STANDARD TIME AT A MODERN WATCH WORKS.

AMONG the many fields of industry in which hand labor has been superseded by automatic machinery, there is none in which the change has been so strikingly complete and successful as in that of the manufacture of watches. That the machine-made American watch of the higher grades can attain as high marks for time-keeping as the finest products of the skilled watchmakers of some of the older countries of Europe has been proved by tests at the National Laboratory, London. This fact is the more remarkable when we remember that the Waltham Works, from which the test watches referred to were selected, is turning out watches at the rate of nearly three thousand per day.

It is not our intention to describe, just now, the wonderfully complex and ingenious machinery by which the American watch is made; that is a long and deeply interesting story in itself. The present article will show how one great, modern watch works maintains its own private standard of time, for the guidance of the workmen in the various rooms of its vast establishment, in regulating the watches that are turned out at the rate of so many thousand a day.

The possession of some Standard of Time must be reckoned as one of the absolute necessities of the highly-developed life of to-day. Every man's watch is his own particular standard. In case of doubt as to its accuracy he refers to some other higher standard, such, for instance, as a public clock or the chronometer in some watchmaker's window. In case these higher standards should disagree, it is necessary to go to some ultimate standard, superior to all of them. The ultimate standard in the United States is the time determined at the Naval Observatory, Washington; and this is referred to the transit of fixed stars across the meridian, which is a time which never varies, and therefore is the absolute standard.

Many years ago the Waltham Watch Company realized that it would be to their interest to get as closely in touch as possible with the prime source of time, which, for them, would be the transit of any celestial body, preferably a fixed star, across their meridian; and acting under the advice of the late Prof. Rogers (at that time connected with Harvard Observatory, Cambridge), they built in the works an observatory, and put in a transit of the size and form that is standard in the Geodetic and Hydrographic Surveys. In connection with the observatory they also constructed a clockroom, in which they placed two master clocks, which were designed specially for the purpose by the superintendent of the works. As far back as the forties the longitude of Harvard Observatory from Greenwich had been established by taking the mean time of forty box chronometers. At a later date this longitude was verified by means of cable connections between a chronograph at Greenwich and a chronograph at Harvard University, connected by the transatlantic cable. In 1880 the longitude of the Waltham Observatory from Harvard was similarly established, by means of two electrically-connected chronographs.

As the plant of the company increased in size, the vibration of the heavier moving machinery, that was transmitted through the earth to the clockroom, caused perceptible variations in the time of the two master clocks. It was decided, therefore, to build the new clockroom, of which we present several illustrations, install within it the two master clocks, and add a sidereal clock. The room was completed early in 1904 and is now running, as we shall show later in this article, with exceptional results as to accuracy.

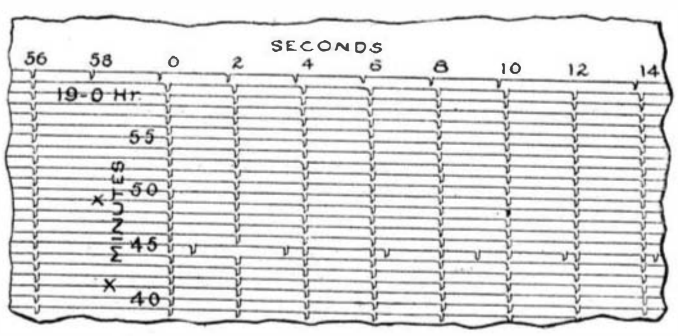
Thermostat for Regulating Temperature of Clockroom.

The clockroom, which is located in the basement of one of the buildings, is built with a double shell of hollow tile brick. The outer shell rests upon the floor of the basement, and its ceiling is within two or three inches of the basement ceiling. The inner shell is 10 feet square and 8 feet in height, measured from the level of the cellar floor. There is an 18-inch space between the walls of the inner and outer shell and a 9-inch space between the two ceilings. On the front of the building the walls are 3 feet apart to accommodate the various scientific instruments, such as the chronograph, barometer, thermostat, level-tester, etc. The inner house is carried down 4 feet below the floor of the basement, and rests upon a foundation of gravel. The walls of the inner house below the floor level consist of two thicknesses of brick with an air space between, and the whole of the excavated portion is lined, sides and bottom, with sheet lead, carefully soldered to render it watertight. At the bottom of the excavation is a layer of 12 inches of sand, and upon this are built up three solid brick piers, measuring 3 feet 6 inches square in plan by 3 feet in height, which form the foundation for the three pyramidal piers that carry the three clocks. The interior walls and ceilings and the piers for the clocks are finished in white glazed tiling. The object of the lead lining, of course, is to thoroughly exclude moisture, while the bed of sand serves to absorb all waves of vibration that are communicated through the ground from the various moving machinery throughout the works. At the level of the basement floor a light grating provides a platform for the use of the clock attendants.

Although the placing of the clockroom in the cellar and the provision of a complete air space around the inner room would, in itself, afford excellent insulation against external changes of temperature, the inner room is further safeguarded by placing in the outer 18-inch space between the two walls a lamp which is electrically connected to, and controlled by, the thermostat, of which we give an illustration. The thermostat consists of a composite strip of rubber and metal, which is held by a clamp at its upper end and curves to right or left under temperature changes, opening or closing, by contact points at the lower end of the thermostat, the electrical circuit which regulates the flame of the lamp. The thermostat is set so as to maintain the space between the two shells at a temperature which shall insure a constant temperature of 71 deg. in the inner clock house. This it does with such success that there is less than half a degree of daily variation.

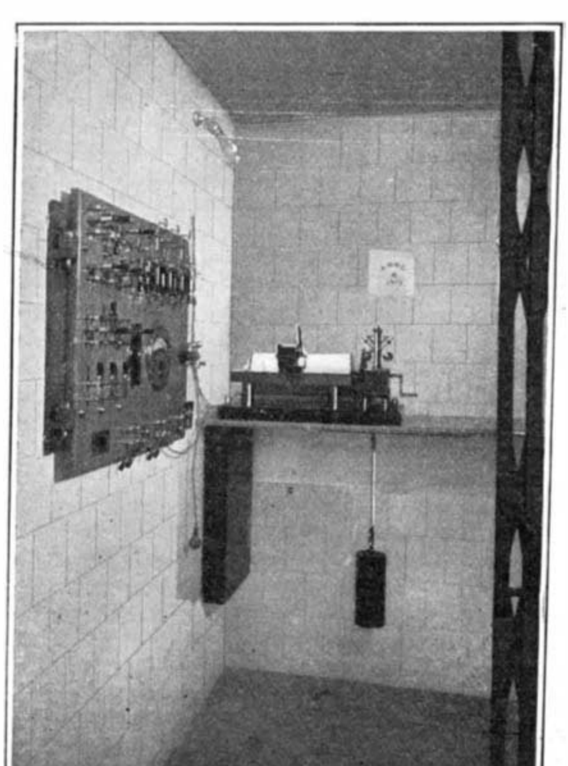
The two clocks that stand side by side in the clockroom serve to keep civil time, that is to say, the local time at the works. The clock to the right carries a twelve-hour dial and is known as the mean-time clock. By means of electrical connections it sends time signals throughout the whole works, so that each operative at his bench may time his watch to seconds. The other clock, known as the astronomical clock, carries a twenty-four-hour dial, and may be connected to the works, if desired. These two clocks serve as a check one upon the other. They were made at the works and they have run in periods of over two months with a variation of less than 0.3 of a second, or 1-259,000 part of a day. The third clock, which stands to the rear of the other two, is the sidereal clock. It is used in connection with the observatory work, and serves to keep sidereal or star time.

Sidereal time is determined by the transit of the fixed stars across the meridian. The stars are at such enormous distances from the earth that their transit is not appreciably affected by the revolution of the earth in its orbit. It is the change of position of the earth with regard to the sun that accounts for the daily difference between sidereal and solar time of 3 minutes 56.55 seconds, the solar day being shorter than the sidereal day by this amount. The passage of a particular star across the meridian at Waltham is noted in the works' observatory on two nights of every week, and an exact record of this time is obtained by



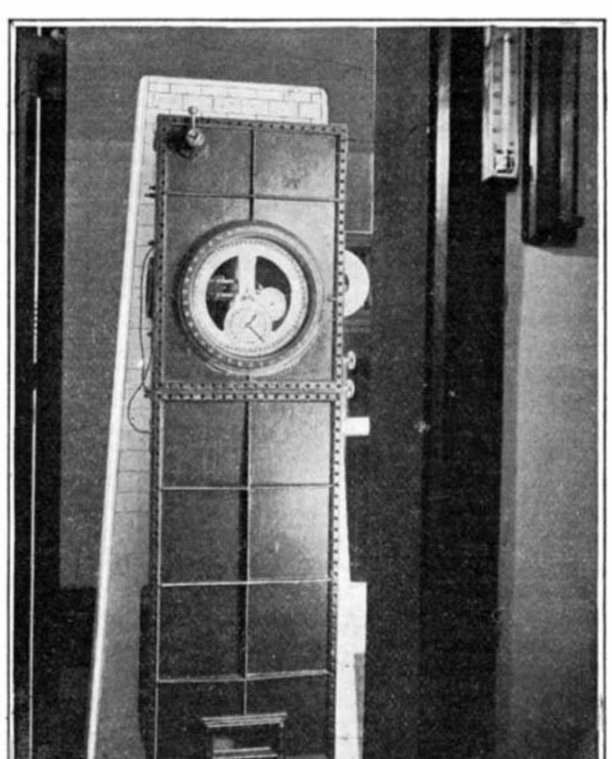
The parallel lines are traced on a rotating drum by a pen which is electrically connected with the sidereal clock. At every alternate second, a jog is made in the line. The intervening jogs record the time of passage of a fixed star across the field of the transit.

Portion of a Chronographic Record.



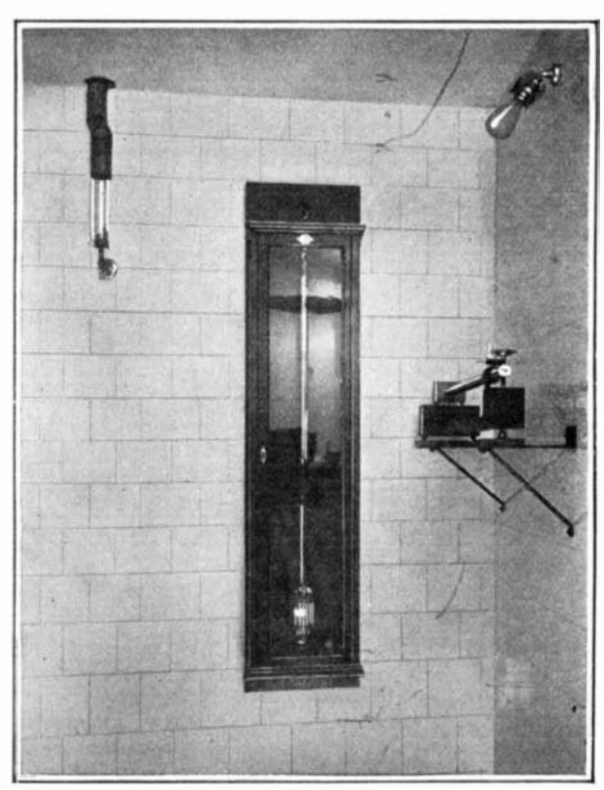
On shelf on rear wall is the chronograph. To the left is the switchboard, for controlling the lights and the electrical connections from the clocks to the various workrooms.

View in Outer Passage of Clockroom.



This clock is protected from barometrical changes by being inclosed in an airtight case to which an air pump is attached.

Astronomical Clock in Inner Building, as Seen from Outer Passage.



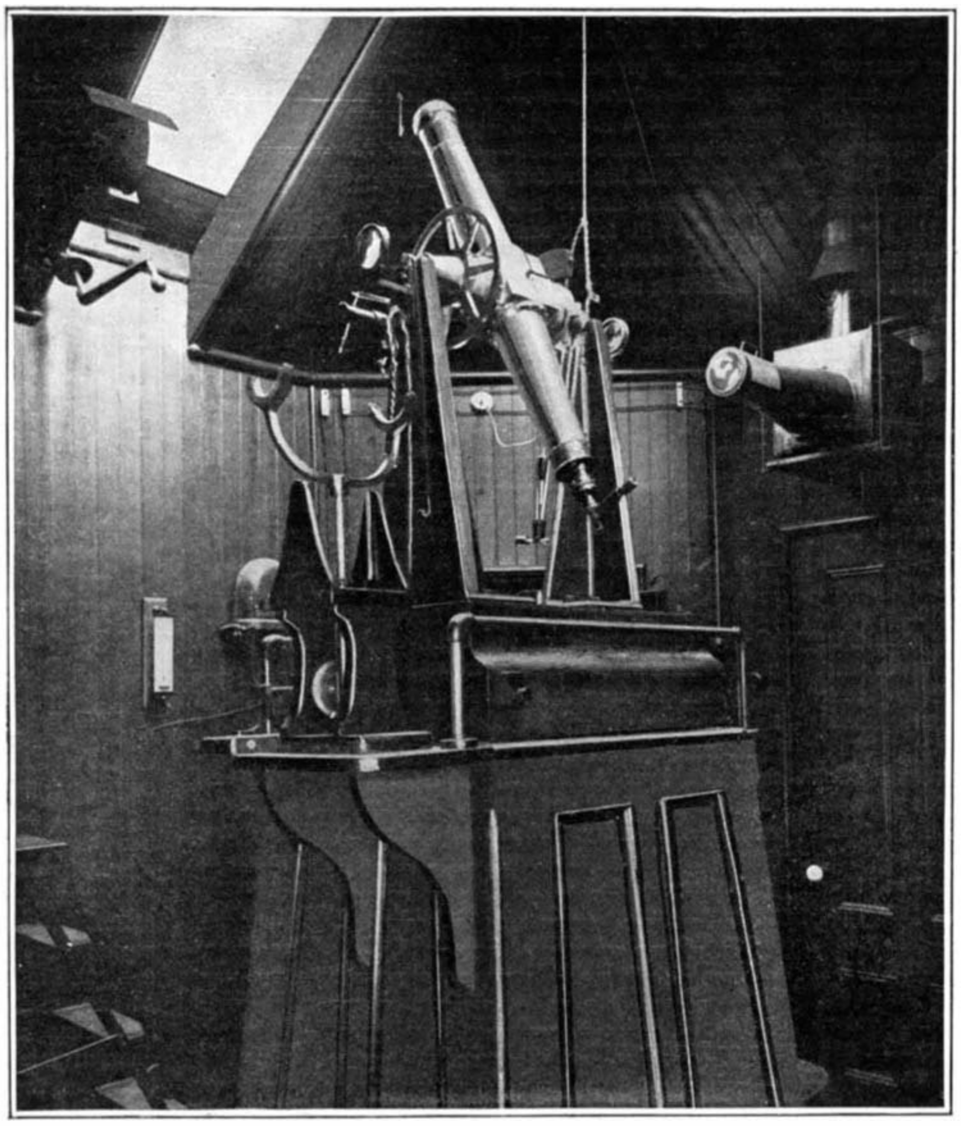
The barometer, and, on shelf at right, the level-tester for correcting transit levels.

Another View in Outer Passage.

HOW STANDARD TIME IS MAINTAINED AT A MODERN WATCH WORKS.

means of a chronograph. The chronograph, which is carried on a shelf in the space between the inner and outer shells of the clockroom, consists of a horizontal metal drum, rotated at such a rate of speed by means of a weight as to give exactly one revolution per minute. Upon the drum is fastened a sheet of paper. In front of the drum is a small carriage, which is moved laterally, by means of a revolving feed screw. This carriage carries a pen that normally traces a continuous straight line on the sheet. The pen is electrically-connected to the sidereal clock, and at every full oscillation of the pendulum, or at every alternate second, the electrical circuit is broken and the pen makes a slight jog in the line. The speed of the cylinder is so arranged that the distance between the jogs corresponds to a certain scale, say of one inch to the second. The pen carriage of the chronograph is also electrically-connected to the observatory, where a button is placed conveniently to the hand of the observer. When an observation of a transit is to be made, the chronograph is started and the observer, with his eye at the telescope, presses the button at the instant that the star passes each vertical hair line (there are five in all) in the eyepiece of the transit. Each time the button is pressed, an extra jog is made on the paper; and by using a scale graduated, say, to 0.01 inch, it is possible to determine to one-hundredths of a second the time of the transit of the star across each hair line. By taking the mean of these five observations, it will be seen that the time of the transit of the star is obtained with remarkable accuracy. The next step is to compare the time of transit as recorded by the sidereal clock at Waltham with the time of transit of the same star as given in the tables of the "Ephemeris." The "Ephemeris" is an official publication, issued annually, which gives the exact position of the heavenly bodies for every day of the year; and from this the exact time of the transit of the particular star observed may be known. Whatever the sidereal clock differs from this time is the error of the clock. The amount of this error is then compared with the amount of error observed at the last observation, and the difference between the two observations, divided by the number of days, gives the daily rate of variation. This rate, as observed at the Waltham works, rarely exceeds one-tenth of a second per day. That is tc say, the sidereal clock will vary only one second in ten days, or three seconds in a month. The variation, as found, is corrected by adding or subtracting weights to or from the pendulum, the weights used being small disks, generally of aluminium.

Summing up, then, we find that the great accuracy obtained in this clockroom is due to the careful elimination of the various elements that would exercise a disturbing influence. Changes of temperature are reduced to a minimum by insulation of the clockhouse within an air space, in which the temperature is automatically maintained at an even rate. Changes of humidity are controlled by the specially designed walls, by the lead sheathing of the foundation pit, by the preservation of an even temperature, and by placing boxes of hydroscopic material within the inner chamber. Errors due to vibration are eliminated by placing the clocks on massive masonry piers which stand upon a bed of sand as a shock-absorbing medium.

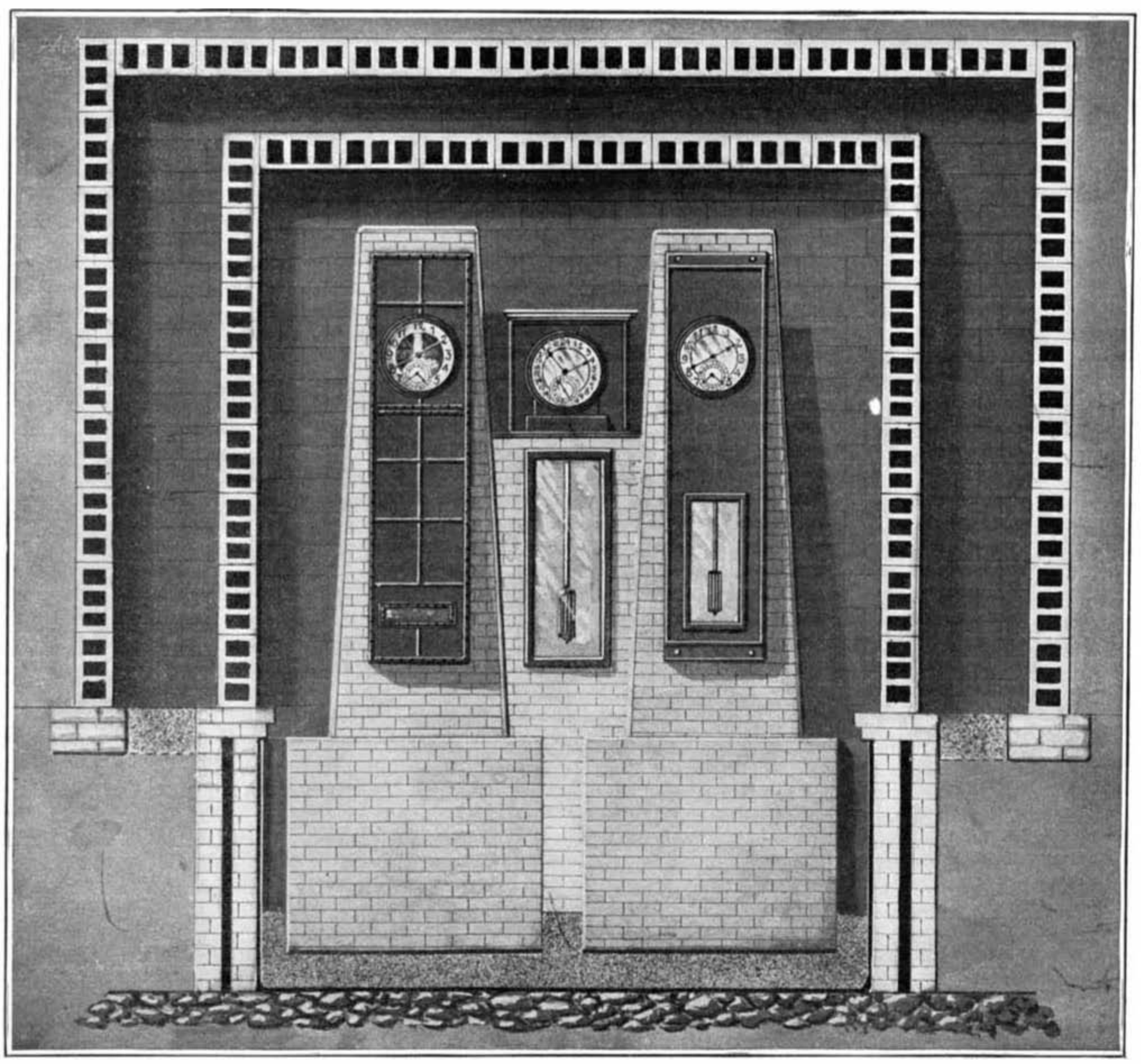


Interior of the Observatory, Showing the Transit.

The astronomical clock is inclosed in a barometric case, fitted with an air pump, by which the air may be exhausted and the pendulum and other moving parts relieved from barometric disturbances. For it must be understood that variation in barometric pressure means a variation in the density of the air, and that the speed of the pendulum must necessarily be affected by such changes of density.

This equipment is the only one in the world forming part of the equipment of a watch factory, and is believed to be the equal of anything of the kind yet installed.

In conclusion, it may be mentioned that of late years it has been the custom of the company to submit a percentage of its watches to the National Physical Laboratory at the Kew Observatory, London, an institution which accepts instruments of precision from applicants all over the world, tests them, and makes a report. Eighty-six per cent of the watches submitted by the Waltham Watch Company have been accepted and passed in Class A. A mark for accuracy of as high as 80 to 85 per cent is a common figure. This result is extremely interesting as showing that American automatic machinery has been brought to such a pitch of perfection that the machine-made watch is able to hold its own at this laboratory with the finest products of European hand labor.



The building is designed to protect the clocks from disturbing influences that would cause variations in the time. Temperature changes and moisture are precluded by the double walls and ceiling providing an 18-inch air space between. Vibrations are avoided by placing the clocks on heavy masonry piers built on a bed of sand. The pair of clocks in the front are the master clocks, which, by electrical connections, give the time throughout the works. The sidereal clock to the rear which is checked, twice each week, by observing the transit of the stars, serves as the standard for the whole works.

Sectional View Through the Clockroom.

HOW STANDARD TIME IS MAINTAINED AT A MODERN WATCH WORKS.

A Chicago machine and Chicago operators won all the prizes at the speed and accuracy contest open to all comers at the Coliseum on March 20. There were $165 in prizes offered in three classes—adding department store checks, adding columns, and multiplying. Owing to lack of time, prizes in the first two classes only were contested for. An operator at Marshall Field & Company's retail store added correctly five hundred department store checks in four minutes and fifty-five seconds, receiving first prize for speed and accuracy in adding department store checks. An operator at the Illinois Central Railroad Company freight auditor's office added correctly six columns of numbers, each equal to a ledger page, in four minutes and thirty-nine seconds. An employe of the C., B. & Q. Railroad car accountant's office won the second prize in the same class in four minutes and forty-one seconds.