of some precious stone such as sapphire or ruby. The escape wheel is cut by an automatic machine carrying six cutters, and it takes six cuts to form each tooth. The pallet stones, *D*, *G*, are ground to size in blocks of forty or fifty cut to proper length, and shellacked into the pallet. The jewel roller pin is ground with copper laps and then polished with shell laps charged with diamond dust.

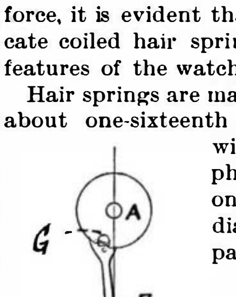
THE HAIR SPRING.—The duty of the hair spring is to absorb the momentum imparted to the balance by



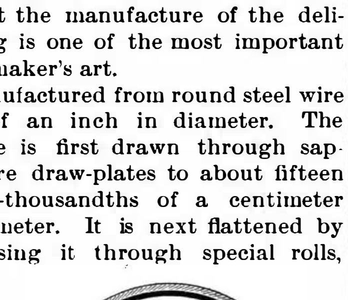
15.—Watch-hand Polishing Machines.

the pallet and fork, bringing the balance to a stop, and then, by virtue of its resiliency, rotate the balance in the opposite direction, bringing the roller pin into position to receive another impulse from the pallet. As it has to do this with the nicest accuracy of time and force, it is evident that the manufacture of the delicate coiled hair spring is one of the most important features of the watchmaker's art.

Hair springs are manufactured from round steel wire about one-sixteenth of an inch in diameter. The wire is first drawn through sapphire draw-plates to about fifteen one-thousandths of a centimeter diameter. It is next flattened by passing it through special rolls,



16.—Fork, Pallet, and Escape Wheel.



17.—Action of Heat on Watch Balance.

and to reduce it to perfect gage, it is drawn through diamond dies. The average hair spring is about nine inches in length. Three of these lengths are wound together inside of a circular bronze box, in which they are heated and tempered, and they are then finished and blued. The springs are next fastened to a brass collet at the center and to a steel stud at the outer end. When the spring is in place in the watch, the collet is fastened to the balance wheel shaft, and the stud to the frame of the watch.

MAKING THE BALANCE.—In making the standard number of 18,000 vibrations per hour the rim of the ordinary balance will travel 3,479 feet, or two-thirds of a mile in the hour, that is to say, about eighteen miles per day. If the motion of a balance should be defective to the extent of making only 17,990 vibrations per hour (only ten below the standard), the watch will lose two seconds per hour, or forty-eight seconds per day—over three-quarters of a minute. Hence we can understand the necessity for making the "balance" live fully up to its name. To make the exact number of vibrations, both its diameter and its weight must bear an exact ratio to the strength both of the main spring and the hair spring, not merely at the time it is inserted in the watch, but under all the possible conditions of service. It is necessary, therefore, that the elastic strength of the hair spring should be at all times invariable. If, for some cause, such as change of temperature, it should increase, the frequency of the vibrations of the balance would increase, and vice versa. Moreover, the length of the spring is constantly changing. It lengthens with a rise and shortens with a fall of temperature. As it lengthens, the frequency of the vibrations reduces; as the spring shortens, it increases. Hence, unless some automatic compensation is introduced, the balance will vibrate faster in winter and slower in summer.

The compensation is introduced by so constructing the balance that the heat which weakens the elastic force of the hair spring serves at the same time to reduce the diameter of the balance, so as to exactly adapt it to the force which the weakened spring is capable of exerting. To secure this end the balance is made of two metals, steel and brass. The arms, *A*, and inner portion, *B*, of the rim (Fig. 17) are made of steel and the outer portion of the rim of brass, the metals being carefully fused together in a special furnace (Fig. 2). The rim is cut through on opposite sides at 1 and 2, the point of severance being located close to the arms, *A*. Now, since the expansion and contraction of brass is nearly double that of steel, it follows that under a rise of temperature the two halves of the rim will be curved inward, as shown in Fig. 17. This brings the center of gravity of the rim nearer the center of the wheel and lessens the degree of force that must be applied to give it a certain rate of vibration. Similarly, under a fall of temperature, the brass in the rim contracting more than the steel will tend to curve the rim outward, enlarging its diameter; consequently, in cold weather the balance enlarges as the spring shortens and in warm weather it grows smaller as the spring lengthens, the compensation being wonderfully accurate. The little screws, *C*, *C*, around the rim serve two purposes. First, by increasing or reducing their number, we can change the actual weight of the balance; second, by changing their position on the two halves of the rim and placing them nearer to or farther from the ends, we can change the effective weight of the rim in respect of vibration. For a screw placed near the supporting arm will not, under the changes of diameter due to temperature, be so effective as one placed near the point of severance of the rim. Hence, by shifting these screws, it is possible to secure a marvelous nicety of adjustment, so exact that, as we pointed out early in this article, a watch can be made that will not vary more than twenty-three hundredths of a second in a day.

To facilitate the turning of the balance, the fine needle-like ends of the staff on which it is carried are borne by small end jewels, *A*, Fig. 13; and the holes in the jewels, *B*, in which the staff turns are rounded. The bearing surfaces are so proportioned that the friction is the same whether the watch is in a horizontal or perpendicular position.

Experience has shown that the best constructed balance may vary from five to one hundred and twenty-five seconds per hour when subjected to the influence of magnetism. Polarization of the parts of the movement demoralizes the sensitive hair spring and balance. In Fig. 14 are shown two hair springs, *A* and *B*, which are mechanically identical. The spring, *A*, however, has been polarized, and the effect when the two are brought near a magnet is very marked. One of the greatest achievements in modern horology has been accomplished by the Waltham Company in substituting for steel as used in the balance, roller, hair spring, and pallet and fork, metals or alloys which are non-magnetic, but which possess the properties of elasticity and expansion in such relative proportions as to enable them to compensate for the varying conditions of heat and cold.

With this brief mention of what may be considered as the last and greatest triumph of the watchmaker's art, we close our description, necessarily all too brief and fragmentary, of one of the most characteristic and successful of our American industries.

BUDDHA'S tooth, presented by the people of Burma to a temple in Ceylon, has been seized by the custom house officers. The relic is inclosed in a jeweled case. The Burmese do not wish to pay any duty, and appealed to the Secretary of State for India for relief.

SCIENTIFIC AMERICAN

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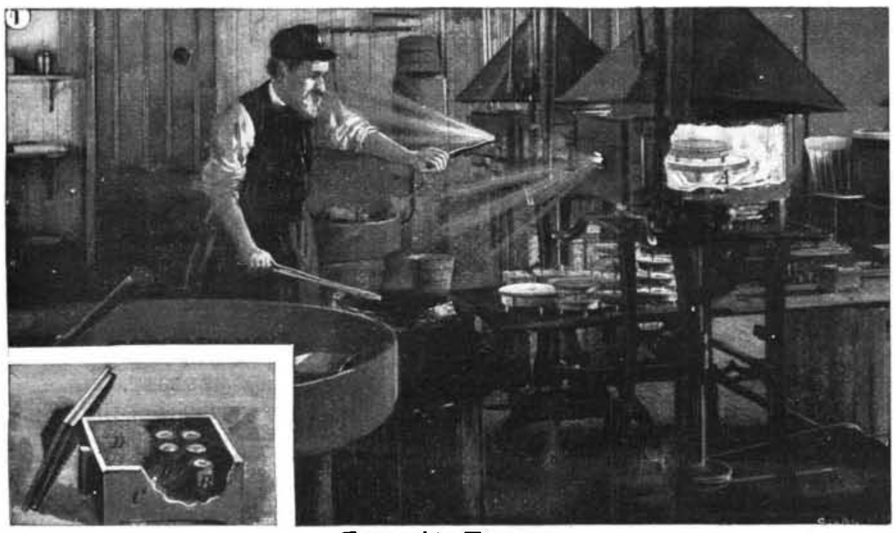
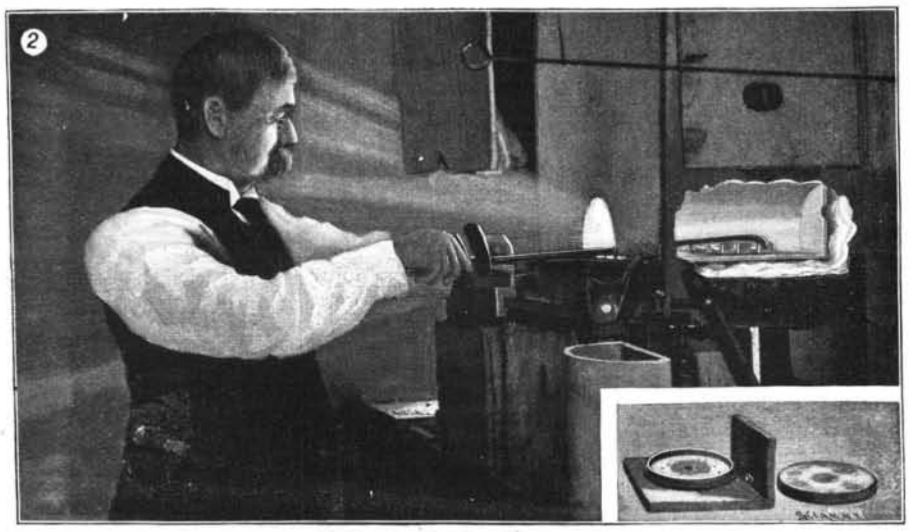
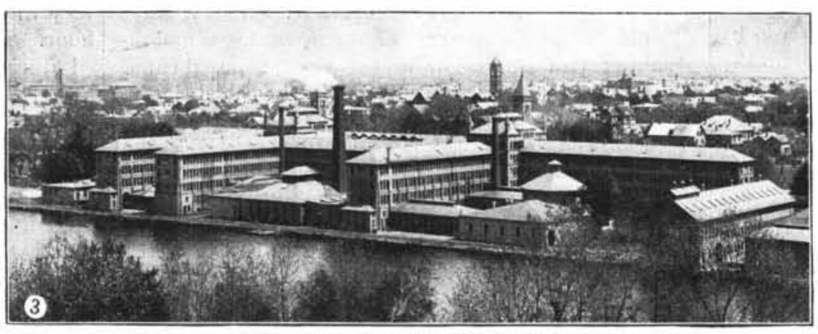


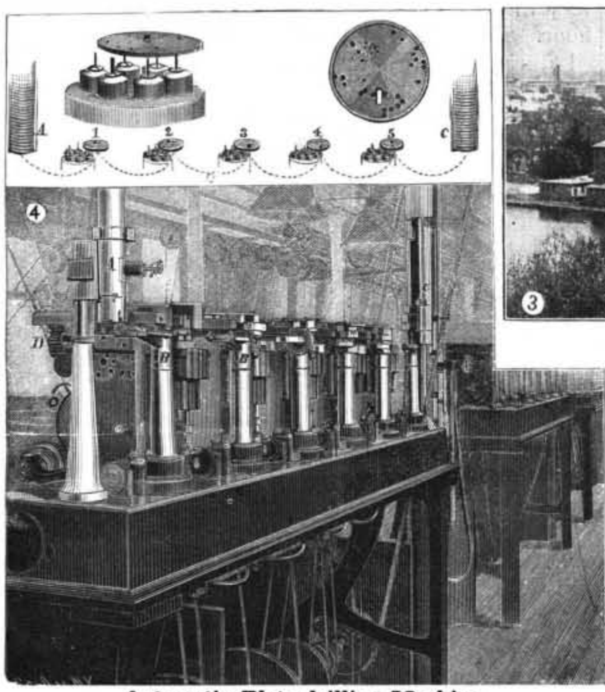
Tempering Furnace.



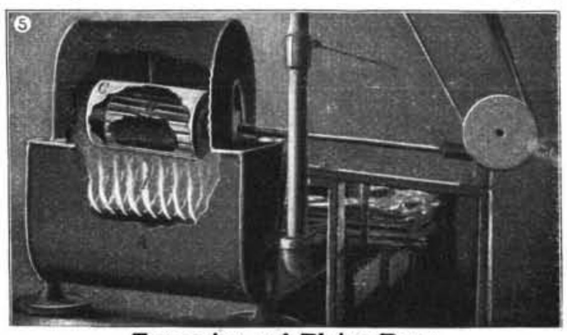
Balance Melting Furnace.



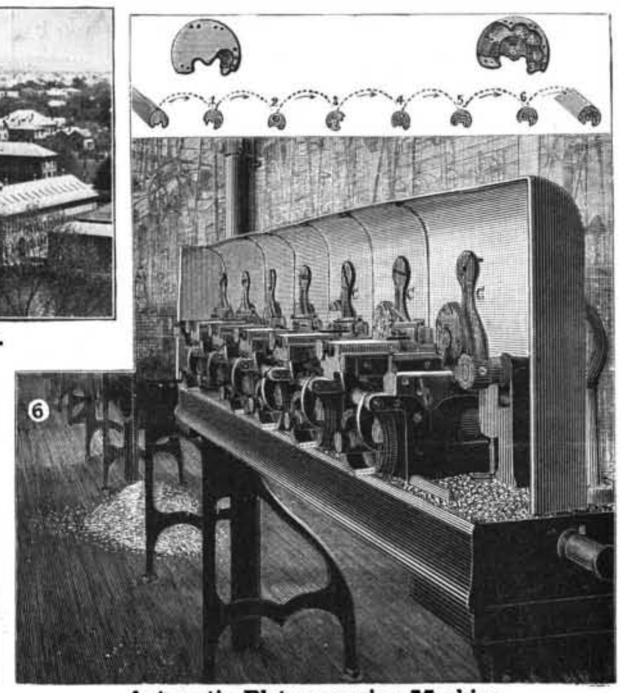
Factory of the American Waltham Watch Company.



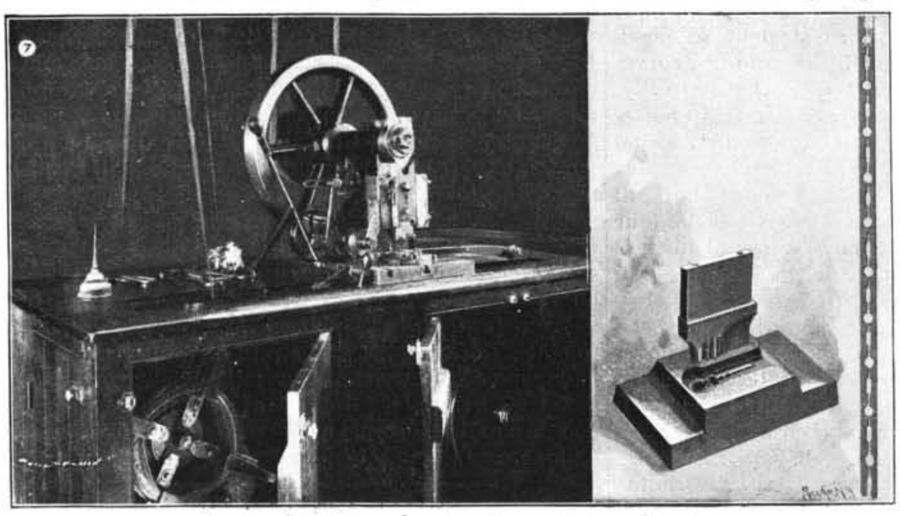
Automatic Plate-drilling Machine.



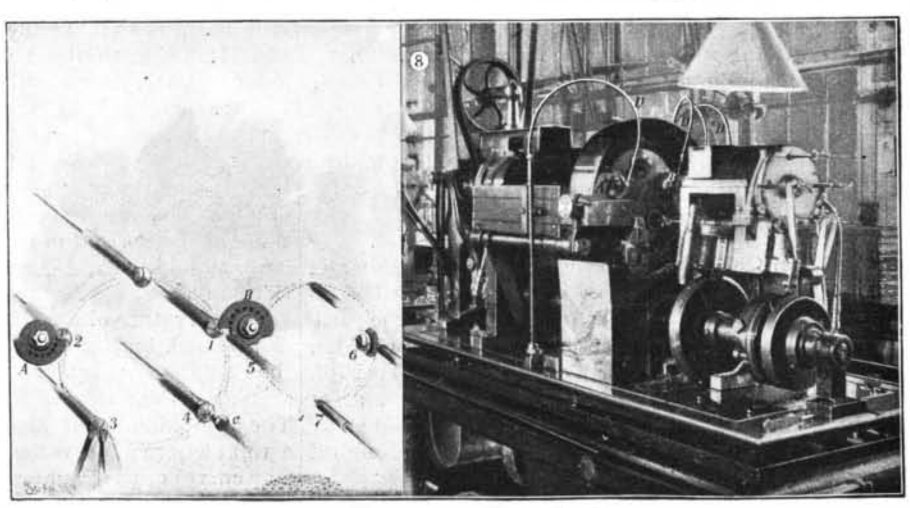
Tempering and Bluing Drum.



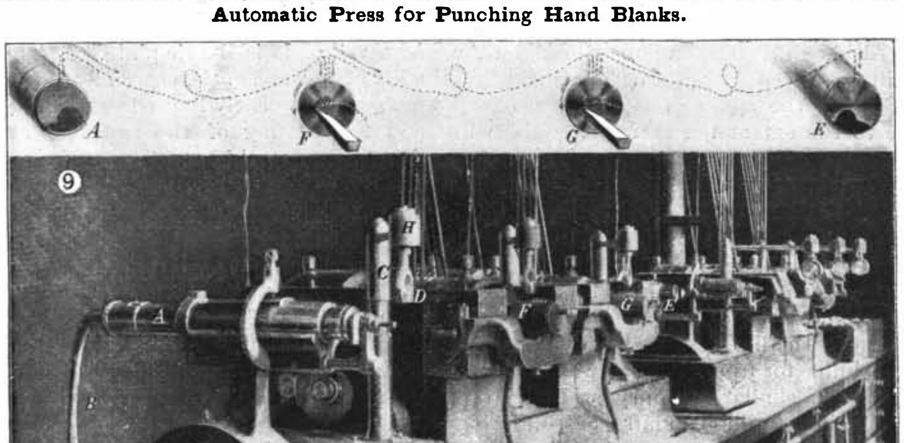
Automatic Plate-recessing Machine.



Automatic Press for Punching Hand Blanks.



Automatic Screw-making Machine.



Automatic Plate-facing Machine.

One of the Departments.

THE BUILDING OF A WATCH.—[See page 132.]