THE AMERICAN WATCHMAKING FACTORIES AND THEIR TOOLS

by Mr. Ch. HOURIET
official delegate of the Swiss Confederation to the Chicago Exhibition in 1893

With 47 figures in the text

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Contents

Note

The pages which follow were written by Mr. Ch. Houriet, of Couvet, delegate of the Swiss Federal Council to the International Exhibition at Chicago in 1893. They are the reproduction of a series of articles, published in our journal, in which the author endeavoured to describe, with a competence that nobody will dispute, the principal machines with which the great American manufactures of watchmaking make the parts of which we know. These articles were considered by us to be of sufficient interest to benefit from being joined together in one volume.

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Foreword

Sent by the Swiss Federal Council to the Chicago Exhibition to give an account of the current conditions under which the manufacture of watches in America is done, of the quality of its products and its means of production, I had, at the time of my departure, no idea of how to achieve my task, because at this time there were only very limited data on the number of American exhibitors; there was even talk of an almost complete abstention of the large watchmaking factories.

I proposed in any case to visit them, and I had consequently drawn up a list of those existing, approximately twelve; but except what I had heard after the Philadelphia Exhibition, and with some information that I had occasionally obtained on their vitality and their products, I hardly knew them.

When I arrived in America, I did not know how I could proceed to fulfil my mandate; however I had in hand my nomination as official delegate, accompanied by a very flattering recommendation from Mr. C. Person Cheney, American minister in Bern; some friends and watch houses of our country had given me introductions to their representatives in the United States, and I had received from the Steering Committee of the *Journal suisse d'Horlogerie* letters of introduction to the principal special overseas journals, requesting them to facilitate my access to the American watch manufactures; these letters were very useful to me.

I arrived in New York on June 4, and, on the following day, I found the occasion to present myself to Mr. Mulford, administrating director of the *Jewelers Circular*, who, with great kindness, was put at my disposal, and led me without delay to the various offices which the American factories have in New York; he had the kindness to introduce me and get for me, forthwith, introductions to the factories themselves, following recommendations from their branch offices in Boston, Chicago, etc.

When I learnt that only the factories of Waltham and Waterbury displayed at the International Exhibition, and also that several others would be closed during July, I decided to start by seeing them before going to Chicago.

I first visited the *Standard Watch Co.*, in Jersey City, then the *Howard* factory, in Boston, where I was received by Messrs Rufus, B. Carr, director, and William B. Learned, superintendent of the manufacture of the watches; a German employee guided me through the factory, showing and explaining to me many interesting details.

After having obtained from Mr. Robbins, one of the chiefs of the *Waltham Co.*, an introduction which he gave me in person, I went to the factory at the hour indicated and was received by Mr. E. A. Marsh, head mechanic, who did the honours for me, and introduced me to Mr. Duane H. Church, the technical superintendent, by whom the factory must, it appears, have the machines regulated.

Also on that occasion I had the opportunity to visit the *American Watch Tool Co.* at Waltham and the *United States* factory.

At the factory of *Elgin*, where I went from Chicago, a clerk gave me a tour of some workshops, and the director, from whom I requested some information on the number of workmen and production, referred me for these details to the office in Chicago.

At the *Rockford* factory, I made an appointment with Mr. A. Guinand, a native of Le Locle, whom I had met at the exhibition. He occupies an important position in this factory, and had, he says, attended a public course that I had given at Le Locle in 1883 and that he had subsequently developed his theoretical knowledge. He presented to me to Mr. Knight, the superintendent, and the chief technical officer, and showed me the details of manufacture which would interest me.

Returning to Chicago, I went to see the factory for watchmaking tools of Messrs *Slaon, Chace & Co.*, at Newark, and the special watches of *Waterbury*, where I met, by chance, one of our Swiss manufacturers who had come to see the mechanic, Mr. Chace, of the house that I have just mentioned, which supplied the tools used at Waterbury. We were thus able to see the factory in detail and with full knowledge of the facts.

In general, I can say that I was well received everywhere, and I thank all those who facilitated my access to these factories. Naturally my visits were more or less long depending on the workshops which they agreed to show me; I am grateful to the heads and employees of the factories who accompanied me and the kindness with which they showed me the details that I wished to know. As much as possible I took advantage of the benefits given to me, but considering the vastness of some of the establishments, the amount of different work involved in the execution of parts such as pinions, wheels, escapements, balances, springs, balance springs, dials, hands, etc, whose manufacture is joined together under the one roof, many details have escaped me; so I can only do a brief review of what particularly struck me, and of the things seen in a particular factory or by supplementing with different details seen here or there.

In some cases, I also make assumptions, but I will not deny you the information as far as they appear acceptable.

On the other hand, I have sought, by frequent visits to the exhibition pavilion of the Waltham factory, to understand the functions of the twelve machines which accompanied the 2,000 movements representing one day's production, and although bringing together the machines, the lack of accessories and their running empty allowed me to understand only some of the functions.

To describe them, I have added to these lines some sketches made from memory, including the parts necessary for comprehension of the text, because a full implementation would have obliged me to make over-complicated drawings; besides, I did not seek to reproduce the exact forms, but only the provisions.

I bought, in the factories which I visited, that is to say in their principal offices, the original types of movements or watches; I chose the newest, while seeking to vary qualities or the sizes. This I could do thanks to the credit which the State of Neuchâtel had placed at my disposal, but it was not possible for me to buy some of the higher qualities, whose prices are fabulous.

Their description will make it possible to realise the progress made and to understand why a particular part is made in a particular way.

General relations between the factories

Certain factories produce only movements, others complete watches with metal cases (nickel, aluminium, bronze, etc); the noble metal cases are made in special factories. In general, the watches are specialities of inexpensive pieces; I only visited the *Waterbury* factory in this category, because its installation, which is relatively recent, must, according to what I heard, be better than those of Cheshire, Trenton, etc.

Factories only making the movement have as their leaders *Waltham* and *Elgin*, of about equal importance, both in extent and in quantity of products: they all have the similarity of the little variety of their products, which are simple movements in four sizes, 0, 6, 16 and 18 *size*. Some, like those of *Howard*, are of 14 size; I was told that special cases are needed for the other sizes of this factory.

If the two first appear to be intent on making movements of the same dimensions in one or other of these sizes, they have other differences: thus the 16 size of Waltham, whose first manufacture was not earlier than 1888, cannot be put in the cases of Elgin; the diameter is larger, and the winding stem is placed much closer to the dial, which makes it possible to make thinner cases.

The prices of these two factories are about the same, and they have agreed to decrease them by increasing the discounts to intermediaries. The other factories are obliged to follow these fluctuations; the prices of the products of *Standard* are even lower, as is their execution. Those of *Howard* are, on the other hand, very high, in spite of a discount of 30% made under the pretext of discontinuance. This factory also makes tower clocks and pendulum clocks.

In addition, there are striking differences between the methods and the means of production; one can characterise them by saying that the factories in Illinois employ the processes of Elgin, and those of Massachusetts use the processes of Waltham; there are, moreover, as in Waterbury, installations set up by independent mechanics.

Everywhere the machines, like all the mechanical products of the Americans, are of a very beautiful construction; but, by their improvements, those of Waltham are better, and from this point of view, its display at Chicago is as interesting to the American factories as it is for ourselves.

This superiority, which I also found in some details of execution of its movements, as in its methods, struck me all the more as hitherto I had only known the products of *Elgin*, that I had always admired and believed better than all those of its American competitors. At the time of my last visit, I was disappointed when I saw the methods that this factory employs, and I can say that, thanks to our immense variety and the improvements introduced since the "look out!" of our delegates in Philadelphia, we surpassed them, not generally, far from it, but, thanks to the momentum, our growth continues, while over there manufacturing remains what it was then.

I naturally make an exception in favour of the machines of Waltham. I will endeavour to emphasise some of the clever designs; but I will say from the start they can only be used for a considerable production, and could be implemented only thanks to the huge capital available to this company.

The mechanics about which I spoke previously also provide Switzerland with machine tools; I could cite factories almost entirely equipped by them. The fact that many compatriots work in the American factories also makes it possible for us to compete on about equal footing.

It is through quality, price and variety of products that we must maintain our reputation and compete with the great American production; since the issue of perfecting manufacture is, as we see it, now a question of working to improve our commercial processes.

Import duties to the United States make it difficult for us to compete with products similar to those of the factories, especially in lower qualities such as lever movements without jewels; but I will note the fact that as soon as they are jewelled, the increase in price is relatively high.

The large American factories now make all the parts which they need, which offers an advantage for the regularity of execution and the ease of assembly; but, on the other hand, they cannot improve them as we do, by the fact of the methods used. Thus they maintain the use of hands of a uniform design; the dials of the better pieces resemble those of lower qualities too much and are not equal to ours: I saw some using colour, or painted and decorated under the flux, on which I could put the name of the Swiss supplier.

In the less important factories, many supplies, main springs, dials, balances, jewels, are bought in from Switzerland or England. I am told that they preferred to buy balances for 0.45 francs, which would have cost 0.90 francs if made on the spot. This is a part relatively difficult to make very well: I found defects in all those which I had the occasion to examine; the screw holes are very large.

I also noted on several occasions, imperfections which I did not expect and which must require a lot of care during inspection. I also heard that what maintained the high prices was the quantity of parts that had to be rejected; the care needed to avoid this waste would give a higher cost price than that which one gets having restricted oneself to using only perfect parts. However that does not appear to me to be always the case, because in unjewelled qualities I saw, for example, the shakes adjusted by the assembler.

Moreover, I attended tests in the grey, such as the adjusting of the arbors between the plates, the enlarging of the pivot holes of the centre wheel by testing them, work done, admittedly, by the mechanical means which the worker has and alows it to be done thoroughly and quickly, but which left me convinced that interchangeability is not perfect, and that the methods of manufacture still require some final improvements.

The preparations for the manufacture of a simple movement and to make all the parts are much more considerable than for us, where we can make most of them in independent workshops, and by using the initiative and experience of qualified people and, when it is a question of obtaining them in small numbers, we can do without mechanical means and replace them by the skilled hands which are common in Switzerland.

This difficulty, as well as the large expenses of setting up, prevent America from making varieties and especially complicated pieces, of which I expected to find some specimens in the process of manufacture, but which was not the case; they even have given up making simple chronographs.

Our current methods, to which we apply the assistance of the machine more and more, thus give us a great superiority over the American watch making industry, and I will summarise my view by saying that that we are “watchmakers” and Americans are “mechanics”.

Description of the factories, their distribution, interior details

The appearance of the American factories varies naturally with their dimensions and the environment in which they are built; however they are generally related to a standard form, a quadrangular building with three floors assigned to offices, flanked by narrower and lower wings for the workshops.

At Waterbury, the central building, dominated by steeple, has a facade with a large arched door giving access to a broad staircase; it almost has the appearance of a stately residence and the climbing plants give to the building a special stamp.

All these factories are built out of red brick; those of Illinois concrete. The floors are high, the windows of the workshops are not continuous, but are separated by narrow piers.

The interior arrangements are very well organized and are distinguished from ours by the finish of the facilities, comfort and even luxury. Everywhere there is much consideration for wellbeing: the spaciousness, the staircases are wide; there are vast cloakrooms, fitted with large hand basins with towels and soap, cabinets essential for cleanliness. Everywhere there is electric light, steam heating and water pipes on the ceilings of the workshops in the case of fire; many pipes are connected to a central pipe and are terminated by stoppers made from very fusible metal. A rotary jet can automatically propel water over a large area.

The workshops are large; there are two lines of benches on each side of a wide central passage, at one end of which is the office of the foreman and assistants, inspectors, accountants and weighers, where the work is received and distributed. Sometimes this office is simply a space separated from the workmen and the machines by an iron balustrade adorned with lattice.

In the middle of the workshop is an enamelled container, with taps and glasses, which contains ice-cold water essential to the Americans.

All the workmen and women have small chairs with backs; where a worker has several machines to supervise, the floor is furnished with rails and the feet of the chairs with wheels, so that the worker can move quickly from one machine to another while remaining seated.

I was struck by the cleanliness of the clothing, and even of the freshness of the workers, always with tidy hair and delicate complexion, and avoiding splashes from the machines by using chest guards and cuffs of white paper.

I do not know the degree of severity in monitoring, but I noticed great order, each one seeming constantly to be at work.

In all the factories, I was shown with pride the engines (horizontal steam engines), running silently and without vibration. In order not to harm the cleanliness of the engine rooms, the boilers are in separate annexes.

In each workshop there are usually four rows of transmissions running the machines placed on the four rows of benches through counter shafts fixed on an axle placed 60 cm above the bench. All run without noise; so is there almost no difference between the workshops that are filled with machines and those for assembling. In addition, each workman has a small milling machine, doing the work which is carried out in our workshops with a fixed graver (adjusting shakes, etc). In Elgin, these machines have a crank and are operated by hand.

Various work; machines and methods

Turning

Except for some parts in which the principle or overall execution differs from ours, I will not be able to go into the details of every tool, but I will describe the work applied to different parts.

As all the factories make their pinions from plain steel, and that they also make their barrel arbors, stems, arbors and screws, the role of turning is very important.

Before describing the various machines used, I will say that making these parts generally involves: the first roughing out and a light final cutting before hardening and, after hardening, other final improvements, such as polishing stems, pivoting, etc

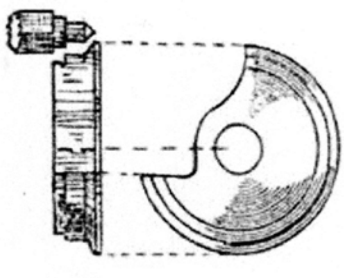

Fig. 1

The machines for roughing out (turning) are similar to the tools used by heavy engineering; some new details are identical, so much so that one wonders which of the two industries, mechanics or watchmaking, used the ideas developed by the other.

Thus, turning is done with shaped cutters, the cutting face having the shape of the part to be turned; these cutters consist of notched discs (fig. 1) which can be sharpened for as long as the development of their circumference allows it. It goes without saying, after each sharpening it is necessary to reduce the edge to the height required by the position of the axis of the work piece; moreover, so that the edge has the wanted cut, it must form a certain angle to the radius, and the centre of the cutter is placed a little above the axis.

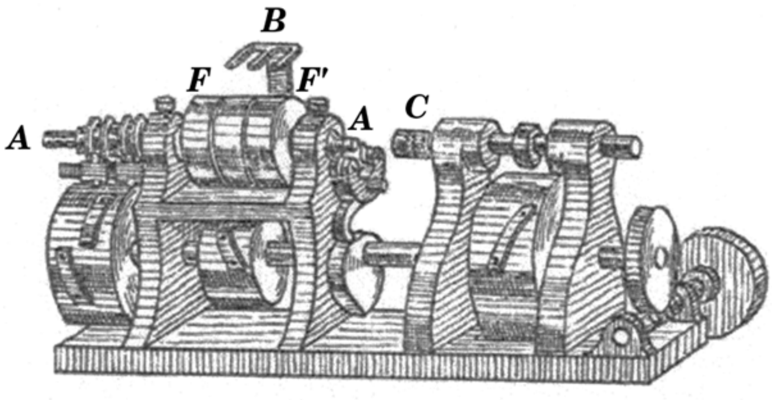

Fig. 2

This work is enough in some cases, to make short screws for example, but it usually requires improvement which I will refer to later on for other parts.

The automatic machines to make screws are, with the elimination of several unnecessary accessories for short watch screws, a reduction of those of the large mechanical workshops, which run themselves.

They are composed (fig. 2) of a bored arbor ***A***, through which the rod passes, and on which are two fixed pulleys ***F***, ***F'***, separated by a loose pulley. Two belts, of which one is crossed, are maintained by a double clutch fork ***B*** on one of the external pulleys and the interior one; the change of position of the fork moving the belts, so that the arbor turns in one direction or the other for turning or tapping.

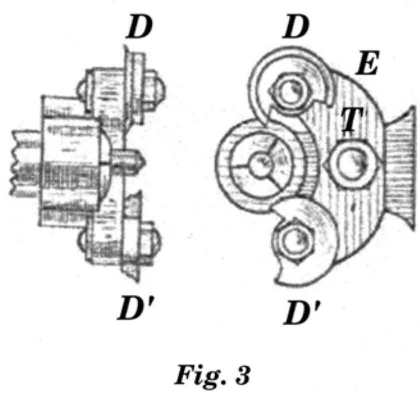

Fig. 3

The gravers to cut off the body and to cut the head behind are circular cutters of form ***D D'*** (fig. 3), and are generally mounted, in small machines, not on a cross slide, but on a part ***E*** swivelling around an arbor ***T*** parallel with the arbor ***A*** and fixed under the headstock. These cutters never work simultaneously, one moving away while the other approaches; each one of them is actuated by a special eccentric (figure 2 shows only one), which advances it to the desired depth and is regulated by a contact screw, against which the eccentric is supported.

The die, mounted on an axis ***C*** (fig. 2) opposite the head of the arbor, is that employed by large mechanics; the axis is brought forward until the screw penetrates the die and is only involved while tapping. Having arrived at the required depth, the die is released from the ratchet teeth and becomes free on its axis; by withdrawing it, it couples with opposite teeth, so that the arbor turns the other way until it gets entirely clear. The cutter placed behind then cuts the head to length, after which the rod advances the quantity needed for making a new screw.

The advance of the rod and tightening are done from behind the arbor by a mechanism which, if not new, is at least little known.

The arbor ***A*** (fig. 4), which must be of a certain size, is bored through all its length and contains two freely adjusted tubes one inside the other. It is closed at one end by a fixed part, ***B***, conical inside and bored with a hole through which the rod passes freely. The first of the interior tubes ends with an external cone, split into three or four parts; this cone, when pressed against ***B***, tightens on the rod. The second tube, simply split, holds the rod with a firm friction. These two tubes extend from behind the arbor and carry the discs ***C*** and ***D***, which have grooves into which penetrate fingers which advance or move back the tubes, independently of each other.

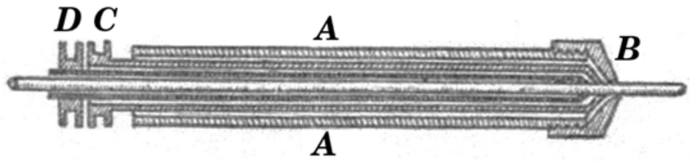

Fig. 4

Here how is it functions: while the rod is held by the chuck of the external tube ***C***, the inside tube ***D*** moves back a distance equal to the length of the part to be made, then the chuck is released by a small movement back and the rod advances with the tube ***D***; the chuck then presses against the external cone ***B*** and the rod gripped again ready to be turned.

All the movements of the die, the fork and the fingers are actuated by bands fixed on drums set on a lower shaft turned by an endless screw. These drums (fig. 5) are an improvement on the use of cams with helicoid sides, the position of the bands ***B***, ***B'***, being adjustable according to circumstances. These machines do not slit the screw heads; that is done separately. The machines at Waltham are mounted on a large plate, and beside the arbor is the apparatus to slit, the screw being taken, at the moment when it would fall, by a grip which transports it in front of the cutter to be slit. This arrangement is similar to that of which the *Journal suisse d'Horlogerie* has already given a description (11th year, page 106).

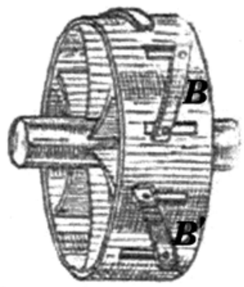

Fig. 5

At Elgin, the machines to make screws are operated by hand. I saw eccentric banking pin screws, for overbanking of the escapement, being made by a worker who put the rod successively in three different machines; one turned the eccentric body, the next threaded it, the third cut it, and the screw was still slit separately.

A machine exhibited by the Waltham Watch Co, being used to make balance screws, therefore relatively small and using easy to work metal, carries out all the operations simultaneously; it is one of most beautiful machines to work metal which appeared at the exhibition.

Instead of only one arbor, there are of them six assembled on a turret (fig. 6) and turning in a large casing ***A***, so that it can occupy six different positions to which correspond the advance of the rod, turning and threading the body, and turning and cutting off the head. Facing this last

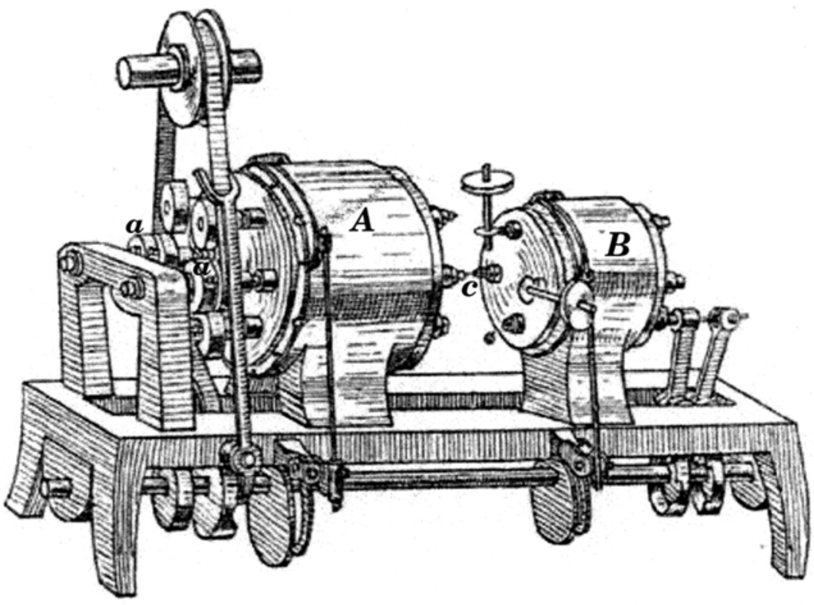

Fig. 6

position is a concentric chuck ***c***, part of another turret of four arbors turning in the small casing ***B***; this chuck seizes the screw by the body and passes it alternately in front of cutters to slit and deburr; in the fourth position, the screw is driven out of the chuck from behind and drops completely finished.

There are only two arbors of the large drum which turn, those shown at the height of centres; on the prolongation of their arbors are two loose pulleys ***a***, ***a***, on which rests the belt which allows the change of notch, then the belt rests on two new arbors. The complication of the accessories did not enable me to draw the various tools, gravers, dies, etc, placed between the two drums, nor to show the many eccentric cams (there are no less than thirteen) actuating all the operations.

As there was no rod in place, it was difficult to understand how it advances, because it should not extend beyond the pulleys of the arbors which pass in front of the loose pulleys ***a***, ***a***, but *une solution de continuité*, indicated on the figure, is furnished with spiral springs, which makes it possible to suppose that this advance takes place by a small longitudinal displacement of the fixed pulleys.

Figure 7 shows a face view of the drums, and makes it possible to understand the various positions of the arbors to which correspondence following operations:

Large drum ***A***: 1 & 2, advance of the rod; 3, undercutting the body; 4, threading the body; 5, turning the head; 6, cutting off the head. Small drum ***B***: 1, screw taken; 2 & 3, slitting and deburring; 4, release of the finished screw.

As all the operations are made during the space of time required by that which has the greatest duration, plus the change of a notch of the large drum, one realises the immense production of this machine, which is equivalent to five machines with only one arbor. According to the inscription which surmounted it, its production is 12,000 screws per day; according to the speed at which I saw it running, I counted one third less for ten hours, which is quite reasonable. One would need four machines of this kind to make the screws necessary for the movements which Waltham manufactures in one day.

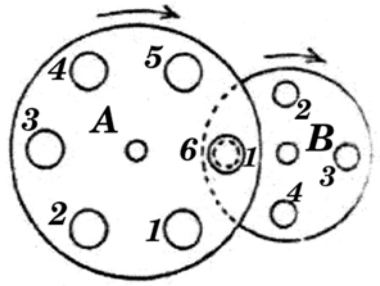

Fig. 7

The pieces, such as pinions, barrel arbors, etc, which have stems on both sides of a core, are trimmed in a special way; either, taken from the rod, they are cut to length on the same lathe, or both ends of the rod are cut in advance, as is done in the factories of Illinois; only one end is done initially, the second being done by tightening the first in a concentric chuck.

When the parts have long stems or several successive stems, or when they require operations for which it is not possible to use only form cutters, there is a graver or accessory holder ***A*** (fig. 8); it is a turret with horizontal axes for three or four tools, such as boring cutters, gravers, drills, etc. The axis of each of these tools can be driven longitudinally; its movement is regulated by a set screw; one, fixed, is used as stop for the advance of the rod which is tightened by hand, the same as the movement of the tools and their selection; the latter is also done by a belt which slips in a throat and actuates the revolver when it is set in motion. For this first work, one does not worry about finish, the stems and shoulders are finished later.

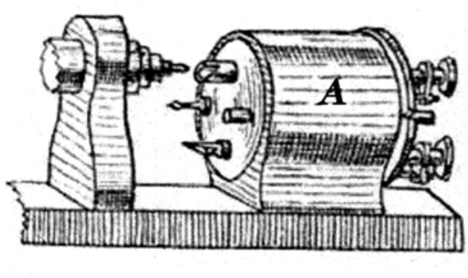

Fig. 8

The machine which Waltham displayed roughs out two ends by two lathes mounted on the same rectangular base; the arbors are parallel, but turn in reverse directions so as to act in opposite ways (fig. 9).

The part, turned on one end and cut from the rod on the first lathe, is taken by an oscillating grip ***A*** which carries it in front of the head of the second lathe; there, it is pushed into the concentric chuck by a mobile tail-stock ***B***. The chuck is actuated from behind the lathe. The part is turned, then once loosened, it is driven out of the chuck by a pin ***C*** which freely passes through the arbor. All the movements are controlled automatically by rods and eccentrics.

A similar machine, seen at the United States, has two parallel lathes, but turning in the same direction; the grip which transports the piece from one head to the other makes, while oscillating, a half-turn on itself.

A large machine, seen in the electricity building at the exhibition, making terminals, which require several operations, had the two arbors superimposed on the same frame; the part was transported from one to the other by a grip fixed at the end of a vertical arbor which had a helical groove on its circumference forcing it to make a half-turn on itself during its descent.

If the provisions of these three machines vary, the functions are the same and their running is very interesting to observe.

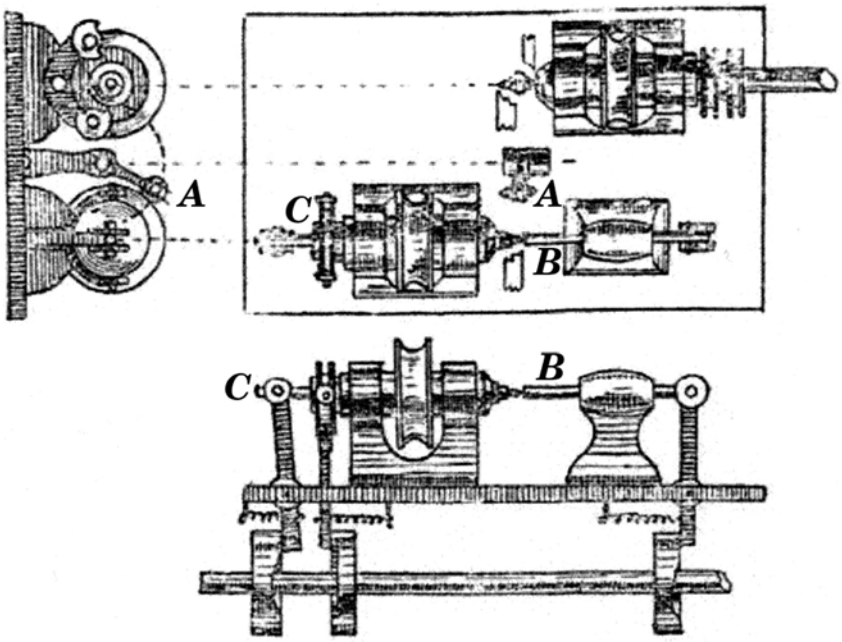

Fig. 9

The finishing of turned parts is very important since some do not undergo any other operations, even after hardening; thus one is restricted to polishing the barrel arbors, the pinion stems of ordinary quality are not even smoothed, etc. This finishing is generally done with machines operated by hand, but with the movement of the graver being automatic, and these machines operate on only one stem; this fact makes it necessary to have a great number of different machines; there are roughly forty doing this work at Waterbury.

Once the part is in place, when the coupled arbour starts to turn the graver advances, following the stem over all its length and moves away to return quickly to its first position.

This automatic movement of the graver is much used. It is also used to form pivots; the slide-rest graver is placed on the bed of the lathe on the opposite side to the worker, who puts the part in place without any inconvenience. For stems the part is held in the air by a concentric chuck; for pivots it is held between centres.

There are small lathes which are useful, if not to entirely form the pivots of escapements (that may be done for those of relatively large pinions, 0.2 mm for 13 lignes), at least to trim them into the form when they will be finished after hardening.

Waltham displayed a turning machine where setting the part in place is done automatically; it has (fig. 10) a series of lathes of which each one turns a stem of a barrel arbor, these arbors passing automatically from one lathe to the next.

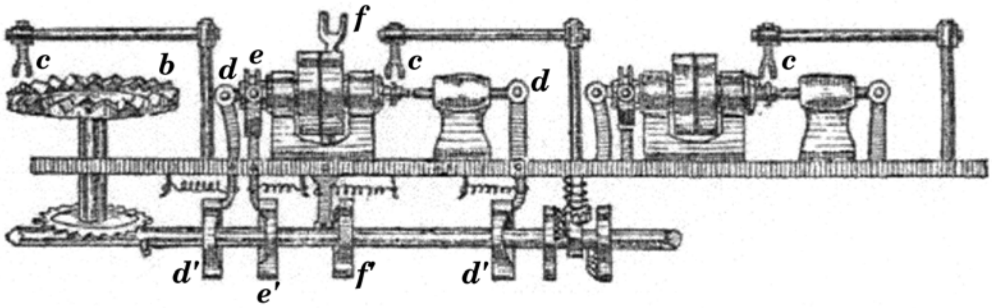

Fig. 10

The parts roughed out by the preceding machine are placed in notches on the circumference of a circular plate ***b***; a spring clamp ***c***, placed at the end of a horizontal arm mounted on a vertical axis, takes one of them and, by a circular motion of the axis, places it opposite the head of the first lathe, where it is set in place, as in the second lathe of the machine represented figure 9. The clamp then returns over the plate ***b*** which, in the interval, has moved so as to present another loaded notch to it.

The part whose stem has been turned is taken and transported from the first to the second lathe by a clamp, similar to the first, which makes a half-turn on itself and places it so that the second stem to be finished is on the opposite side of the core, and so on; there are as many lathes as stems, and when the first part has passed by all the lathes, as all the stems are finished simultaneously, it results in a production much more constant and regular than by hand work. It is enough to take care that the plate ***b*** is always loaded, and especially that the work of the various gravers is perfect.

One sees at ***d'***, ***e'***, ***f'***, the cams which actuate the levers ***d*** operating the spindles of the lathes, the levers ***e*** controlling the concentric chucks and the forks ***f*** of the belts. This unit is a clever but complicated mechanism, because it is a matter of operating the arbors, the gravers, the chucking and the transporting clamps, so that all the movements are done at the correct moments and with least possible wasted time.

The grip which takes the parts to transport them from place to the other deserves a special description; it is made (fig. 11) of two spring leaves ***a***, ***a***, assembled so as to leave between them a space sufficient for the passage of the arbor core; their spacing corresponds to the diameter of the stems to be gripped, that a small bulge maintains in place.

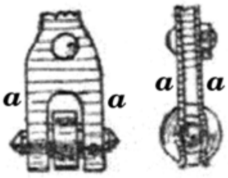

Fig. 11

It is critical in an assembly of machines such as I have just described that, if it is necessary to sharpen one of the gravers or stop one of the lathes, the others cannot function during this time. Moreover, it is difficult to see, at first, when an imperfection occurs in one or the other of the steps, and to disentangle the parts made since the imperfection occurred. The whole thus requires very careful monitoring.

Balance staffs are also finished all over before hardening, and I saw some employing, for ordinary quality movements, pieces where only the pivots had been re-finished and the stems had not even been smoothed. In the better qualities, these various parts are smoothed or polished after hardening by cementing the part, the same part being used to round the two sides. The work of finishing the pivots is done in the air, without our burnishing, on very small lathe, with support by hand; the workmen who do this appeared to be very skilful and to perform this cementing easily. They have in hand a small micrometer to check centring and dimensions.

The lathes which they use (fig. 12 & 13) carry small grinding stones mounted in a carriage fixed on the slide-rest in the place of a graver; it can be moved in all directions.

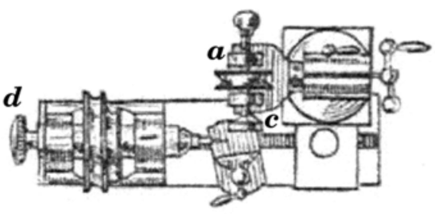

Fig. 12

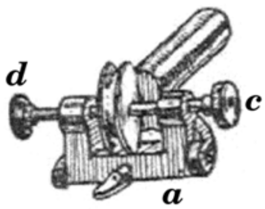

Fig. 13

The grinding stone ***c***, whose face touches the work, is fixed on a small, very mobile axis with a knob ***d*** at one end which is held in the hand.

In spite of the care which one can give to hardening arbors, there must be a tolerance for their finishing; some small differences between measurements of those which I have got prove it. Besides, their cost price, tiny up to the point where they are given to the pivoter, makes it possible to put aside those which, during hardening, have been distorted too much to remain within the limits of this tolerance.

If I have given so many details of these methods of turning and finishing and of the machines assigned to these operations, it is because the principles of this manner of manufacture is rather different from ours. With regard to turning, our processes are, it seems to me, preferable, since our machines generally have a side movement which makes it possible for the graver to move along the length of the stems (Schweizer system), but we do not finish before hardening. However this operation is much more difficult after hardening, and it is this difficulty which the Americans avoid; but in addition it gives a more precise result, because I do not believe that, even for the short barrel arbors and in spite of the precautions taken with hardening, one can avoid any buckling. I had proof of it at the factory at Waltham: I have in my hands an arbor which, when placed between plates, was free in one position and ceased being free when it made a half-turn, which could only come from it being badly out of round; having pointed out this irregularity of play to the workman charged to free these arbors, he was restricted to increasing the play around it without worrying about the cause of this defect.

For a long time we have had independent workshops employing turning machines of different systems, and providing parts of all dimensions and forms to the factories and stores; we can, for example, buy arbors outlined precisely where all the various stems, undercuts, etc, are made, but with dimensions in the diameters and lengths larger than those of the finished part. However these details made in advance become perfectly useless: it is only when the outlined parts have a precise purpose that one can benefit from it; I have seen special parts, where the rough parts had been brought to an almost perfect degree of finish and without increase in price; there was even economy, since less matter had to be to removed, the stems being shorter, and the parts could be made from rods of a smaller diameter.

If one could, not only in current manufacture, but in that of spare and even complicated pieces, prepare the parts from the beginning for their final dimensions, one would be very surprised to note how much useless work can be avoided, and consequently lower the cost price without decreasing the value of the work itself.

The American factories could, thanks to the uniformity of their products, push this preliminary work on their parts to the extreme; I am persuaded that the higher prices of their better qualities is relatively much higher than is due to the extra work done compared with lower qualities, and I would readily believe what I have heard said, that it is the sale of the former which allows the reduction of the price of the latter, in spite of the difference between the quantities sold of one and the other.

Gear cutting

Let us pass to gear cutting. The pinions are made from the full steel and cut, whereas we replaced this method by the use of grooved rods, which undergo consecutive operations, which gives a lower cost price; with some exceptions, this reason made us put the American system to one side. It is necessary, consequently, to give some preliminary details before approaching the description of an assembly of automatic machines, not only for gear cutting, but also for their feeding, such as the factory at Waltham displayed.

The scrupulous exactness of the methods of planting, boring pivot holes, and setting jewels or chatons in the movements, allows the direct cutting of the wheels to the desired diameter and with the final shape for the teeth, without requiring our rounding up.

The cutter and the tools used for its construction constitute the fundamental principle of the care given to the execution of gear cutting. The cutters are similar to our old fly cutters, but, instead of having a single tooth, there are a certain number of them on the circumference; the graver which is used to turn them is a circular form cutter, and the carriage on which it is fixed has a fast movement in and out producing a serration on the circumference which it turns (fig. 14) of which part is removed by milling slits in the direction of the radius (fig. 15). The faces of the remaining sections have the form of the cutting to be made, and they can be reground without changing this form, in spite of the reduction in the diameter.

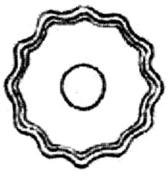

Fig. 14

Fig. 15

The section of the circular graver doing this turning (fig. 16) has the form of a space and on the two sides the form of the teeth of the wheel to be cut; this graver is composed of three assembled discs, that in the middle as thick as the width of the space. Special machines are used to give the epicycloidal form to the interior edges of the others.

As the wheels at Waltham have the bottom of the space rounded, I presume they use cutters of only one part.

Considering their durability, these gravers have a value making their meticulous execution possible, which is very expensive: I had to give up procuring the tools to make the cutter and to shape the discs, because of their exorbitant prices (240 to 250 dollars each).

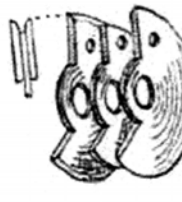

Fig. 16

Because of the amount of work which pinion cutting involves, all the machines work automatically, at least those which I saw. The lathe with tail-stock which carries the piece to be cut is assembled on a slide moving back and forth under the cutter carried by a carriage which enables it to lift up for the return passage; in the machines which the mechanics of Newark provide, the cutter is fixed, and the slide, independently of its horizontal movement, drops, and the lathe goes down to pass under the cutter when returning. In either case, three cutters separated by discs are assembled on the arbor (fig. 17) which, alone or with its carriage, can be driven in the direction of its axis, making it possible for each one of these cutters to be successively presented to the top of the piece to be cut ***P***; thus making three consecutive cuts corresponding to the work of roughing, final cutting and finishing by each fraise.

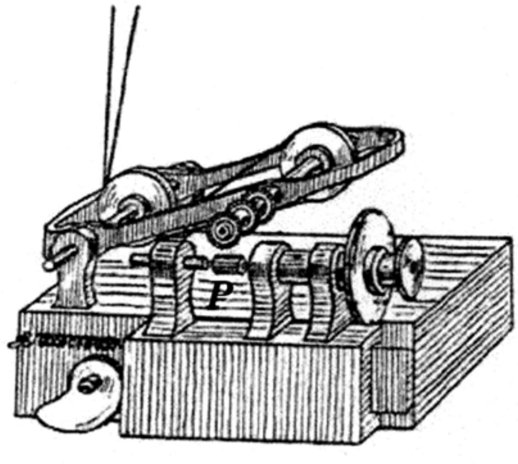

Fig. 17

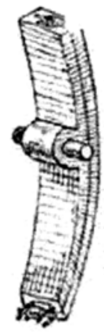

Fig. 18

At Waltham not only are these functions done automatically, but it is the same for feeding, i.e. for the replacement of the cut piece by another to be cut without manual assistance. For that, a tube (fig. 18) of rectangular form, and mobile on two pivots, internally has the shape of the part to be turned; its lower end carries spring leaves similar to those of figure 11, blades which prevent the parts that one puts in the tube at the top from passing out, but by taking them by the points, they can be drawn out one by one. At the moment when the cut part falls, the bottom of the tube moves between the centres of the lathe, which function like those of the machine to finish arbors; the tube, being withdrawn, gives up the part, which is replaced between the springs by the one which follows; thus the worker has only to take care that the tube is always filled.

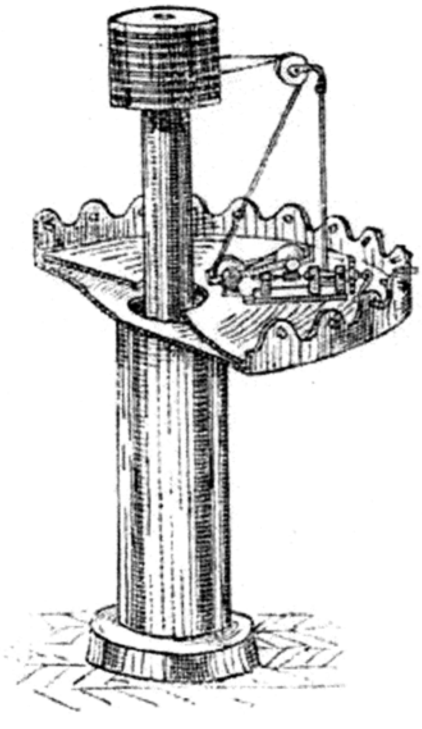

Fig. 19

The Waltham factory displayed an assembly of eight of these machines which, considering its arrangement, seemed to be made especially for exhibition; it was placed in one of the corners of the pavilion, occupying a very restricted space. A fixed circular plate, mounted on only one foot (fig. 19), carried a mobile disc on which were placed the eight machines laid out like the rays of a wheel; this disc turned slowly, making the eight machines successively pass under the eyes. The fixed plate was provided with a vertical edge furnished with notches and pins (the anterior part of this edge has been removed on the figure). Figure 20 shows the position of the pins which, by the action of knee-levers that the machines carry, cause the slides, on which the parts to be cut are mounted, to move in and out from the centre to the circumference of the disc; the change of notch on the divider is produced in the same way.

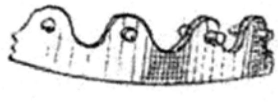

Fig. 20

The machines cut pinions of eight leaves. There are twenty-four serrations carrying pins, thus making three turns for the consecutive work of three cutters to each pinion; every nine serrations, a pin is removed, which allows the change of the cutters, and the twenty-eighth corresponds to the replacement of the part.

According to where one stands near the plates, one sees each machine in passing carrying out one or the other of these operations: it is necessary to move with the disc to follow the action of it. The cut pinions all fall at the same point, at the twenty-eighth serration.

A vertical arbor, which comes from the foot of the plate and which turns much more quickly than the disc, carries at its top a pulley with eight slots in which the cords run to actuate the cutters via counter-shafts placed at heights corresponding to the slots; one of these counter-shafts is shown on figure 19. The movement of this arbor, on which that of the disc depends, is transmitted from under the floor.

This unit is of a really clever design, but, except for the removal of some cams which eight independent machines would require, I do not see the advantage it has over the latter, the production being the same; setting up and adjusting all these functions requires much care, and a waste of time when seven machines are idle while one deals with one of them, because, unless all the system is stopped, it must be followed as it moves round. It is true that each machine has its own feeder, and it is not necessary that they all run at the same time; the case where they function simultaneously to produce identical parts must seldom arise, and, in spite of what I was told, I do not believe that there are several assemblies of this model even in the factory, where I saw many of these machines, but in parallel placed one beside the other. None the less, I admire the presentation at Chicago and the beauty of its execution.

Cutting the winding wheels is done with similar machines, except for the chucks which vary with each part; I did not see any with automatic feeding.

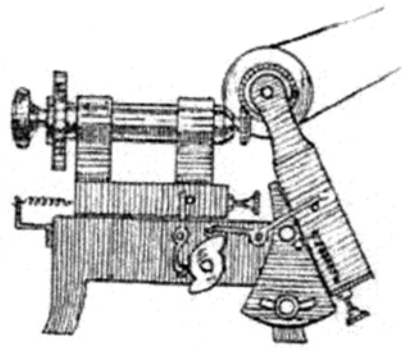

Fig. 21

I saw in a factory, two different machines making the two sets of teeth of the crown wheel; the various slides were operated by hand. Elsewhere, I saw an automatic machine simultaneously making both gears (fig. 21).

The piece, fixed on an arbor carrying the divider, has a horizontal movement to pass the cutter, fixed underneath in this case, then stops in one of its extreme positions; the cutter, assembled on an inclined slide, then moves to cut it in front. The same eccentric cam, via levers, moves the two slides alternately.

The cutting of flat wheels is done with the very small centre hole not being bored or stamped; they are held by the arms and the interior of the rim on a chuck (fig. 22) split into four or five parts, according to the number of the arms; the wheels are adjusted there exactly; a number can be put on to be cut at the same time with cutters (fig. 15) giving the final form.

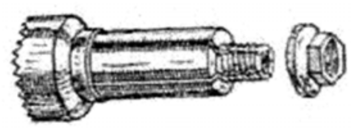

Fig. 22

The escape wheels, which are always made of brass, are cut on machines presenting successively, according to the chuck which carries them, five or seven cutters or knives, each relieving one side of the teeth. The knives, which is to say the rotary gravers, are fixed at the ends of arbors assembled on a turret (fig. 23). Each notch corresponds to the work of a graver; the rotational movement of the arbors is given by a belt on pulleys which is at the end opposite to that of the gravers; the movement of the chuck and the change of notch are made by levers operated by hand.

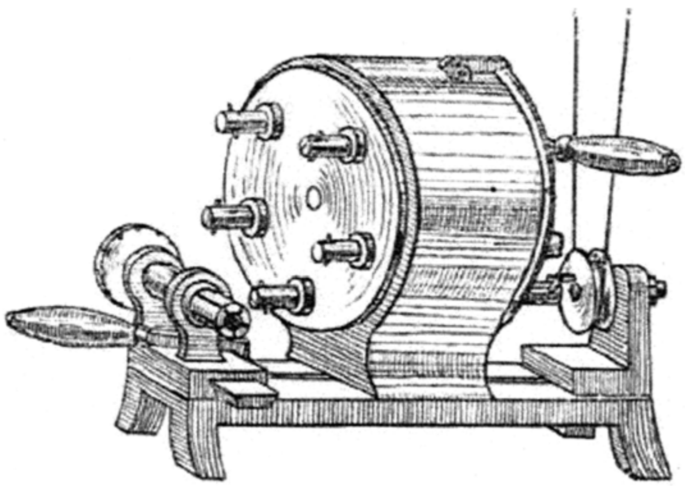

Fig. 23

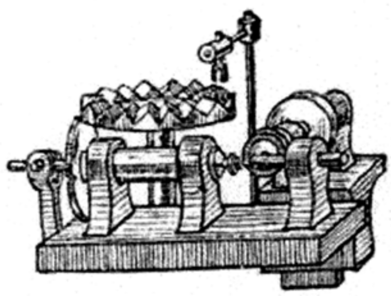

Fig. 24

I saw, to mill snails and the hooks of the barrel arbors, as well as squares, tools and processes which, as in our premises, vary from one factory to another and give the same result. If I speak about the machine to make squares at Waltham, it is because the company displayed one of them in particular, which is the first of the series of lathes for turning barrel arbors. The pieces are placed in a plate furnished with notches (fig. 24), in which a worker replaces them as soon as necessary. This plate is above the machine. The movement of the spring grip is relatively complicated: at the point where the figure represents it, it goes down to take an arbor; its arm then has a small angular displacement, after which the vertical axis drops to bring the arbor in front of the concentric chuck; it then returns to place itself above the piece which, by the change of notch produced during this time by the rotation of the plate, replaces that which has been removed. This spring grip absolutely has the appearance of a bird watching for the moment to seize its prey.

On seeing these different machines with automatic feeding close to each other, I made the remark that by placing them yet closer, one could, since the display machines did not have anything to produce and lent themselves to it, have removed the plates carrying the pieces. The machine to make the squares (fig. 24) would have taken them from the finishing lathe (fig. 10), which itself would have been supplied by the second cutting off lathe figure 9. By adding some apparatuses, one could have seen the pieces being made from one end to another, from cutting from the rod until their finishing, while passing through all these operations without the assistance of the human hand.

These few specimens of automatic feeding simply constitute a first step toward the elimination of mechanical labour, that of feeding by hand, the value of whose suppression will lie especially in the work that it will give to the engineer to conceive it and to the mechanic to carry out the complications; they will require in their turn to have sufficiently intelligent workmen to supervise the setting up and running.

Stamping

At the time when I visited the American factories, the *Journal suisse d'Horlogerie* described, under the authorised pen of Mr. Sivan (18th year, page 5), the process employed by the Americans to make their presses; I thus return to this only to confirm what he said.

Each press is assembled on a block or special die holder, composed of two parts (fig. 25): one, lower, receives the die; the other, higher, carries the punch fitted at the end of a central cylinder which slides in a bearing formed from very fusible metal cast between the block and the punch.

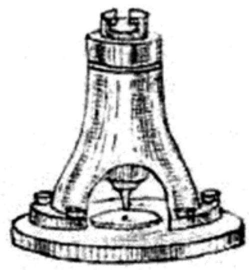

Fig. 25

Once the press is made, these two parts are screwed together and always remain joined, unless one needs to improve or refresh the die.

There are many presses, many blocks, whose dimensions vary according to those of the dies. For the manufacture of just one movement, a great quantity of these presses are needed, and as they constitute the fundamental base to reproduce the same parts constantly, all the precautions necessary for their maintenance and their conservation are taken; thus, at the Howard factory, I was shown a vault with thick and armoured walls, which held all the sets employed by the establishment; this vault is furnished with shelves, filled with blocks on all the circumference, and as each side of the vault is approximately 3 metres, one can imagine the number of blocks which it contains.

The large factories At Waltham and Elgin, which have vast mechanics' workshops, make their own presses; the others get them from the mechanics cited previously. I saw some in preparation at the Webster factory for all kinds of parts, solid or with hollows; I even brought back a specimen of a wheel (for an alarm clock probably) where, in addition to the arms, the teeth are stamped.

In general, the arms of the wheels are very narrow and the rims are very true, which is due to the rigorous mechanical construction of the presses. I had in my hands many of these wheels which, the press having been finished with a grinding stone after hardening, were perfectly identical and rigorously presented the identical division into five the arms, which is essential if they are to fit freely and without play on the chucks of the gear cutting machines.

Stamping is done by means of presses of two different models (fig. 26 and 27). That which figure 26 represents is employed the most; they are of all sizes, with wheels varying from 30 cm to 2 metres in diameter, depending on their use. The wheel is always on the axis which carries the eccentric cam, without intermediary gears. In general, the middle size models are most numerous: I counted up to ten similar ones in the same workshop.

In the small factories, the large models are missing. After enquiring, I learnt that stampings of the large parts, plates and bridges, come from a special factory which provides the raw material for the cost of cutting.

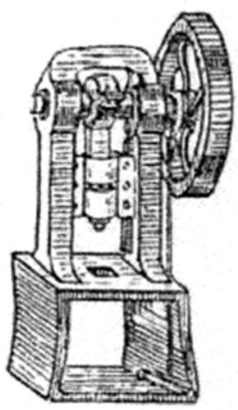

Fig. 26

Fig. 27

The height adjustment is done between the rod and the adaptor by a threaded vertical stem. That of the press represented in figure 27 depends on the position of the core of the rod; this mobile core is itself an eccentric which one can move so that its centre of rotation is further from or closer to the centre of the cam on the arbor, and thus change at will the path length of the rod; an azimuth reading device makes it possible to note the displacement of the core in the rod and to always put it at the same division for the same block; so avoiding the trouble of regulating the height each time.

In both models, the wheel is free on the arbor. It is coupled by means of a foot pedal; thus the workman has his hands free to hold the strip or the part. When stopped, the cam always occupies the highest position of its travel; the rod can be made to descend once by releasing the pedal as soon as the clutch is engaged, or run continuously by maintaining a foot on the pedal.

The number of blows varies, according to dimensions of the presses, from thirty to one hundred per minute.

The few hand presses which I saw, used particularly by the mechanics for tests, have, instead of a beam, a horizontal wheel (fig. 28) whose hole is threaded, and which actuates the screw via a ring carrying a key slipping in a vertical groove in the screw. The lower part of the ring and the upper part of the wheel carry teeth acting one in the other; the variable position of the two parts makes it possible to regulate, within the space of a tooth, the stop height of the adaptor.

Fig. 28

Fig. 29

I also saw a small lever press (fig. 29) operated by the foot and which seemed to me to be used to stamp small wheels.

One also sees in the press workshops small power hammers being used for various purposes. The one I saw working formed the canons of the seconds hands; these canons are made of steel and separately from the hand; they are made from steel approximately 1.5 mm thick, struck by this power hammer, until it arrives at the final thickness, on a succession of flat dies, which have a small recess or a hole preparing the matter which forms the canon, which is still solid. The drilling of the hole in the canon and the stamping of the hand are done later on.

Execution of various parts.

Balances, main springs, and dials are done by processes which differ from ours; they vary even from one American factory to another, so that I will describe only those which interested me.

The starting point for making balances is, in general, the stamping of a steel disc and a brass disc.

The latter is taken in flat, thin metal, and it is pressed so as to form a bowl in which is soldered the steel disc. After the soldering, the superfluous matter is removed from bottom and the circumference, the latter with a punching machine using the hole as a guide.

The methods of recessing, making the arms and turning, differ little from ours.

In general, I found the rims thick, especially in small balances. Almost all are cut. The manner of adjusting them in the round, which done by hand, depends, as in our premises, on the fidelity and skill of the workman.

On the other hand, there are clever machines to drill and tap the screw holes.

Waltham displayed one which is entirely automatic. The balance (fig. 30) is fixed on an arbor carrying a dividing disc, and rotates successively to present at the same place all the positions on its circumference which must be bored. A long slide, which carries a pointed fraise, a drill and a tap, brings each one of these tools alternately to the desired point. The machine stops once a turn is completed, and the balance with all its holes bored and tapped is replaced by another.

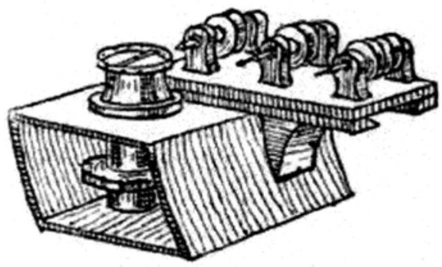

Fig. 30

For main springs, the raw material is prepared in strips from 20 to 30 cm wide, rolled to the desired thickness, and can be 20 metres long. These strips are cut into blades by means of circular shears (fig. 31) made up of an assembly of intersecting discs and mounted on parallel axes like those of a rolling mill; at first glance, this machine resembles a notch rolling mill.

After leaving this shear, the blades are rolled up on reels, the spacing of whose sides corresponds to the width of the blades (fig. 32), and then they pass successively through various machines to mill or grind the edges round, and to draw down the thickness in a sapphire die (fig. 33), as we do it for balance-spring wire.

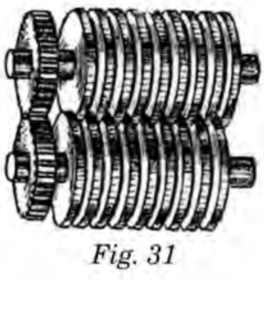

Fig. 31

Fig. 32

From there, the blades are prepared for hardening, in pieces cut to length and finished at their ends, or even in their full length as is done at Waltham. For that, the reel containing the whole length of the blade is put on its pivots in the furnace to which a basin is directly adjacent. The blade, reddened to the desired temperature, passes through the bath to be rolled up hardened on a new reel (fig. 34).

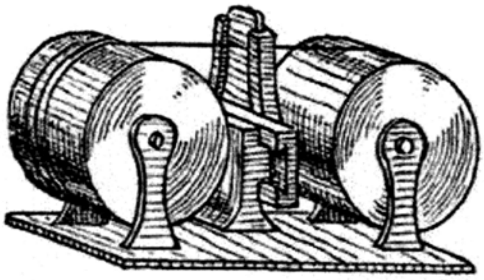

Fig. 33

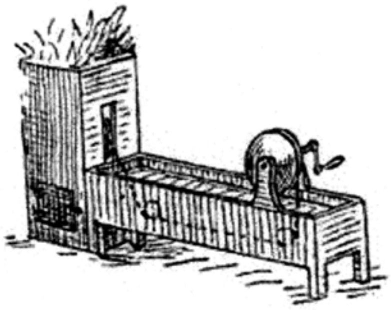

Fig. 34

The rotation of the latter is controlled by hand, according to the colour of incandescence of the blade leaving the furnace; naturally the operation is done in a dark place.

It is tempered by moving the blade past rollers heated by gas (fig. 35). For smoothing and polishing, the apparatus with rollers is similar; the rollers are furnished with leather or felt and polishing matter, and turn in different directions.

Setting the colour is done on the same heated rollers. The heat is regulated so as to be constant, and more or less colour is obtained by the speed of passage of the blade, which is cut in lengths only when completely finished. The drilling of the holes in the ends and their shaping completes the operation.

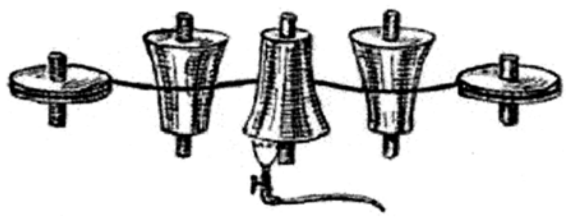

Fig. 35

The springs which I saw finished in the workshop had the outer end bent back, but I did not learn if they keep this form when they were put in the barrel.

I saw dial making only at Elgin, but I believe the processes are similar in the other factories. The fact that the workshop was directed by a French employee enabled me to follow the manufacture from beginning to end.

The copper plates are prepared with a raised edge (pressed); the centre and second holes are made in advance by a cutter.

To charge them with enamel, these plates are placed on screens, which are put on a trolley rolling on a small railway from 2 to 3 metres long. This carriage passes (fig. 36) under a hopper containing the powder, which opens to drop the quantity necessary on the plates below, the carriage passing more or less fast or repeatedly, according to the thickness of the final layer.

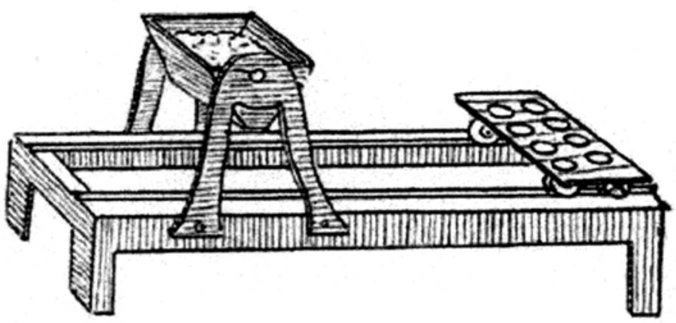

Fig. 36

The baking ovens, served by workmen dressed like kitchen boys, are placed nearby in the same room. The screens with their plates covered with enamel go in whole.

Painting is not done by hand, but by a transfer process. A worker uses a brush to put the colour, black for the hour figures, red for the minutes, on engraved copper plates, having care to leave it only in engraving; these plates are passed to another worker who spreads a transparent liquid over all their surfaces, which gradually solidifies and takes the consistency of blotting paper; so that this matter is initially spread out uniformly everywhere, the plates are put on horizontal platforms which have a fast rotational movement. Once the matter has hardened and dried, it is detached from the engraved plate, and it carries with it the colours which the engraving contained, thus representing a complete dial whose figures and letters are reversed.

Placed on the enamelled plates, by aligning the centre and seconds holes, these false dials, after a light pressure, are removed and leave the painting adhering to the enamel, which is again passed through the furnace to be fixed.

These various operations are done in very little time, and the total execution time for a dial depends only on the intervals necessary for drying and passing through the furnace. The daily production must be immense, and I suspect, unless this workshop makes dials for other factories, that it does not work continuously.

In addition to the small number of sizes necessary, the models are varied a little from the point of view of quality relative to that of the movements; there is be a difference between ordinary qualities and better ones only in the choice, for the latter, of the best dials.

Success depends on the care given to avoid any discontinuity of painting, of the equality of the lines, sometimes more molten on one side than other, the exactness with which the film was placed on enamel, and of the skill with which it was removed; these are dexterities that must be easily acquired with a large production.

Dials that I have seen showed irregularity in the position of the red figures for the minutes compared to that of the black figures, which makes me suppose that their reproduction is not done at the same time.

In general, the holes, especially those for seconds, are a little large and the edges are rainbow-coloured.

Inscriptions on the movements.

American movements are covered with inscriptions: names of the factories, the models, numbers of patents, etc. in English, Gothic and ornamented letters, which appear engraved, but which are reproduced by a process that I also believe is used at home for the marking (*cylinder eight holes*) of the domes of ordinary watches.

The machine used (fig. 37) is generally employed for similar work in hardware and jewellery; the price lists of the large mechanics contain several models of them. It consists of a roller on which the inscriptions to be marked are reproduced in relief. The rotational movement of this roller is communicated to a horizontal slide on which the piece is fixed; the roller is pressed on it by pushing on a pedal actuating a lever. A crank moves either the slide or the roller. The position of the roller, relative to the slide, must be always be the same, to allow successive passages, and to make the marks to the desired depth.

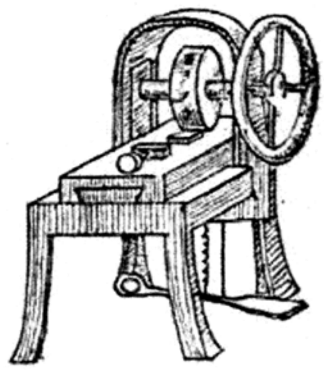

Fig. 37

The machine in itself is simple, but the execution of the relief engraving of the roller must be difficult. I suppose that it is done, or at least that it is prepared on the machine itself, a die stamping on steel being used to mark the roller.

Polishing.

I spoke previously about the polishing of pivots of the escapement by a small grinding stone; the other larger pivots, the stems, the fittings, the shoulders of the arbors, etc, are generally polished by the apparatus known as a *wig wag*, which is one of the many accessories offered with the small lathes for repairers.

This tool (fig. 38), assembled on a counter-shaft of the lathe, is actuated by an eccentric which transmits a back and forth movement to it; it carries at its end the polishing *iron* which presses and rubs on the pivot or stem fixed between the centres of the lathe.

The various edges of this iron, with fins cut crosswise (fig. 39), are used successively as they wear.

To keep it flat, a fin presses on the centre of the lathe.

For changing the piece, the stem is tipped back to rest on the fork ***F***.

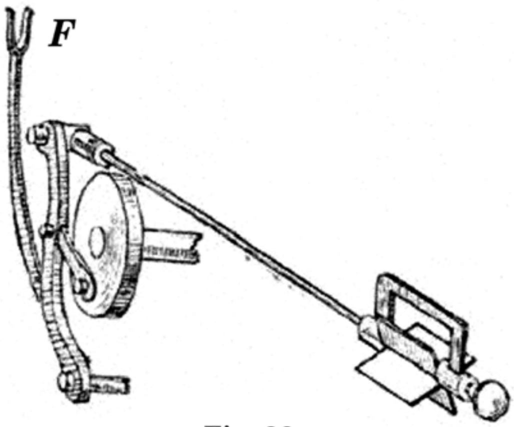

Fig. 38

I also saw composition (zinc and bronze) grinding stones used, whose regrinding was done by means of an abrasive wheel placed on the bench on the side opposite to the lathe (fig. 40), the grinding stone, assembled on a carriage, being able to go from one to the other.

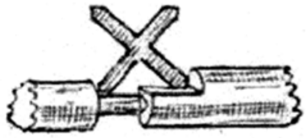

Fig. 39

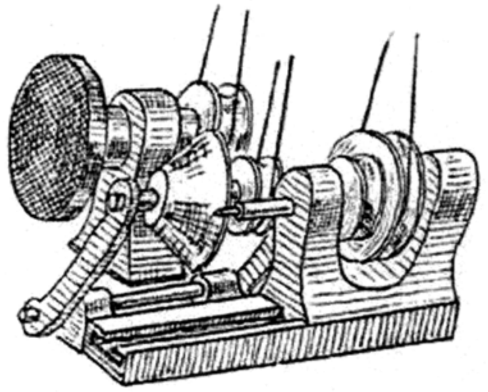

Fig. 40

I did not see the work performed, but it seems to me that the emery dust produced by the grinding stone must be a drawback for the success of polishing.

The house at Waltham had an assembly of machines to polish the leaves of the pinions, where the same wig wag apparatus was used. The leaves of the pinions are rubbed in the direction of their length.

This assembly is made like that of figure 19 (page 14). It has a similar arrangement, i.e. a circular plate with rotary movement carrying eight or ten machines passing successively under the eyes. The movement back and forth was very fast, and the whole attracted attention by its complexity.

One way used in other factories to polish the leaves of pinions, and which corresponds to ours, consists (fig. 41) of using a thin grinding stone of wood whose periphery has helical stripes; one approaches it to the pinion, held between centres, parallel to the stripes which rotate the pinion; the grinding stone is charged with cutting or polishing material.

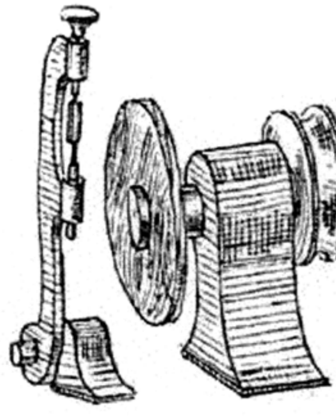

Fig. 41

When one wants to smooth or polish the flat parts, steel wheels, parts of the mechanism, springs, etc, they are always cemented onto round plates, made of cast iron or brass and about 5 cm in diameter. As many pieces are placed one beside the other as the size of the plates allow.

The first side is cut down on an abrasive wheel, then the parts are cleaned and set upside down to make them the right thickness, to smooth them or polish them.

Workers are constantly occupied cementing them and cleaning the pieces to remove the shellac.

The grinding stones for smoothing or polishing are horizontal (fig. 42). The plates carrying the parts are held above; the end of a vertical arbor, mounted in a carriage, supports them on the grinding stone while making a movement from the circumference to the centre.

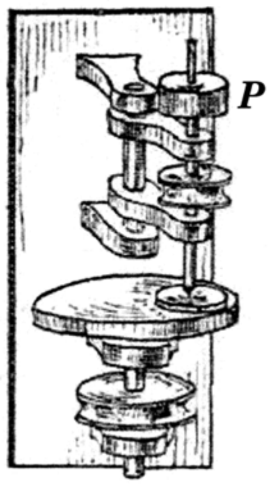

Fig. 42

A weight ***P*** fixed on the arbor, mobile vertically, provides the necessary pressure.

The screws with flat heads are polished in the same way, by cementing numbers of them on plates with holes for the bodies.

Generally, the tops of the heads are polished with a bevel; they are held by the body in a chuck; the polisher moves back and forth resting on a tilted stop which gives the small angle desired.

A polishing machine for screw heads, shown by the Waltham factory (fig. 43), has a turret on a horizontal axis, resembling that of figure 6, page 9, and having the same mechanism for change of notch. It carries five arbors, of which four turn simultaneously by the effect of a belt embracing their pulleys.

These arbors occupy alternately five different positions, to which correspond the deburring, trimming, polishing, etc; the fifth, stationary (higher position), must correspond the replacement of the part, which I could not understand at the exhibition, the various tools which should have functioned in front of the arbors not being complete.

In a machine with a different arrangement, seen at the factory, the screws were cemented lightly by their heads on a plate which presented each body, one after the other, to a revolving, threaded chuck. They were released from the cement as soon as they were screwed home.

Manufacture of the movement.

I include under this heading the execution of the parts forming the frames, that is the plates and the bridges, by the operations of turning, recessing, milling and drilling, which are done in workshops similar to those of our ébauche factories, but with a degree of finish which we ourselves have only reached in the last few years.

After being pressed out, trimmed and brought to thickness by means which do not differ much from ours, the starting point of the later operations is the drilling of the holes which will be used as reference points to place the parts on the machines.

These holes are generally stamped. There are usually three of them on plates; however the Rockford factory uses only two.

The drilling of the other holes, for screws and pins, is done with plates used as guides (gauges), of which all the holes are furnished with tempered steel canons; the plate or part is held under the gauge by pins entering the reference holes, or by shape for some bridges.

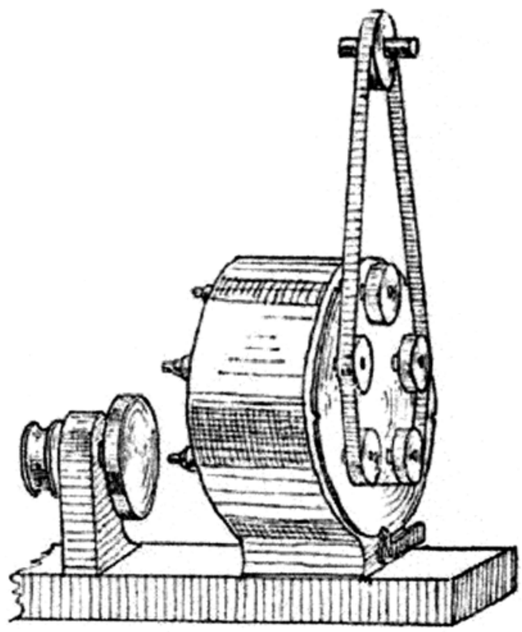

Fig. 43

Drilling.

The drilling machines generally have several drills assembled on parallel vertical arbors, which can be brought successively above the vertically mobile platform which is actuated by a hand lever.

The multiple arbor drilling machine is much used by mechanics; I saw ones of all sizes at the exhibition. The manufacturers of electrical appliances even showed some in which several drills (twenty-four) worked at the same time; it goes without saying each arbor of which can move to drill the hole in the desired place, on the same plane surface.

The use of drilling machines with various drills is almost necessary for drillings to gauges, to make it possible to bore holes of variable sizes without removing and replacing the pieces under the gauge for each one.

The use of the gauges requires drills entering the holes exactly and sufficiently long to go through the piece below the canon. The straight drill, having the shape of a half-cylinder, or that milled helical, is essential to allow the release of the chips.

The Americans make the latter very well in all sizes; however the former, known as *canon bits*, are more generally employed in watchmaking.

At Waterbury, all the holes in the plates and bridges, including those of the train pivots, are stamped out; it should noted that the plates are very thin (two are superimposed to obtain the desired thickness), and that the feet of the cocks are only bored after they are cut off.

The three train holes, which are reasonably large, are not stamped out at the same time as those of the screws and the pins, but only when the recesses for the shoulders are milled to the final depth.

Recessing and milling.

In addition to the recesses themselves, all the hollows, undercuts and countersinks for the plates and bridges, are generally done with gravers; I seldom saw cutters used, even for recessing bottom plates for the parts of mechanism.

All the hollows are done on centring plates, on which the pieces are fixed by the guide holes or the shape for some bridges.

For each hole in the centre of a recess or a hollow the plate is fixed in position on a face plate which carries, in addition to the dogs and the collets necessary, a counterweight to balance the lathe and prevent vibration. For this the plates are even sometimes entirely recessed into the face plates.

If one counts the number of recesses or turnings which a simple movement requires, one will not be surprised by the number of face plates in a set for a lathe, and which fill a rack placed near the tool. It even seemed to me that at Waterbury there was a lathe for each recess.

I do not know if the recesses are made with several gravers; they all have a small bevel, but those which I have seen are not smooth enough to have been retouched: the lines of the graver can be seen under the nickel plating.

It is known that in the movements with two plates with pillars, in spite of the perfect similarity of the top and bottom plates, one cannot make them correspond exactly; that probably comes from one or other of the necks of the pillars being out-of-round or the play which they have in the holes, which moves them during riveting, etc. To avoid these defects, I saw, at the Howard factory, the holes for the pillar plate bored on a lathe, to adjust the pillars and to work their upper ends with a single centring.

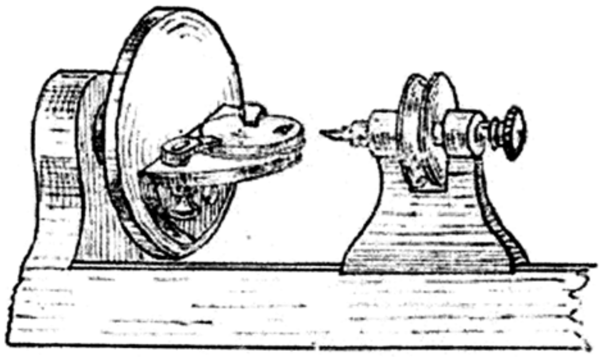

Fig. 44

For the movements with rocking bar winding, where the hole for the stem is between the bracket and plate, I saw these holes being bored on a lathe. The platform carries (fig. 44) a square on which the plate is fixed horizontally and turned at the same time as the cutter, but in opposite directions.

This prevents deflection of the drill, but this plate attached square is not easy to make.

Planting.

All the operations are done on plates and bridges without any holes for the mobiles being bored, nor even marked in advance, this work being done later once the parts of the frame are assembled.

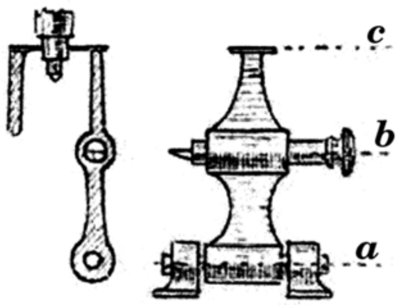

Fig. 45

The holes are drilled from above and below on lathes called planters with a tool to measure the stems, which has (fig. 45), instead of the slide rest, a carriage on which the fixed graver is placed at ***b***, at half of the distance which separates the beaks between which the piece measures itself, at ***c***, from the centre ***a*** of pivoting of the carriage.

Thus the hole made by the graver has a radius equal to half the diameter of the measured piece, arbor stem, wheel pivot, centre chaton or jewel.

These lathes also have a second tool which is used to create the end play; the piece, supported between two parts of the fixed graver, advances the graver more or less to more or less deeply cut the support of the shoulder or the bottom of the recess of the chaton. Also, the face plates have not only their special platform, but the arbor of the lathe has its bearings adjusted in a steel casing which is fixed on the top part of the headstocks.

Each arbor has its special method for holding the parts, which generally includes a second mobile platform behind the first; by operating it one makes the dogs rotate to bring them on the part, on which they press by a movement from behind.

Considering the number of mobiles in a movement, the different arrangements of the dogs for each one of them and the work involved in making the various arbors, one will realise the price that it must cost for a lathe for only one calibre.

The holes are cylindrical; it remains to give them a light reaming. That is done by means of a similar machine to a horizontal drilling machine, in which a broach occupies the place of the drill. The piece is placed on the platform without tightening, and the workmen lowers the reamer until the pivot that he tests enters freely. A screw stop on the vertical slide makes it possible to regulate the descent.

I also saw tests of the play of barrel arbors between the plates; the workman added side play by means of a small vertical milling machine, which one also sees in the workshops of the assemblers, where it is sometimes moved by hand using a crank.

For these tests in the grey, the top plates are screwed on the pillars, but to avoid the trouble of using a screwdriver, the workmen who do this have small knobs whose threads corresponds to those of the pillar screws.

The parts which were measured for drilling the pivot holes remain in the work boxes with the frames, and are probably numbered at this time, all the parts of an American watch carrying the whole or part of the number of the plate. I also learnt that a note is made in an *ad hoc* book of all principal measurements of the parts, the diameters of the pivots and jewel holes, spacing of the shoulders, etc., so as to be able to replace a part lost or broken without having to resort to the movement; the repairer only has to send the number to receive a similar part (?).

Before being distributed to the work boxes, the various parts, arbors, stems, pinions, winding parts, ratchets, etc, are received by examiners who inspect them and then give them to the store, where they are placed in glass bottles, a very practical method which, independently of any other control, makes it possible to see what is the provisioning one part or another.

I would have wished to be able to give an account of the tolerance allowed in various measurements at the time of this inspection, tolerances for which the aim of perfection of the methods employed is to reduce as much as possible, but which, in spite of that, cannot be a negligible quantity: there are too many elements to consider, in a pinion for example, like the thickness of the leaf, its shape, the diameter of the pinion before and after polishing, the diameters of the pivots and the heights of the pivoting, to guarantee them all perfect.

The tests in the grey are only partial, and only for the parts which are fitted in the top plates, three quarter plates or bridges, which carry the number of the bottom plate and go through smoothing and nickel plating or gilding which must remain fresh. On this subject, I will say that, while we use a very simple smoothing for the nickeled American kinds, I noticed that the Americans themselves make them very embellished.

Gilding is done by a special process called “by the brush”, without preliminary graining, and which appeared me to have a brilliant shine.

The assembly workshops are generally placed on the higher floors, in order to be well lit, and also have a double line of benches, those of the second row being especially occupied by workers who do the first assemblies, mounting the lower parts, the trains, the barrels. They do not employ a mainspring winder to put the springs in the barrels: they are given to them in rings a little smaller than the barrels, which enables them to put them in directly without unrolling them.

The benches are very high and on two levels, the lower being mainly used to put the work boxes. In general, the workers seem to work rather on that than on the bench; I noticed they are very skilful.

The workmen of the first row reassemble the escapements, the mechanisms, dials, hands. The escapement fitter-adjusters, who install the balances, are in a special workshop, containing the lanterns, ovens, etc, necessary for the observations for adjustment to positions and temperature.

At Waterbury, the finished watches are placed on large tilted boards.

Each factory also has a repair workshop to replace the parts returned by watchmakers. That of Rockford is directed by a compatriot and employs several Swiss workmen; French is spoken there especially.

Adjustment.

This is for us one of the most interesting parts, considering the methods of the Waltham factory, which displayed the machines that it employs at Chicago. There, especially, one finds the application of the principle which is used as a basis for all American manufacture: “to facilitate the details without being dependent on the greater or less ability of the workman”.

The Waltham factory now makes all the adjustments of the Breguet spiral spring by a special process, “bending before hardening”.

It is understood that the diameter and the weight of the balance, the section of the balance spring blade and its length, are determined in advance as exactly as possible, so that making the curve does not inordinately shortened or lengthen the definitive length. This preliminary work already simplifies what constitutes adjustment itself.

The parts constituting the assembly of the balance spring with the balance, the fixing of the collet and stud, are each done by a special worker: the first does nothing but pin the balance spring to the collet and cut the ends of the pin which is provided to him finished; the second levels and centres the balance spring, which only then is adjusted by a machine.

This consists (fig. 46) of three apparatuses ***a***, ***b***, ***c***, all quite similar, which are used: first, to classify the balance springs according to the number of vibrations which they give with a standard balance; second, to classify in the same way balances against a balance spring; and third to determine the length of the blade, the balance and the balance spring being joined together.

These apparatuses are automatic meters. They are independent of each other, and each one has a special movement having its engine (weight or spring), with a large and small hand assembled on the axes of the mobiles, an escapement and a balance axis whose end rises up under the brackets.

This end is arranged so that one can fix at ***a*** a balance spring, at ***b*** a balance, and at ***c*** a balance riveted on its axis and carrying a balance spring.

With the apparatus ***a***, under the table the axis carries a balance of a given diameter and weight; the a balance spring to be tested is held at its end by tweezers, as with our vibrators.

While stationary, the two hands are on zero: it is started by the lever at ***d*** which acts on the cam ***e***.

It rotates in a fixed amount of time, then the lever engages in the notch and the movement stops instantly. The two hands then indicate the number of vibrations that the balance spring has made during this time, and it is classified and put in a numbered rack.

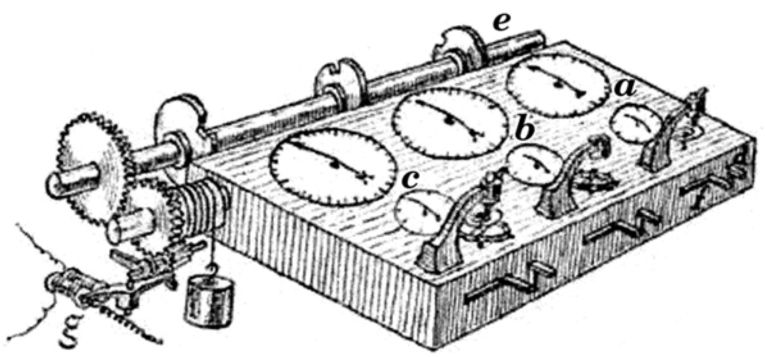

Fig. 46

The same operation is done for balances with the apparatus ***b***.

One then chooses from the rack balances and balance springs which will definitely go together, by taking for example a balance which gives two vibrations less than the desired number and a balance spring which makes two more of them. This balance, provided with the balance spring, is fixed by a small grip on the axis of the apparatus ***c*** where, after some tests, the worker, by giving more or less length to the blade. will be able to make it beat the desired number of vibrations as indicated by the hands. He marks the blade at the place where the stud must be attached.

Before each operation, the hands are brought back to zero on the dials, like those of a stop watch, using the lever ***f***. The accuracy of their indications depends on the rotating cams; for that, the axle on which they are fixed by friction is moved by a weight which runs a train ending in a flirt which is released automatically every second. The regularity of this release is controlled by the seconds pendulum of a precision regulator which, while running, opens the current of an electrical circuit magnetising the reel ***g***.

Whatever the number of cams moving or at rest, the arbor makes each rotation in rigorously equal time.

At the factory, a certain number of apparatuses ***a***, ***b*** or ***c*** are joined together; a worker has fifteen of them to supervise.

The balance spring is attached to the stud by means of a small tool that the worker holds in one hand; the balance and the stud are held in the position that they occupy relative to each other under a cock; the balance can rotate so that the balance spring can be put in the hole of the stud without twisting the it, and without having to worry about putting it out of flat or eccentric.

If, after the operation of counting on the machine, the perfection of the adjustment is not sufficient, it is fixed by the timing screws which the balances carry, they often have four of them.

It is understood of course that the balances, which are always cut, have been put round and poised before they are put in the apparatus ***c***.

I have also seen these operations being done by hand as in our premises.

Production, sizes, prices, types, qualities and details of construction

For these various points, I refer the reader to my report on small mechanics, chapter XIV, pages 67 to 71. (*Rapport concernant la petit mécanique et les applications à la fabrication de l'horlogerie aux États-Unis d'Amérique*, by Mr. Ch. Houriet, official delegate.) I supplement the details which it gives by a sketch (fig. 47) of the special design of the barrel at the factories of Howard and Waltham (penultimate paragraph, page 70), a design which avoids the use of an arbor with core in one piece. The teeth are carried by a canon wheel; it is driven onto a ring which replaces the core. The arbor passes freely through the canon and has two squares at its ends: one, at the top, carries the ratchet fixed by a screw, the other, at the bottom, fitting on a steel drum independent of the teeth.

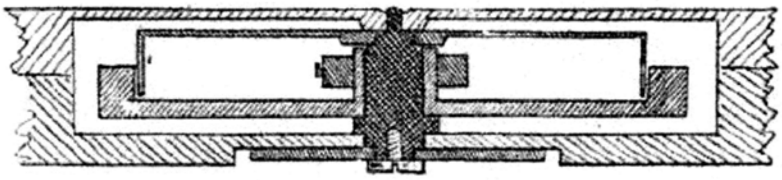

Fig. 47

So if a shock occurs by the unhooking or breaking of the spring, the latter is the sole support.
