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### THE PHILADELPHIA CITY HALL CLOCK.

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For many centuries the pendulum has been recognized as the fundamental element in a mechanism for indicating and recording time. The characteristic of the pendulum which gives it its supreme place in clock mechanism is the fact that a pendulum of a given length, at the same point and elevation, will oscillate in equal periods. This is the theoretical statement of the fundamental law. In order that a given pendulum should follow this law, it must be relieved of two disturbing influences; namely, friction and external influences retarding or varying its original motion. The friction is from two sources: between the parts of the mechanism and between the pendulum and the surrounding air. This friction not only varies the oscillations of the pendulum from their normalcy, but ultimately brings the

pendulum to rest. Unaffected by the disturbing causes which I have mentioned, a pendulum would continue to move forever when once put in motion. The sole object of applying springs or weights to a clock mechanism is to supply the exact amount of energy lost in friction. As it is impossible to make a pendulum to operate under ideal conditions, springs or weights must be used; but to reach as near perfection as possible, the entire mechanism must be reduced to its simplest form. A simple pendulum has mechanical friction at only one point and that is the point of suspension. This is reduced to a minimum by avoiding a bearing in which one part rubs against another, using instead a very thin suspension spring, wherein the only friction is produced by the flexure of the spring as the pendulum oscillates. The air friction, not being avoidable, is made as uniform as possible by enclosing the pendulum in an air-tight casing. A simple pendulum, however, would not indicate or record time and hence it is necessary to add indicating devices called hands, which move in accordance with the oscillations of the pendulum. The whole mechanism, therefore, consists of a pendulum, an application of power to balance friction, and recording and indicating hands. The power mechanism acts upon the pendulum to keep it in motion, and the pendulum, through a detent, reacts upon the power mechanism, so as to use the energy in uniform and equally divided amounts at exact intervals, namely, at each swing of the pendulum. Even allowing for the disturbing elements of friction and the external interferences, the pendulum would still be theoretical, since I have considered a pendulum which is always of a given length. Unfortunately, under natural conditions, a pendulum made of a single material will change its length at each variation of temperature, and means are, therefore, employed to counteract this variation by offsetting the expansion of one material against that of another, so as to, as nearly as may be, keep the pendulum at a constant length. No combination of materials, however, will exactly suffice, and, therefore, there is always under ordinary conditions a third disturbing element, namely, temperature, and this has more

influence proportionately on the variations of the clock than friction, since the friction, both mechanical and of the air, is constant, while temperature is variable within great ranges.

From the requirements and the natural difficulties under which they operate, accurate clocks must be of the finest workmanship, designed upon the highest principles in the horological art and removed from all disturbing influences as far as is possible. So far as the mechanism is concerned, what is called an astronomical clock comes the nearest to meeting the requirements. An astronomical clock is the simplest of all clocks, employing no additional mechanisms for striking the hours, etc. It is unnecessary for my purpose to go into the details of their construction, it being sufficient to say that there are as few bearings as possible, all bearings are jewelled, the gearing is the most perfect, the pendulum hung with the thinnest spring which will sustain its weight; the pendulum is compensated, so far as possible, for variations in temperature and is protected from air movements and, so far as is possible, from jarring from external sources.

What I have previously written is to note, briefly, the principles and necessary conditions under which an accurate timepiece must work. Clocks at first were of the ordinary size and for use within buildings. Finally equal use was found for public timepieces by which the poor as well as the rich might benefit; in other words, a public convenience. That they might be serviceable at great distances, they were necessarily elevated and for the same reason were provided with dials of great magnitude as compared with house clocks, and the mechanism and power applied were proportionately increased. Aside from the increase of friction, there was the increased vibration, owing to the elevation; the external variations of temperature, which not only varied the length of the pendulum, but affected all lubricants which are necessary in mechanism. I have said that an accurate clock must have as little external mechanism as possible added to it. A tower clock, since its hands are exposed to wind and weather, requires at all times considerable energy to operate them, but

owing to changes of wind, and with snow and sleet, *varying* power to operate them. It follows that a tower clock built upon the lines of an ordinary enclosed clock of practical dimensions cannot be extremely accurate, while, being for public use, it should be the most accurate of all clocks.

The tower of the City Hall in Philadelphia was designed for a tower clock, but, owing to the extreme height of the tower and the size of the dial face, presented problems not before encountered in the installation of a tower clock.

The total height of the tower is  $547\frac{1}{2}$  feet from the ground, and the centers of the dials, 362 feet above the pavement. The diameters of the dial openings are 25 feet, including the rim. The height is so great that the dials are often obscured by clouds, and during the erection of the clock the ironwork was frequently wet with deposited moisture, while the pedestrians below were in a dry atmosphere. When only moderate breezes blow in the street, a gale is experienced at the clock dials. The tower up to the level of the clock dials is built of brick faced with marble, but the upper 200 feet is constructed of iron electro-galvanized with aluminum. The tower, of course, is unsupported above the roof of the main building. The top of the tower has a small diurnal motion accompanying that of the sun and owing to the expansion of that portion of the tower upon which the sunshine falls. All of these conditions made the installation of a tower clock of such prominence (which of course must be accurate) practically impossible, if built as a primary clock.

Mr. John S. Stevens, Chairman of Clock Committee and a member of this Institute, in view of the future installation of a clock in the tower, made a special study of tower clock mechanisms and had visited all the most prominent tower clocks in the world. From his investigations, he foresaw the practical difficulties. At this juncture, Mr. Stevens consulted me, as I had previously designed and constructed the largest clock in the world at Minneapolis, Minn., the dials being 22 feet 8 inches in diameter.

After examination of the building and tower, I under-

took the designing and erection of a time-indicating device suitable to the location and conditions, and the clock at this writing has been in operation two years. The departure from the older method is radical and will be understood by the following text accompanied by illustrations. The conditions under which such a clock must operate and the magnitude of the dials and of the hands is such that their designing becomes an engineering problem and not a horological problem. But in order to have accurate time, there must be an accurate timepiece, the construction of which belongs to the horological art. How I have combined the two will be seen by the description. In brief, the *real* clock, the accurate timepiece, serves only to put in motion and to control the tower mechanism, and there is, therefore, really no *clock* at all at the great height of the dials. The dial mechanism is operated by compressed air. The whole is based on the fundamental principle of all modern mechanisms, namely, the governing and directing of great forces by comparatively feeble ones.

*Fig. 1* is a view of the City Hall in Philadelphia taken from the roof of the tall office building across the street. The form of the building is a quadrangle, with a court in the center, which covers four city blocks, two streets running through the building, one north and south, one east and west. The tower rises from the north side of the quadrangle at such a point as to be supported on east and west by the building itself. The clock dials are 362½ feet from the ground at their centers, the tower rising nearly 200 feet above this point. The astronomical clock is placed in the lowest room of the tower, which is just above the roof of the building itself. Air pipes lead from this point over 200 feet to the dial room above. These pipes also lead downward into the basement of the building, where there are air compressors operated by water for furnishing the power in emergencies, the main air compressor being operated by electricity and located in the dial room.

As the astronomical clock is the heart of the whole apparatus, my description will begin with the astronomi-

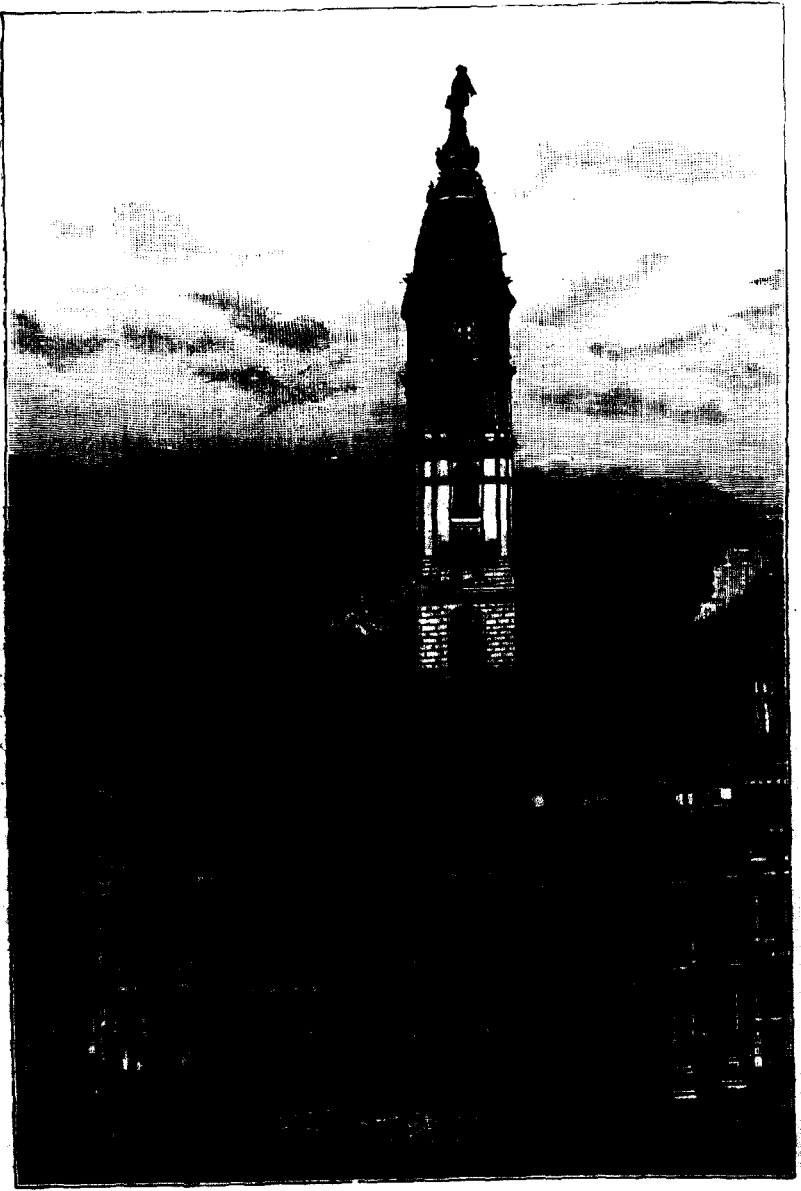


FIG. 1.—City Hall, Philadelphia.

cal clock and its immediate accessories. The best location for this clock would have been, of course, on the level of the street or below, but owing to the peculiar construction of the building, such a location could not be secured. It was, therefore, determined to put the astronomical clock in the next best position.

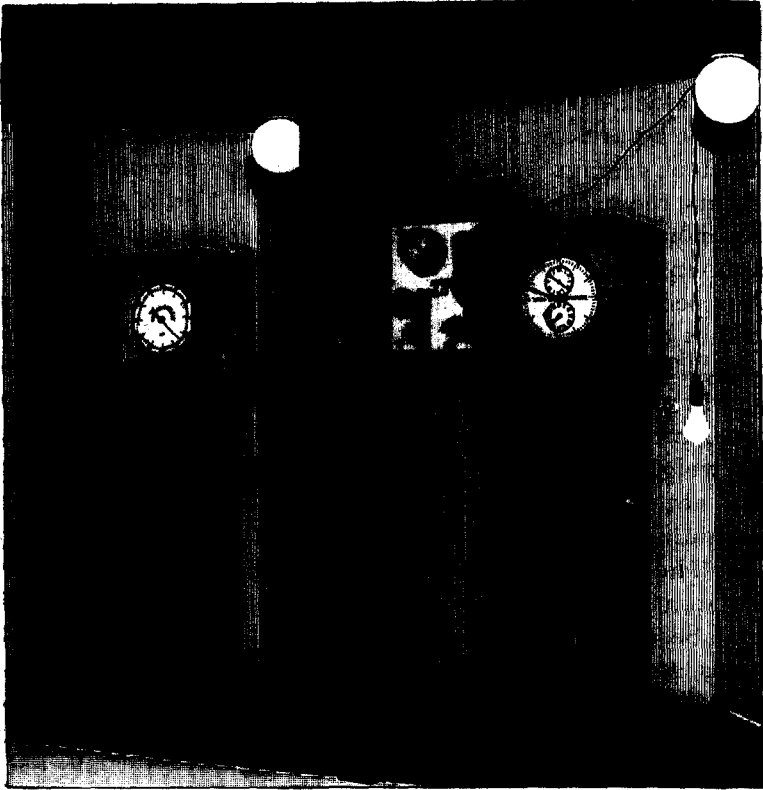


FIG. 2. — Partial view of clock room.

In the lowest room of the tower, which is on the seventh floor of the building, the walls are 13 feet thick. One corner of this room was selected and iron girders were let into the walls so as to cross the corner, and these girders furnished the foundation for the clock room, being entirely independent of the floor of the room, so that they would not take up any jar or vibration which the floor might have,

being as rigid and solid as the tower itself. Using these girders as a foundation, there was built a room of iron and copper, the foundation work being covered with marble, and the inside surface of the tower walls which came within the clock room were faced with glazed tiles. This clock room was made as perfectly air- and dust-tight as possible, by having all the glazings, as well as all the door openings, fitted with felt. This prevents the accumulation of dust, which would be detrimental to the working of the astronomical clock. The room is so tight that after six months' use not a particle of dust could be found to have settled on the clock casings in the room. A general view of the front of this room is shown in *Fig. 2*. *Fig. 3* is a cut of the astronomical clock as it appears standing alone. The clock is mounted on an iron pedestal weighing over 500 pounds. This pedestal has three adjusting screws, as will be seen, so that the clock may be brought to a perfect level at any time. The pendulum is enclosed in the pedestal. The weight also falls within the pedestal, but in a separate compartment from that of the pendulum, the object being that the weight when it falls, necessarily passing the pendulum, will not thereby influence the air friction, the air friction remaining constant at whatever position the weight may be. The dial mechanism of the astronomical clock is above the iron pedestal and enclosed in a glazed casing which may be removed when necessary. This is set upon felt strips, so as to provide against dust, as in the case of the room itself. The casing is not removed to wind the clock, but a plug is removed from the glass in front and by means of a long key the clock is wound through the hole once each month, the plug being replaced after each winding. The clock, therefore, has a double protection against dust, that is, the dust-proof clock room and the dust-proof case.

As is common with astronomical clocks, the dial has three circles, the minute circle above the center, the hour circle on the circumference of the dial and the twelve-hour circle beneath the center.

Again referring to *Fig. 2*, there appear to be two astronomical clocks. That is not the case. The clock to the



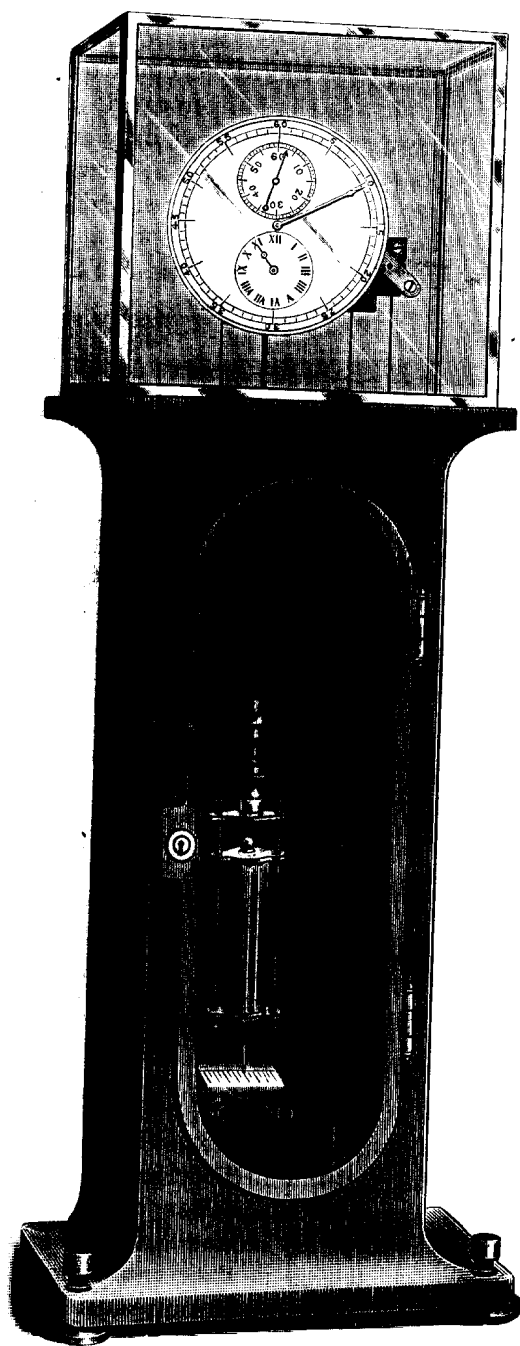


FIG. 3.—Astronomical clock.

left, marked *B*, is called an auxiliary clock. It is mounted in exactly the same way as the astronomical clock, but is of much cheaper mechanism and is used only in emergencies when it would be necessary to oil or otherwise adjust the astronomical clock. In *Fig. 3* small pipes will be seen passing up through the pedestal of the clock at the rear, and are seen on either side of the pendulum. These pipes con-

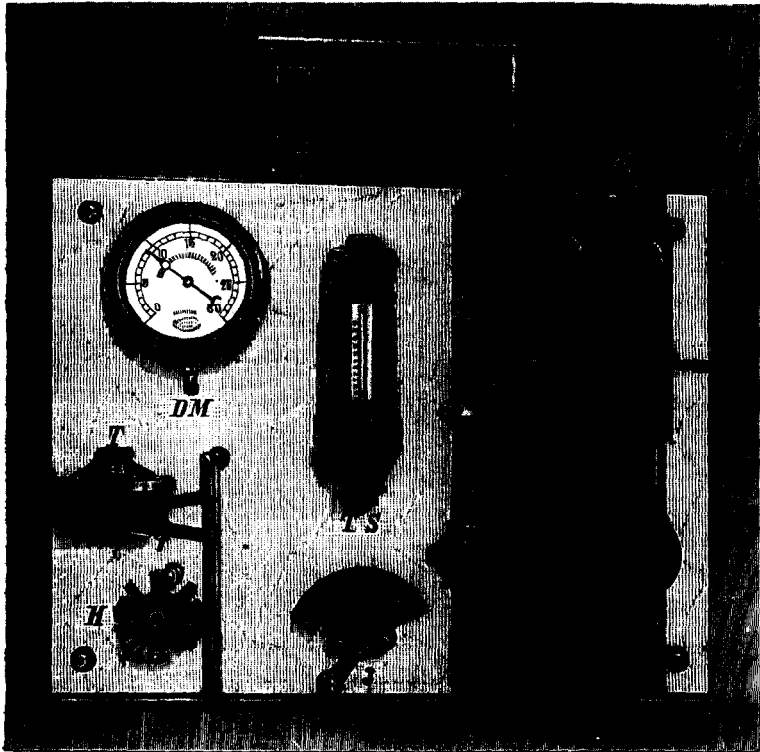


FIG. 4.—Thermostat, air switches, electric switch, telegraphic sounder, etc.

vey the compressed air to and from the clock mechanism. The function of the astronomical clock is to control compressed air, which moves the hands of the dials 200 feet above. On the rear wall of the clock room there is placed some accessory apparatus, which is shown in *Fig. 4*. *DM* is a pressure gauge which indicates the pressure used, shown in the cut to be about 9 pounds, although the exact pressure is

immaterial. At the left is a telephone by which any desired person may be called up from the clock room, and communication may be had if necessary with the local observatory, but the time is really governed by the electrical relay *Z*, which is placed above the telephone. This electric relay is connected by direct wire with the U. S. Naval Observatory in Washington, and each day, just before high noon, the relay begins to repeat the second movements of the pendulum in Washington. Ten seconds before the meridian the relay rests, and the first click after the rest is exactly noon. This relay is made to sound so loud that it is not necessary to go into the clock room to hear it, and, of course, the dial of the astronomical clock may also be seen through the plate glass of the room. In this way it is not necessary for any one to enter the room oftener than once a month. The presence of the human body in the room for more than a few moments has been found to be detrimental. The room is so tight that the moisture given off by the human body, which, of course, is considerable, remains in the room and is detrimental to the delicate mechanism. For this reason admittance to the room is denied, even to the attendant, excepting once a month.

Handle *3* is a switch for the compressed air. From the position in which the pointer of the switch is shown, the astronomical clock controls the tower mechanism, but if the pointer be reversed to the left, the auxiliary clock controls the mechanism, and the reversal of this index is all that is required to change the tower mechanism from the control of the astronomical clock to that of the auxiliary clock, or *vice versa*. In the center of the marble slab which supports these accessories is seen a device marked *T S*. This is a thermostat, which also controls compressed air, and the compressed air in its turn controls the electric switch *H* through the mechanism *T*. In the room at one side is an electric radiator or heater, and the current which supplies it is controlled by the switch *H*. The thermostat has the function of supplying or shutting off this current at the proper temperature. The thermostat is set at a temperature of 75° F. As soon as the temperature of the room reaches this

point, the thermostat, through the compressed air, opens the switch *H* and, therefore, the source of heat is removed. When the temperature falls less than  $1^{\circ}$ , the thermostat, through the mechanism *T*, closes the switch *H*, and the electric radiator or heater again comes into action. This apparatus is so perfect that the temperature of the clock room never varies more than  $1^{\circ}$ . It is set at  $75^{\circ}$ , so as to be as near as possible to any summer heat which might enter the recesses of the clock room, and, therefore, is as warm in the winter as it gets in summer, and remains during the year at the constant temperature of  $75^{\circ}$ . This eliminates from the problem the question of temperature, which is one which has been found most troublesome in securing accurate time mechanism. This is the only astronomical clock in the world which operates under such perfect conditions.

It will be interesting to know how the astronomical clock, without interfering with its delicacy and accuracy, can operate four sets of hands, each weighing 500 pounds. I will refer to *Fig. 5*, which is a more or less diagrammatic and sectional view of the controlling mechanism. *R* is the inlet for compressed air, which is supplied by one of the vertical pipes in the clock pedestal, as before stated. This air is supplied to two portions of this mechanism, one portion to a valve marked *V* and the other to the vertical passage where there is a threaded pin valve *X*. The air which passes through this pin valve underneath the flexible diaphragm *m* passes upward through the small tube *u*, which is continued into the clock mechanism and terminates at *n*. On the second hand arbor of the clock, that is, the arbor above the center, is placed the cam *g*. The lever *H* is fulcrumed as shown and lies across the opening of the pipe *n*, so as to close this pipe when it rests upon it. During the revolution of the second hand arbor, the cam *g* one-half of the time will raise the lever *H* from the pipe *n* and leave it open. During the other half, it will be closed. The opening in the pipe *n* is larger than the opening through the pin valve *X* to the clock chamber *m*. It follows, therefore, that when the lever is removed from *n* by the cam *g*, the chamber *m* will collapse from lack of pressure. When

$n$  is closed, the chamber  $m$  will expand, since the pressure passing through  $X$  will accumulate. These actions take place each minute, the chamber  $m$  being alternately repleted and depleted of air. The diaphragm itself is not much larger than is shown in the cut. The movements of this diaphragm inward and outward operate the lever  $b$  against the spring  $W$ . Connected with this lever is a toggle which operates the valve  $V$ . It is unnecessary to give a minute description of this movement. When the cham-

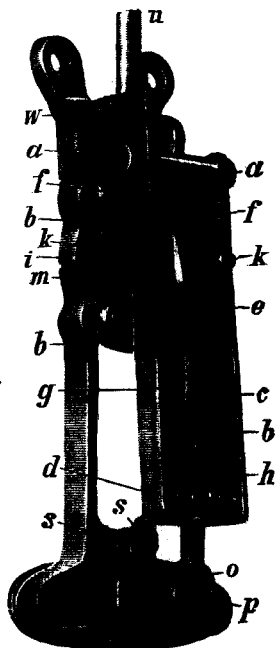
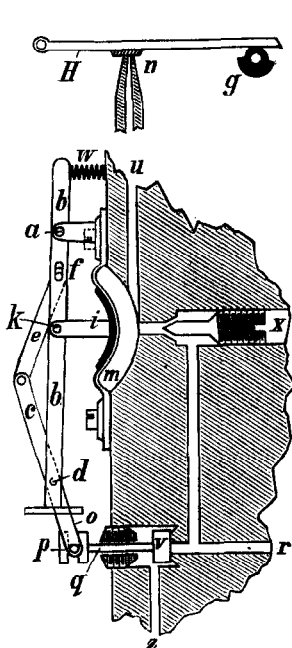


FIG. 5.—Controlling mechanism. FIG. 6.—Controlling mechanism.

ber  $m$  is full of compressed air, the valve  $V$  will be in the position shown in the cut and no air can pass by it. When, however, the chamber  $m$  is depleted, the spring  $W$  forces the lever  $b$  back and through the toggle reverses the valve  $V$  so that it closes the outlet  $q$  for the air, but opens the air passage at  $V$ , the valve itself resting to the left, instead of to the right. There is now freedom for the air to pass from  $r$  to  $z$ .  $z$  is the passage which leads to the air pipe which passes up the tower to the dial mechanism. All the pas-

sages and mechanisms are about the size shown in diagrammatic view *Fig. 5*. The real mechanism, however, is best seen in *Fig. 6*.

It will readily be perceived that when air is supplied through *Z* it may press upon any piston, diaphragm or any like device which may be in the dial room, and this device may have sufficient power through the proper mechanism to operate the clock hands. As the cam (*Fig. 5*) is upon the second hand arbor, it is evident that air will be supplied once each minute, and as the diaphragm *m* will be depleted once each minute, there will be a supply of air through *z* to the clock mechanism each minute and a release of this air each minute through the opening *q*.

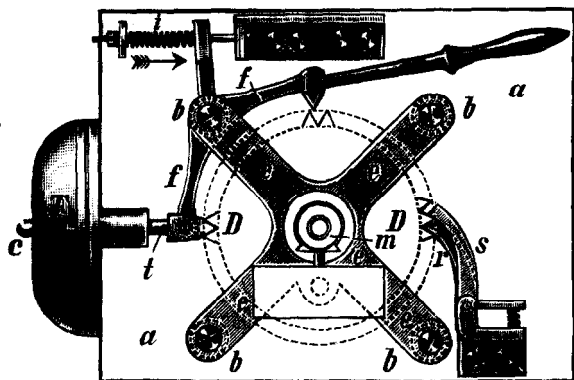


FIG. 7.—Minute mechanism in dial room.

To show how the impulses of air which are controlled and sent forward by the master clock serve to operate the dial mechanism in the tower above, we will refer to *Fig. 7*, which is a more or less diagrammatic illustration of the minute mechanism of the tower clock. The view is taken from above. *T* is a metallic chamber, concave and fitted on the inner side with a flexible woven air-tight diaphragm. The air from the master clock below sending forth impulses enters at the point *c*. The pressure of the air moves the piston having the rod *t*, and this rod *t* is fastened by a link to the anchor *f-f*, which swings in roller bearings at *b*. Studs *b-b-b-b* support the cross *c-e-e-e* which forms the

upper bearing of the shaft *m*. This shaft is prolonged upwards as seen in *Fig. 8*. Upon this shaft is a tooth wheel *D-D* having thirty teeth in the circumference. The relation of the anchor points to these teeth is such that when the anchor is pressed forward by the piston rod *t*, it forces the wheel *D* forward one-half tooth and at the same time raises the anchor point *t* from contact. By the reverse movement of the piston *T*, the first anchor point is withdrawn and the opposite one inserted, which in like manner forces the wheel *D-D* forward one-half tooth. It will be observed that this anchor effectually locks the wheel; in other words, while it rests or while in process of movement, it is impos-

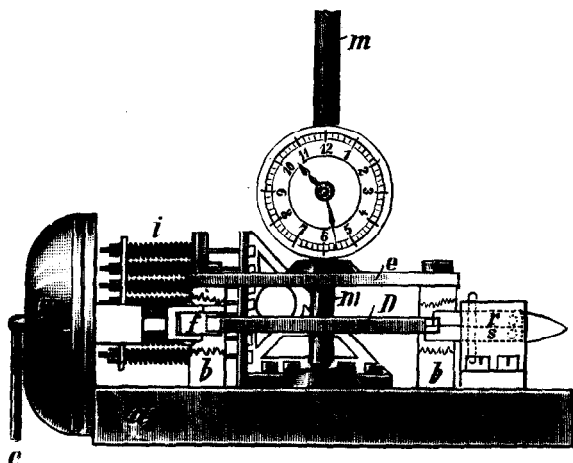


FIG. 8.—Side view of minute mechanism.

sible for the hands to fall either forward or back. In order to keep the hands in an absolutely rigid position, although there may be a movement taking place of the anchor *f-f*, pawls *r* and *s* fall into the teeth of the wheel on the opposite side from the anchor. There are two of these pawls, so that one locks at one-half of a minute and the other at the other half minute. While the piston *t* is pressed forward by the air pressure, it is pushed back by the springs *i*, of which there are seven, as shown in *Fig. 8*. The springs are divided into several, so that the breakage of a single spring will not effect the stoppage of the clock. *Fig. 8*

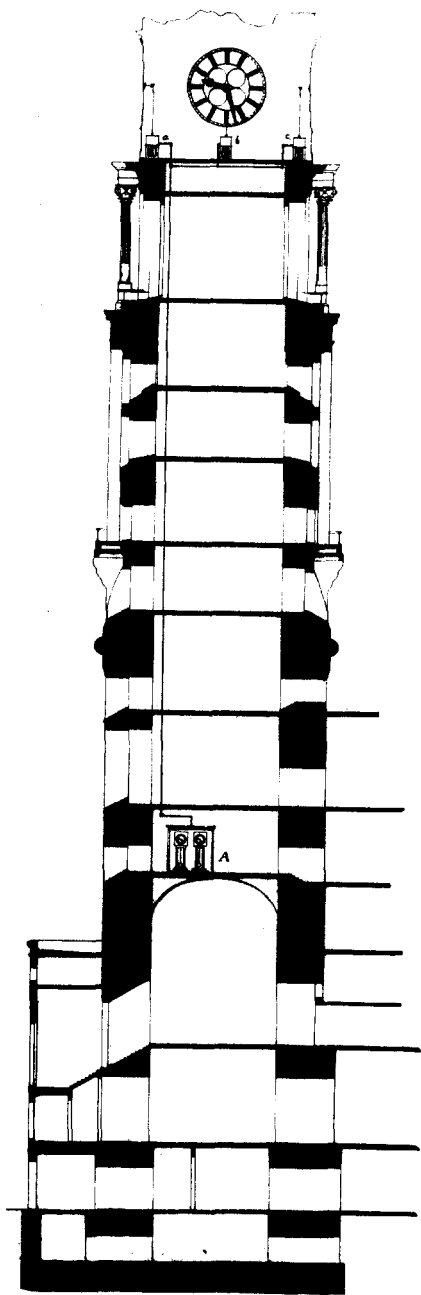


FIG. 9.—Vertical section of tower.

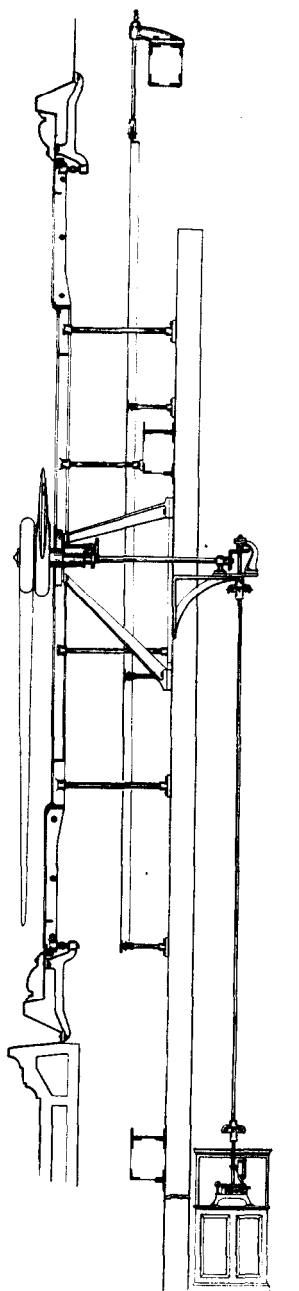


FIG. II.—Cross-section of dial, etc.



shows the same mechanism as in *Fig. 7*, only in elevation. It will be noted that a small dial is attached to the vertical shaft *m*, so that the time may be read from this mechanism.

All four dials of the clock are not operated by a single one of these movements for two reasons: First, the impossibility of putting one center movement in the dial room, owing to the fact that an elevator passes through the center, and second, each one being independent, removes the possibility of all four dials stopping at once, owing to trouble with a single movement.

*Fig. 9* shows a section of the tower from the foundation to the dial room. This shows the exact thickness of the tower walls in proportion to the interior space. It will be readily seen that at the point *A*, where the master clock is located, the walls are extremely thick, therefore substantial. As has been previously explained, the clock case *A* does not set as shown in this sketch, but is firmly attached across the massive walls and is independent of the floor. In *Fig. 9* it will be noted that the outlines of the dial room are very light. This is because above the foundation of this room, for 200 feet the tower is built of iron, instead of brick, the iron being plated with aluminum.

*Fig. 10* is a plan view of the dial room, the dials themselves being marked *A, B, C, D*. The movements which I have described and which are placed in dust-proof cases made of oak and glazed with plate glass are shown at *E, F, G, H*. *I* is the elevator well. *J* is a case containing the apparatus for turning off and on the lights morning and evening (which will be described hereafter), together with the switches for the electric motors for the air compressors which are located in the same room. The outer line of *Fig. 10* is an outline of the stonework of the tower below. The dark circles are the foundations of columns which rise either side of the dials. The thin ornamental line connecting the dials at the corner is a cross-section of the ironwork of the dial room.

*Fig. 11* is a cross-section of the dial, its supporting frame and of the reflecting sheet behind the dial. It shows the movement, which we have just described, in its case at the

bottom, with the vertical shaft at the side opposite the center of the dial, which shaft, by miter gears, connects with the horizontal shaft of the minute hand.

Fig. 12 is a larger, but, of course, imperfect view of the miter-gearing and connections. *A* is a universal joint. *B* is a worm gear wheel having a key at *c*. This is for the purpose of adjusting the hands on the shaft *f*, in their relation

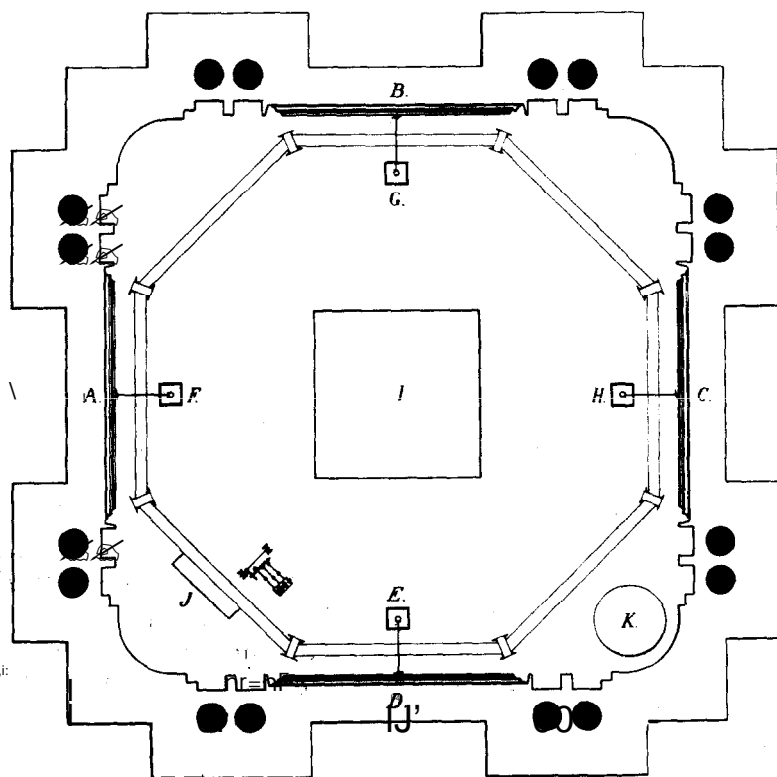


FIG. 10. Plan view of dial room.

to the shaft *m*, so as to register them with the minute marks. This adjustment is, of course, only performed once.

The dials are the largest in the world, having a diameter of 25 feet across the centers from the extreme edges. Fig. 13 is taken from a photograph made before the dials were

glazed. Through the openings; the city may be seen. A man stood, as shown, in one of the center circles. *Fig. 13* plainly shows the construction of the dial. It will be noted that it is sectional, having twelve separate sections bolted together, that is, for the hour sections. The minute sections are also twelve and external to the hour sections. The whole is thoroughly braced and fastened rigidly to the iron-work of the tower, which is shown by the vertical riveted sheets. The center portion of the dial is much too large for a single sheet of glass, being some 15 feet in diameter.

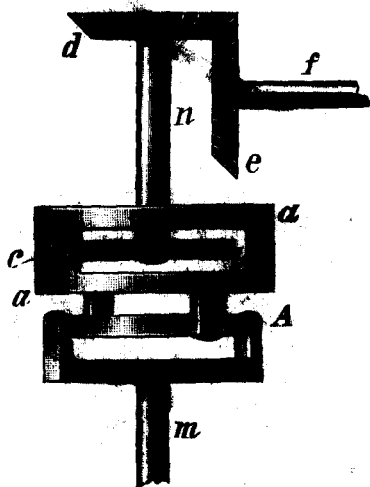


FIG. 12.—Universal joint and miter gear.

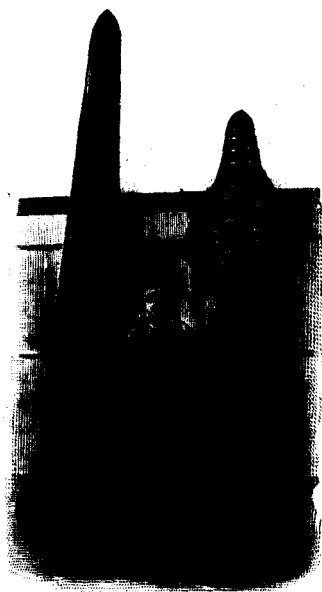


FIG. 15.—The clock hands.

It is inadvisable to section such a space radially, because the framework may be confused with the hands. By the arrangement shown, it will be seen that none of this framework is parallel with the hands at any point; consequently, cannot be confused with them; besides, the framework is comparatively light, so as not to be seen at a great distance. When seen, it is more or less ornamental. This framework is glazed with extra thick plate glass, the same being ground upon both sides. It required 2,000 feet of plate glass to

glaze these dials and sufficient glass if laid upon the ground to make a walk ten feet wide and the length of a block. The framework of the dials is made of cast iron, into which the glass is fastened with metallic clamps and bedded with elastic putty, of which it took 1,000 pounds to set the glass for four dials. The dials are perfectly water-tight. The

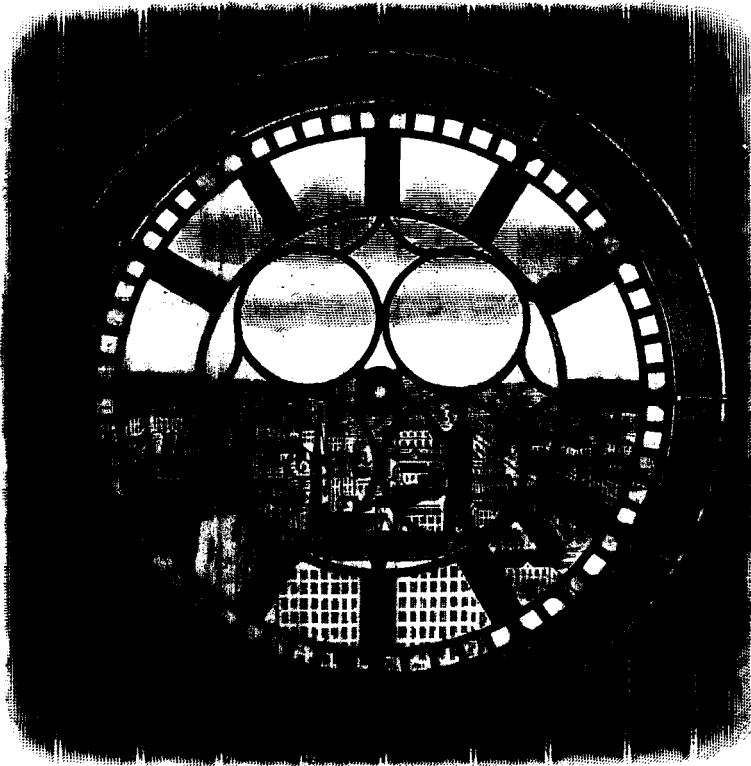


FIG. 13. — View of dial framework before glazing.

facing of the dials upon the outside is entirely of bronze, one-fourth of an inch thick. No iron of any sort appearing, all screws and bolts are made of bronze, which will endure, of course, always in any kind of weather. The dials are so far above the ground that during their construction the workmen were often in the clouds and the ironwork was

kept wet with the deposit from these clouds. Consequently, iron used exteriorly would be out of the question.

*Fig. 14* is a sketch showing the dials from the outside. It also shows in sections the reflecting sheet which is behind the dial, the tower itself is supposed to be removed or transparent. It will be noted that there are no marks as 1, 2, 3, 4, 5, etc., in Roman numerals. Each block has the same value. All tower clocks previous to the large clocks designed by me have had the Roman numerals. I expected much criticism when dials were put up without these numerals, but strange to say, there is not one person in 100 who ever notices that there are no numerals, and no one has ever yet criticised the arrangement. (The first dial with such markings was designed by Arch. Kees, Minneapolis.) The truth is that these spaces and especially the numerals count for little on a clock face. No person over ten years of age would ever mistake the time of day to the extent of more than two or three minutes, if there were no marks whatever on the face of the dial. It is the hands which tell the time; therefore, they must be large and prominent. The hands of this clock are of such construction and of such importance that their description is necessary. They are, therefore, shown in *Fig. 15* taken from a photograph where the hands were set up against a wall, one of them not being completed. The minute hand is 12 feet in length and the hour hand in same proportion. It will be noticed that the hour hand is much heavier than the minute hand and of entirely different form, so that the two can never be mistaken, one for the other. The hour hand is nearly  $2\frac{1}{2}$  feet across at the center. These hands require heavy counterbalances, which are not shown in the cut. The sheathing of the hands is made of sheet copper, the hands being elliptical in form. The centers are supported by rigid bronze framework, which is shown in the unfinished hand. The shafts of the hands are trussed, as shown by v-shaped longitudinal braces on each half, the point of the v's on each half meeting at the center, forming an X-truss for the whole hand. The hands are so wide that supplementary transverse V-shaped trusses are also required.

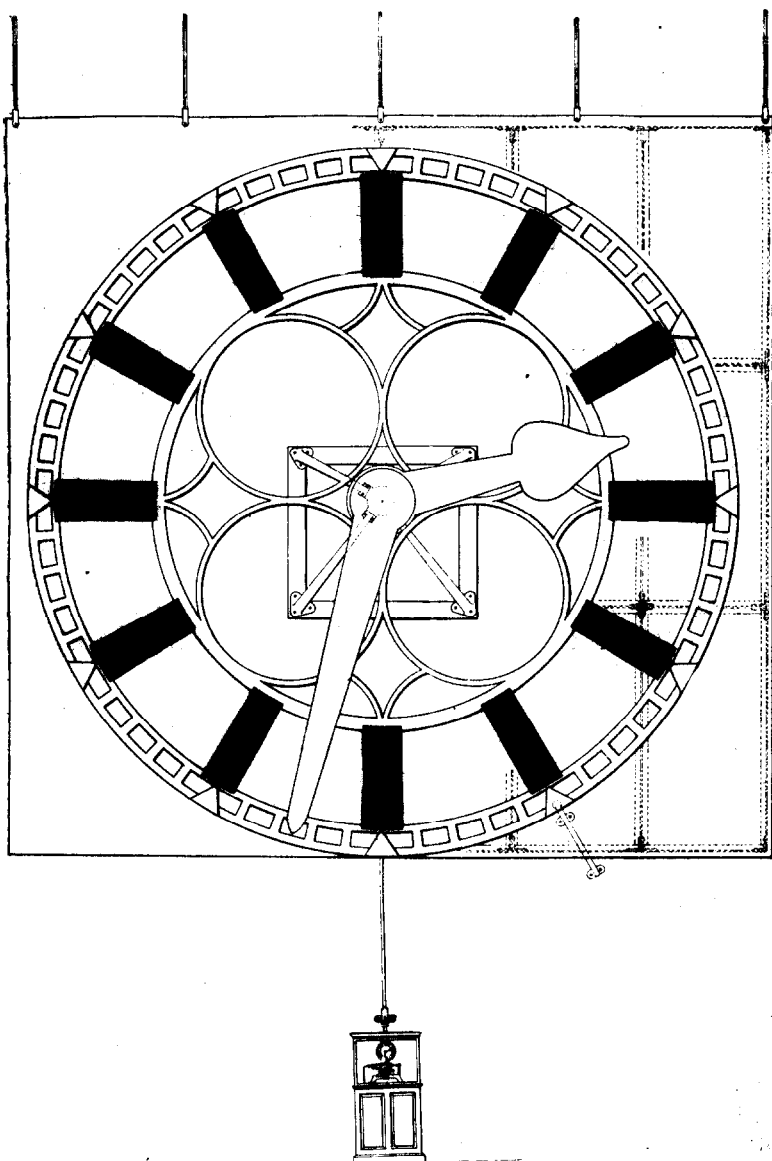


FIG. 14.—Sketch of dial, etc , from without.

The hands are made elliptical so as to oppose as little resistance to the wind as possible. Notwithstanding these hands are made as light as rigidity and durability will warrant, they weigh with the counterbalances an average of 250 pounds each, the hands for the four dials weighing 1 ton. These hands are supported by a phosphor-bronze shaft  $2\frac{1}{2}$  inches in diameter and 5 feet long. As the minute arbor of a clock is always inside of the hour arbor, the minute arbor is also supported by roller bearings at each end. What is called the cluster, or the gearing which reduces the movement from that of the minute shaft to one-twelfth for the hour shaft, is rigidly fastened to the framework, the whole being supported, as shown in *Fig. 11*, by a solid frame which is about 30 inches behind the dial, having braces which go forward to support the axis and the cluster movement at the outer end. A framework of horizontal and vertical beams supports the dial against wind pressure, this support being made at twelve points. Besides being bolted to the ironwork of the tower, the edges of the dial frame are thoroughly bracketed to this ironwork.

In order that the clock may be of value for the whole twenty-four hours, of course it is illuminated, and in this particular it has some very novel features. Very many attempts have been made to illuminate clock dials properly without getting shadows and in only a few instances has it been successful. There hangs from a beam above, by means of rods, as shown in *Fig. 14*, a reflecting frame or sheet. This sheet is 25 feet square and presents a smooth surface toward the dial, the back of it being thoroughly stiffened by angle irons, as shown by the dotted lines in the figure. The same sheet is shown edgewise in *Fig. 11*, the supporting beam at the top being cross-sectioned and the studs below fasten it to the supporting beams to prevent its swinging. This sheet is first given one coat of red lead, two coats of white lead and one coat of white enamel. It is perforated for the insertion of 150 incandescent electric lights having special sockets. These lamps can be put in from the rear. This sheet hangs about 2 feet back of the dial and there is nothing intervening to form shadows.

It requires 600 electric lights, or 50 horse-power, to illuminate. The illumination is the best of any clock dial in the world. The turning off and on of these lights is entirely automatic, and the arrangement, together with some other parts, is shown in *Fig. 16*. *BA* is a four-pole rotary switch, having a capacity of 500 ampères. The four knives are fastened rigidly to the same axis as the lever *i* with a heavy ball. *T* is an expansible chamber with flexible diaphragm,

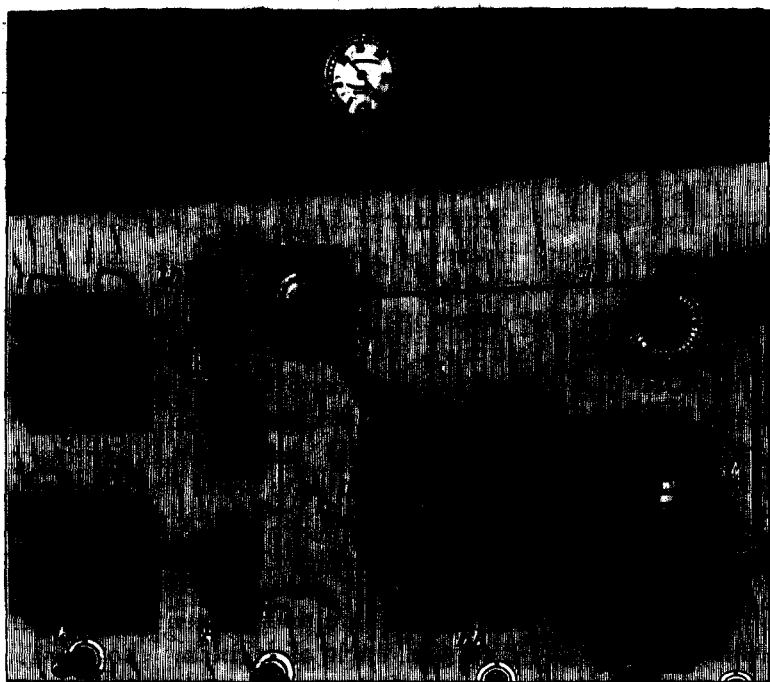


FIG. 16.—Illuminating current switch with controller.

similar to those used on the dial movements. The piston operated by this diaphragm is fastened to the lever *i*, through the connecting rod which is slotted to give lost motion, as shown. When air enters the chamber *T*, it pushes upon the piston, until the lever *i* with its ball is brought to the vertical position. As it passes from the vertical position, the weight of the ball makes it fall to the right, which suddenly makes the four connections. When



the compressed air is exhausted from *T*, the lever is again brought to center and in like manner falls suddenly, breaking connection at the four points. The air is admitted and released from *T* by the device *TN*, which is operated by the same air pressure each minute which operates the four dial movements. The index shown partially in black, partially in white is for twenty-four hours, the lighter portion representing day. The relative length of day and night are adjustable and are changed each week by the revolution of this index. The chamber *T* is filled and exhausted once in

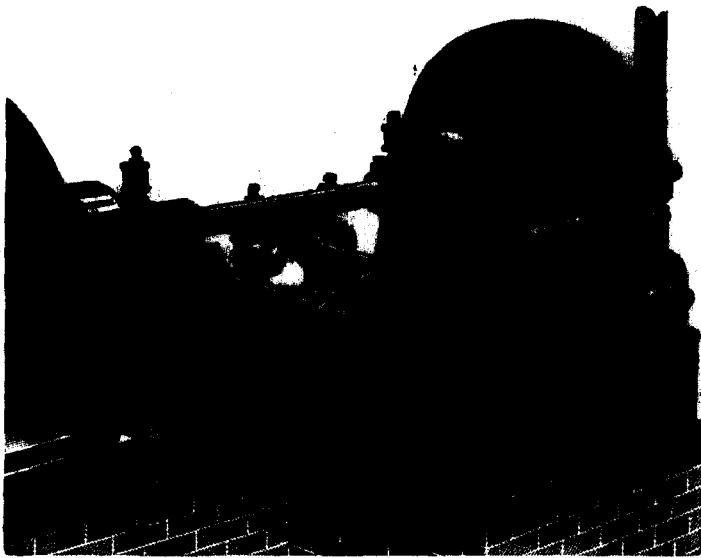


FIG. 17.—Electric air compressors.

twenty-four hours; in other words, the 600 lights are thrown in in the evening and out in the morning automatically. In the same case with this device is the city schedule for street lighting and the clock lights according to the city schedule. On the same marble slab and in the same case there are shown in *Fig. 16* other devices which it is unnecessary to describe particularly. *LD* is a governor for the air pressure, so that it never varies but  $2\frac{1}{2}$  pounds, the compressor stopping and starting with those limits. *B* and *C* are starting boxes for the electric motors. Having described the

dials and supports, hands, etc., I would say that the four dials, their reflecting sheets and supporting framework weigh 48 tons.

I have spoken of the compressed air being produced by electricity and that there are also hydraulic air compressors for supplementary work. I deem it unnecessary to minutely describe these devices. Suffice it to say that *Fig.*



FIG. 18.—Hydraulic air compressors.

17 shows the electric air compressors which are located in the dial room, 362 feet above the ground. They are placed there for the reason that the air which is used at high elevations should be taken from high elevations to prevent unnecessary condensation. To prevent possible accident, there are two independent electric motors for these compressors. In general they work together. If there be an accident to one of them and it should stop, the other continues to do the work just the same, either one having more than twice the power required to do the work. As the electric current might be cut off at some time for some purpose, there are connected with the system and located in the engine room of the building three hydraulic air

compressors with fittings, shown in *Fig. 18*. These are automatic in their action, so that they do not move when the electric air compressors are at work. Should the electric compressors fail for any reason, the hydraulic air compressors take up the work and have ample capacity. It will be noted that there are three of these. The three are con-

nected to two independent water lines, one of these water lines running directly from the city reservoir to the City Hall without any connections; consequently, there is very little liability of an accident happening to it. These hydraulic air compressors are so arranged that, should the water supply fail from either source, the other will do the work. Should either one of the hydraulic air compressors fail to do the work, the others have sufficient capacity. The probability, therefore, of the required air pressure failing is extremely small. As will be seen, the entire mechanism of this pneumatic clock is very simple, very positive and very durable.

This clock has now been running for two years and the derangements have been extremely few, much less than with ordinary tower clocks of much less magnitude. It is so arranged, as has been stated, that there are duplicates for every part which may fail. If the astronomical clock needs cleaning or adjusting, the work is taken up by the auxiliary clock, or *vice versa*. Owing to any derangement of the dial mechanism, only one dial needs to be stopped at a time and the failure of power is almost impossible.

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*Stated Meeting, held Wednesday, October 17, 1900.*

## ALUMINIUM AT THE PARIS EXPOSITION (1900).

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BY PROF. JOSEPH W. RICHARDS,  
Member of the Institute and delegate to the Exposition.

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The five international exhibitions held in Paris, since the first, in 1855, have served as landmarks in the history of aluminium. The Palais de l'Industrie, which was demolished last year to make room for the new Art Palaces, housed the first exhibition of 1855, and in it aluminium made its first public appearance in the shape of a bar, lying on black velvet in a glass case, and labelled "L'argent de l'argile," "the silver from clay." Its production had been difficult, in a chemical laboratory, and it practically