How Time Balls Worked

Featuring

The Cincinnati Observatory

Birthplace for American Astronomy

By Leland L. Hite

Photo from the Cincinnati Observatory Center

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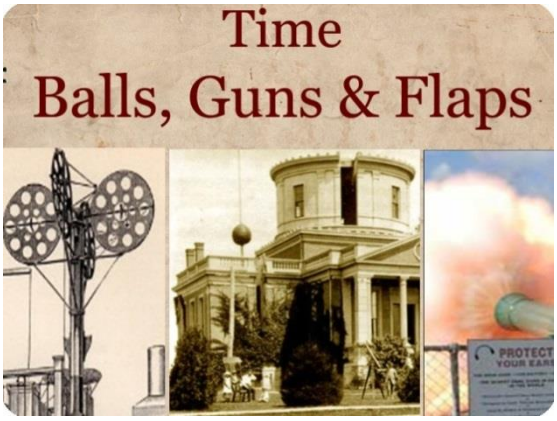
See the video illustrating over 200 worldwide time balls, guns, and flaps: http://youtu.be/mL7hNZCoa7s



July 1, 2014

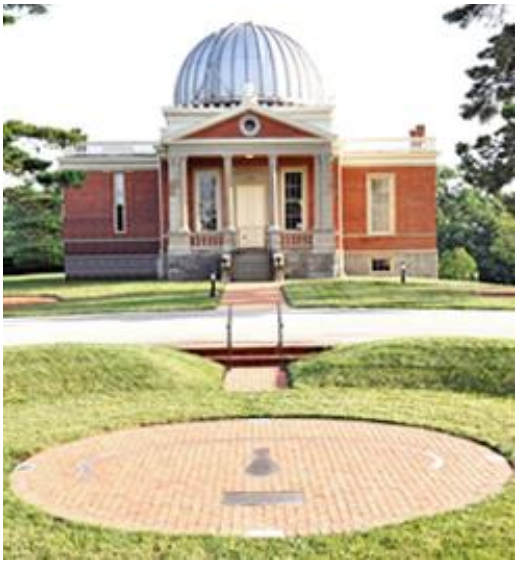
How Time Balls Worked

"Excuse me, do you have the time?" asks a person from downtown. "Sure, it is ten past ten o'clock," answers the person from Mt. Healthy. "Oh my, I have twenty past ten o'clock." Immediately, the person from Loveland speaks up to say, "You're both wrong. The time is twenty-eight past ten o'clock." Who is correct and how do you know?

How was time determined in the Greater Cincinnati area before radio signals, telegraphy, or other electronic methods? Perhaps your answer would include a shadow clock or maybe the pendulum clock. The question is how did a clock registering noon on the west side of Cincinnati coincide with a clock registering noon on the east side? Many citizens depended on railway time, but how did they decide the *correct* time? As civilization evolved and industrialization became popular, knowing the correct time both day and night was important.

To help understand the horology question is to look at how time is measured. Rotation of the earth determines our time, and, since about 3,500 BC, as noted by *Clock a History,* the earth's rotation has been acknowledged by observing the shadow position of the sun. The sundial and shadow clock are typical historical examples for determining solar time.

Two tasks, one of measuring the sun's position and one of displaying solar time, are achieved by a shadow clock. Located in front of the Cincinnati Observatory and often demonstrated to visitors by an outreach astronomer, the Planispheric Analemma Sundial can display time of day with a typical accuracy of 20 seconds. Bigger can be better, as demonstrated by the historic Stonehenge, often reported to accurately predict the rising and setting of the sun, moon, and stars.



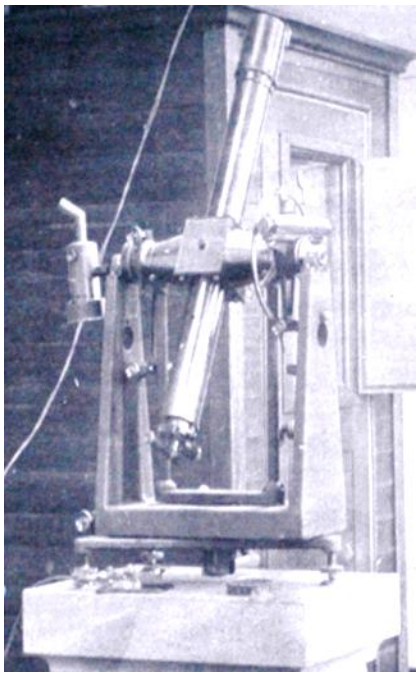
Precisely positioned brick, stone, and bronze make this Planispheric Analemma Sundial accurate to within 20 seconds and visible to all that visit the observatory. Image by L. Hite

An enigmatic structure appeared suddenly at the Cincinnati Observatory positioned around the Planispheric Analemma Sundial. According to Dean Regas, the Outreach Astronomer and Co-Host of the PBS program *Star Gazers*, it appears to be a recreation of the famous Stonehenge monument except made entirely from boxes. Was it made by a race of Celtic giants? Is it alien in origin? What civilization could've produced such a thing? And for what purpose? Image by Leo Sack, Cincinnati Observatory Center, COC

More accurate for the measurement of the sun's position than a sundial is the telescope. Solar time is noted by an astronomer observing the movement of the sun using a telescope constrained to move only in the plane of the observer's meridian. The telescope relies on the rotation of the earth to bring the sun into its field of view and is mounted on a fixed horizontal east-west axis. A *meridian circle telescope* and a *transit telescope* are descriptive terms associated with these special scopes.

Timekeeping for the Cincinnati area began at the birthplace of American astronomy, The Cincinnati Observatory, located on Mt. Ida in Cincinnati, Ohio. In 1843, Mt. Ida was renamed Mt. Adams after the observatory's cornerstone was laid by John Quincy Adams, former President of the USA.

To begin the process of determining time for the Cincinnati area, Superintendent Dr. A. D. Basche, from the United States Coast Survey, loaned the Mt. Adams Observatory its first transit telescope as noted on page 207 in Charles Cist's *Sketches & Statistics of Cincinnati*.



Mounted on a stone pier, the Buff & Berger transit telescope was operational from 1885 to 1888. Image from COC

Unlike the shadow clock, Basche's transit telescope did not display time. Instead, using the telescope, an astronomer observed the crossing of the sun at its highest point in the day. That observation of time was synchronized with the observatory's public clock donated by Wilson McGrew of Cincinnati. Mr. Twitchell, assistant to Professor Ormsby M. Mitchel, began regulating McGrew's Standard Public Clock in 1850, as mentioned on page 18 in the *Proceedings of The American Metrological Society*. Eventually this clock was upgraded to a Robert Molyneux pendulum clock.

A timekeeping outreach program for the public began when the observatory supplied correct time to four jewelry shops in the city below Mt. Adams, as noted in *Annual Report 2011,* Cincinnati Observatory Center. Citizens brought their pocket watches and other spring-driven clocks to the jewelry shops to find if their clocks were going fast or slow. Beginning in 1868 and under the leadership of Professor Cleveland Abbe, the observatory began regulating time more systematically for all the jewelry shops.

Founded in 1842 on Mt. Ida, the observatory was eventually closed because of atmospheric smoke caused by the burning of soft coal. Image from COC

Consistent with many observatories across the country, the Cincinnati astronomical observatory was the only source for exact time in Cincinnati until about 1910. This was not Greenwich Mean Time or Standard Time but Solar Time, or Astronomical Time, or Observatory Time.

To get away from the downtown pollution caused by the burning of soft coal, the Cincinnati Astronomical Society decided to close the observatory. The society constructed a new observatory, now owned by the University of Cincinnati, five miles east of the city in 1873. This move to Mt. Lookout caused the need for a different method of communicating time to local farmers and the citizens of Cincinnati. Former assistant at the U.S. Naval Observatory and director for the Cincinnati Observatory from 1875 to 1882, Ormond Stone instituted the observatory's time ball in cooperation with the Army Signal Service, as reported in the *American Metrological Society Proceedings*. Used in Cincinnati and around the world, particularly along coast lines, this unique method for signaling correct time expanded the observatory's outreach to the public. A 5-foot diameter wire frame ball made from Bessemer steel and covered with black canvas was mounted to a 60-foot pole attached at the rear of the Cincinnati Observatory as explained in the *Construction and Maintenance of Time Balls*. At exactly noon, anyone with a line of sight to the top of the pole could find the correct time by observing a free-fall drop of the ball.

Signaling noon time from the Mt. Lookout Observatory using the time ball lasted from about 1879 to about 1884. Image from COC.

Precisely 15 minutes before noon, the ball was raised, using a windlass, to half-mast, and, at 5 minutes to noon, the ball was lifted to the top, providing viewers with 15-minute and 5-minute advance notices. At astronomical noon in Cincinnati, the ball dropped free-fall style. A hand-operated Prony friction brake allowed the ball to stop gently before the end of its 30-foot travel.

In a handwritten letter from Julius Dexter to A. J. Goshom, dated 16 December 1870 and reprinted in *Chairman of Special Committee of the Common Council of Cincinnati on Standard Public Time*, the observatory sold time to downtown Cincinnati from 1877 to October 1882 for a payment of $1,000 per year.

Synchronized with the observatory's clock, the new City Clock was destined for Fountain Square in downtown Cincinnati as the official city timepiece. Due to a misunderstanding with the telegraph company, this program was not implemented, and, instead of being installed on Fountain Square, the clock landed in a convenient and conspicuous position on the corner of the Carlisle Building, which was at Fourth and Walnut Streets. (See page 8 of *The Cincinnati Enquirer*.)

The Carlisle Building, located at the corner of Fourth and Walnut Streets, featured a time ball and an outdoor clock, both synchronized with the observatory. Image from The Greater Cincinnati Memory Project and the Public Library of Cincinnati.

Encased in an attractive galvanized iron housing ornately designed by the prominent Cincinnati architect for the Carlisle Building, Albert C. Nash, this gas illuminated Ritchie & Son clock from Edinburgh, Scotland, became the city timepiece. The iron enclosure was funded by Sarah B. Carlisle, owner of the Carlisle Building.

Reported on page 12 of *The Cincinnati Commercial* for April 29, 1877, "The details harmonized well in the way of pilasters, belt courses, panels, ornaments, balconies and general proportions in connection with the main building." Support for the 15-foot high clock housing was from a 5-foot-square turret mounted at the beginning of the fourth floor.

The Cincinnati Commercial added that this clock and a companion Ritchie & Son master clock for the observatory cost the city of Cincinnati $2,500.

Clocks manufactured by James Ritchie & Son, Edinburgh, Scotland, were acquired with one clock for the Carlisle Building and a second clock as an upgrade to the observatory's master clock in 1873.
Photo by L. Hite

The Kilgour family, owners of the telephone company (See *Cincinnati Views*.), donated lines for transmitting time signals from the observatory to the downtown clock, as well as the free use of a telephone and telegraph at the observatory, as explained in Charles H. Woodward's dissertation, "The History of the Cincinnati Observatory Since 1870." Ormond Stone proclaimed that anyone was welcome to connect lines to the observatory line and that he enjoyed the free telephone privileges.

Professor Smyth was responsible for installing the time ball on top of Nelson's Monument in Edinburgh, Scotland, in 1853. Image from Edin Photo

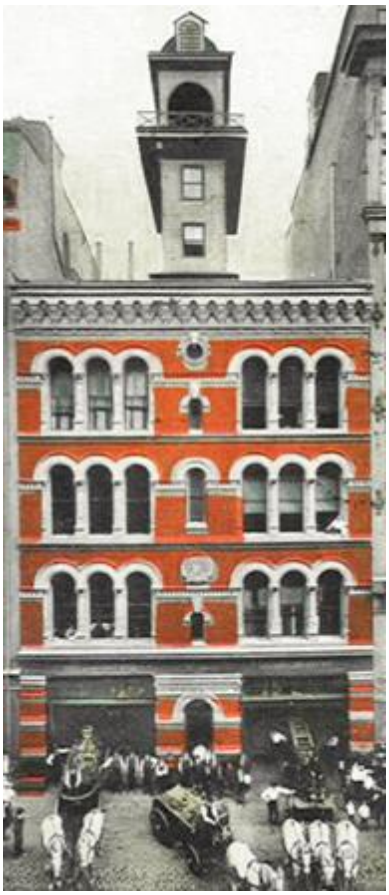
Clock construction was supervised by Professor Charles P. Smyth of the Royal Observatory in Edinburgh, Scotland, and, upon completion, the clock was set up, thoroughly tested by him and his assistants, and pronounced a perfect time-keeper. A set of wires, using the Jones method of signaling, connected the City Clock with the clock at the Cincinnati Observatory so the beating of the two clocks was simultaneous. The Ritchie & Son clock, therefore, indicated exact time for the city of Cincinnati.

A time ball was arranged to drop from the top of the Carlisle Building beginning July 18, 1881, as noted on

Shown is the time ball mounted on the roof of the Carlisle Building at Fourth and Walnut Streets. Image from Phorio (Public Library of Cincinnati and Hamilton County. Genealogy & Local History Department). Illustrated News – Great Exposition Number, August 21, 1886, page 17.

page 66 of the *Ohio Chamber of Commerce and Merchant's Exchange*.

According to page 19 in *Construction and Maintenance of Time Balls*, the 3-foot diameter wire frame ball was mounted to a 30-foot pole and dropped 15 feet at noon. Repeated communication-transmission problems between the observatory in Mt. Lookout and the Carlisle Building caused the ball not always to drop on time. Duhme & Co. jewelry shop paid for the construction and operational of the time ball apparatus while Mr. Carlisle paid for the cost of building the time ball.



Because the University of Cincinnati would not allow a telephone at the observatory, the noon fire bell at the Central Fire Alarm Office for the fire department failed to ring on time. Image from Cincinnati Views

Unfortunately, this time ball service to the citizens of Cincinnati was short lived, lasting only 15 months. The telephone company, in accordance with the vote from the Board of Directors of the University of Cincinnati and the operator of the observatory at their meeting in September 1882, removed the telephone from the observatory.

The phone company then refused to transmit further time signals over their line without the presence of a telephone in the observatory. As explained on page 22 in the *Annual Report of the Directors*, no satisfactory arrangements resulted from this decision, and, on 6 October 1882, the president of the Telephone Company removed the line that transmitted a time signal between the observatory and downtown.

By removing the telephone line that transmitted the synchronized time signal from the observatory to the Carlisle Building and to the Central Fire Alarm Office downtown, the city of Cincinnati no longer enjoyed accurate time.

This telegraphy activated fire and time bell sounded at the Milwaukee (Wisconsin) Fire Department. Image from Old Fire Stuff

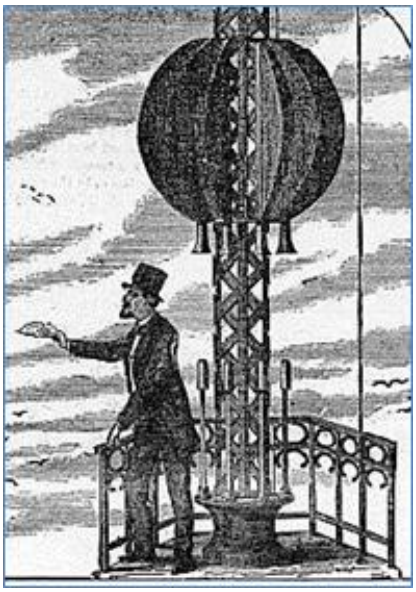
As a consequence, the city's time became irregular. When there had seldom been an error of more than one or two seconds, the noon fire bells for the first professional fire department in the United States were often two or three minutes in error! The dropping of the time ball on the Carlisle Building ceased; however, the Ritchie & Son clock on the same building continued to keep excellent time. The large iron enclosure built around the clock in 1877 so reduced the effect of temperature upon the rate of the clock that it was possible to predict its error within less than a second over a span of 10 days. The clock remained in operation until 1913, when it was transferred to City Hall.

Telegraphy problems between an observatory and a remote time ball were somewhat common. When communications failed, typically a red flag flew atop the time ball pole to announce no time mark today. If for some reason the noon signal from Washington, D.C., was not received at the Western Union Building in New York, a red flag was raised and flown from 12:01 until 12:10, as noted by *Inside the Apple*.

Occasionally a time ball would drop a few seconds late, and, when this occurred, the ball was again raised and lowered for the same number of seconds it was tardy.

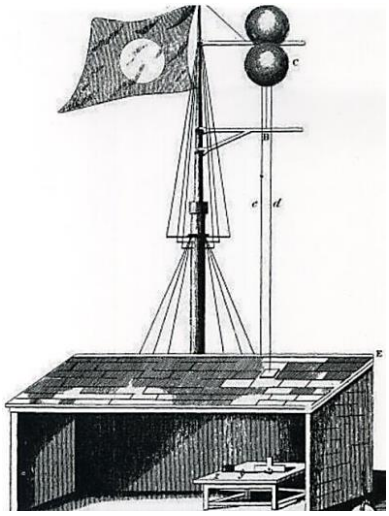
The red flag indicated no time ball today on the Western Union Building in New York. Image from Inside the Apple

Invented in 1819 by Captain Robert Wauchope, a British Admiral, and reported in *A short Narrative of God's Merciful Dealings*, the concept of the time ball was to save a ship's navigator, often the captain, from coming ashore to set a chronometer. (See the *One o'Clock Gun & Time Ball Association*.) Knowing the exact time is critical to establishing exact longitude. As explained in The "American Method," any location on earth can be mapped by knowing the longitude and latitude of the observer. Because the earth rotates 15 degrees of longitude per hour, the E-W position can be determined by a chronometer, and the determination of latitude, the N-S position, can be made by using a sextant to measure a star's position.



This is the Western Union finned time ball mounted on the Equitable Life Insurance building in New York. Image from Western Union Time Ball

First erected at Portsmouth, England, in 1829, an experimental time ball station was set up using two balls, one fixed at pole top and one droppable, as mentioned on page 5 in Marking Modern Times in Urban America. The expectation was that an observer on board a rolling ship might be unable to decide if a single ball had fallen but could decide if two balls had separated. The lower ball dropped at precisely noon. The top ball was removed after learning an observer could accurately identify when the lower ball dropped.



Here may be seen the original time ball design by Captain Robert Wauchope. Image from Maritime Time Signals Collection

Not always a ball and not always smooth were alternate shapes used by some observatories. Light weight was a concern for some and accomplished with semicircular fins made from thin copper sheets and placed about a central axis. Viewed from a distance, the finned structure appeared as a round ball and

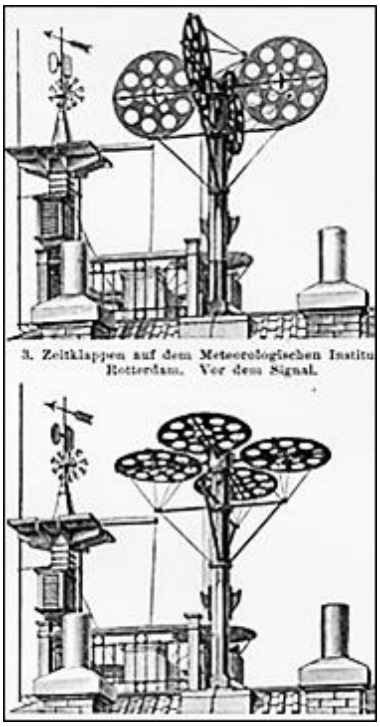
was easier to lift than the metal clad ball.

Other observatories selected a lightweight ball-shaped basket frame to reduce the dropping weight and wind resistance. Additional shapes included a cylinder, a cone, and a vertical disk.

Here is a time ball with basket shape at Gdansk, Poland. Image from Wikipedia

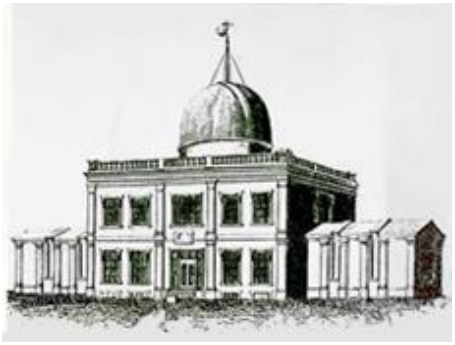
Eliminating the dropping mechanism was important to other observatories and easily accomplished using a time flap. A thin round metal disk, often with lightening holes, rotated from the vertical position to the horizontal position at the designated time mark. From a distance, an observer easily saw the ball shape disappear and thereby received the intended time signal from the observatory. Most often, two flaps, one in the N-S direction and the other in the E-W direction, assured visibility from all directions.

The first time ball signaling of solar time began at the Greenwich Observatory in England in 1833.



This illustration depicts time flaps at the Rotterdam AS Meteor Institute. Image from Etsy

Global time, known as Greenwich Mean Time (GMT), was not used as a worldwide standard until 1954 and is known as *sidereal* (from a Latin word for *star*) time based on stellar observations, not solar time.



Here is the first U.S. time ball at the Naval Observatory in Washington, D.C., in 1845. Image from U.S. Navy

The first time ball in the United States was established at the U.S. Naval Observatory in Washington, D.C., about 1845, as reported in Timekeeping at the U.S. Naval Observatory. The ball attached to a flagstaff atop the 9.6-inch telescope dome perched on a bluff above the Potomac River. (See *A Brief History of the Naval Observatory*.) Released by hand, the ball dropped on the observatory's dome and rolled to the roof below, where it was hoisted by hand to pole top the next day. The observatory's time ball was upgraded and relocated to the State, War, and Navy Department Building in 1885 and was last dropped in 1936.

Before 1883, there was no standard time in the United States, but, in the late 1800s, many major cities had time balls. At noon, people looked up from their work to see the ball drop and check their watches for accuracy. Everybody wanted to be "on time," and the time ball was a signal that a town could depend on.

Jewelers synchronized small-sized time balls in their display windows with their local observatory causing the ball to drop at noon, signaling solar noon in that city. (See page 6 in Marking Modern Times in Urban America.)

A miniature time ball in an Albany, New York, jewelry shop window, and connected to the Dudley Observatory, was the city's public time signal from 1861 until 1867. Between 1863 and 1867, the Detroit Observatory, which received time signals from the University of Michigan, Ann Arbor, sent a signal to a miniature time ball in a jeweler's window in Detroit.

Often jewelry stores displayed an electric clock outside their doors, each store claiming to have the correct time. Observatories sold their time to various organizations such as railway systems and jewelry stores.

A miniature remote-controlled time ball ornaments a jewelry shop window. Image from

Time balls require a line of sight to be effective, but a time gun does not. Not as accurate as a time ball unless the observer could see the gun smoke, a time gun was appreciated by those lacking time ball visibility. Five seconds will pass before the sound from a time gun travels one mile, and an observer at a distance of 5 miles will receive the time mark 25 seconds late. Correction tables were provided to surrounding towns that detailed the expected delay from the gun shot and thereby allowed citizens to set time accurately. Time guns were widely adopted around the world but not often in the United States.

The Cape Town, South Africa, noon time gun fires daily. Image from Cannon Association of South Africa

During the 1860s and 1870s, as the railway system expanded, trains were traveling through 49 city-centered solar time zones. For example, depots with more than one railroad passing through typically had a clock for each railway system, such as the depot in Kansas City, Missouri, with five

clocks for its five railroad times. Consequently, depots had difficulty keeping their schedules on time, and that resulted in accidents and loss of life.

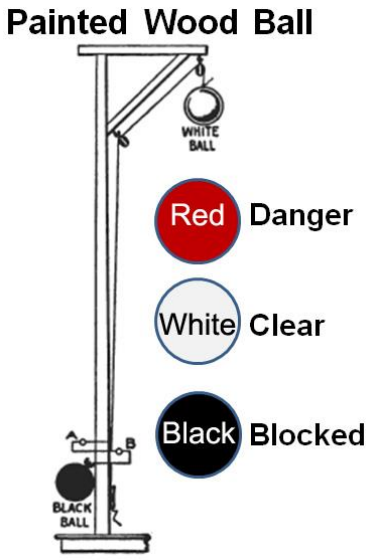
Railways then began purchasing time from astronomical observatories in selected cities. As taught by the largest telegraphy school in the western hemisphere, The Dodge Institute of Telegraphy in Valparaiso, Indiana, OST, Observatory Standard Time, was the only standard time recognized by a railway line. At 11:00 a.m. daily, OST was telegraphed to all points on the railway. (See page 107 through 108 in *The Telegraph Instructor* by George M. Dodge.) In the Midwest, RST, Railway Standard Time, referred to as CST, Central Standard Time, set the station Railway Standard Clock.

Western Union Time was placed in synchronicity with the U.S. Naval Observatory. Image from Timekeeping at the U.S. Naval Observatory

All engineers and conductors carried watches certified by railway time inspectors. Prior to starting a trip, conductors and engineers registered their names and the time after comparing their watches to the telegraph office station clock as required by the railway company.

In the late 1860s, Western Union synchronized designated clocks in principal cities by telegraph with the U.S. Naval Observatory. Eventually this practice spread across the country and became known as Western Union Time.

Railway companies established four provisional time zones in 18 November 1883 to coordinate their train schedules: hence Standard Railway Time. Eventually, railway companies petitioned Congress, which passed the Standard Time Act in 1918 to make railway time zones into law for all of us, as noted in *This Day in History.*



The railway safety signaling system used a ball raised to pole top for a passing train. Image by L. Hite

Long after passage of the 1918 Standard Time Law, Cincinnati remained one of the few places in the country where most citizens obstinately refused to use standard time. (See page 9 in *Time Balls: Marking Modern Times in Urban America*.) Instead, many Cincinnatians kept local solar time while others used only railway time.

The Standard Time Act did not solve all the issues with train schedules. For example, Jim Tripp, a telegrapher at the Grand Trunk RR Station in Valparaiso, Indiana between 1960 and 1963, says, "The interesting things at Valpo were issues with time zones. Our train schedules were always in Central Standard Time, even in the summer. Valpo is close to Michigan, which is on Eastern Time, either Daylight or Standard, and it is also close to Illinois, which is on Central Time. It got to the

point that, if someone called to ask when a certain train arrived, I would always ask first, what time do you currently have, and many thought I was being smart with them, but I needed to convert their local time to our scheduled time."

The railways quickly adopted the concept, known as Ball Signals, of positioning a ball on a pole to communicate safety conditions ahead on the track. At pole top, a white ball indicated a safe condition ahead, and a blocked track was signaled with a black ball showing. Often the engineer would not slow down for a crossing when a white ball was at pole top, and that behavior became known as "highballing a crossing." Red balls were eventually added to the railway signaling protocol to signal danger ahead. As described in *Early Railroad Signals*, beginning in 1869, a ball-shaped structure mounted on a pole and looking like an inverted banjo was named the Banjo Signal. The ball icon remains today a practice used in railroading to communicate a safety condition.

Here is a danger ahead signal at North Conway, New Hampshire. Image from archlapeer

The 100-day Centennial Exposition of the Ohio Valley and Central States in 1888, held in Washington Park, Cincinnati, featured a William Gardner patented time ball as its central attraction. Located in the Park Building on Elm Street, the time ball was placed on a platform 16 feet high and 8 feet square and erected in the glass-enclosed tower over the main entrance to the Park Building. (See page 63 in the *Centennial Exposition of the Ohio Valley and Central States*.)

A time ball was the central attraction of the Park Building on Elm Street. Image from Official Guide of the Centennial Exposition

Facilitated by the Western Union Telegraph Company, a noon time ball dropped and 5 time gongs sounded from a telegraphy trigger signal sent by the U.S. Naval Observatory in Washington, D.C.

As explained on pages 227 through 232 in the *Annual Reports of the Navy Department*, opening ceremonies for the 1888 Exposition featured a time gong temporarily placed on the stage at Music Hall in Cincinnati. Triggering the gong was a telegraphy signal sent from Nashville, Tennessee, by Mrs. James K. Polk, wife of the former President of the United States.

William F. Gardner was the leading instrument maker for the U.S. Naval Observatory, and five Gardner clocks showing Intercolonial (sixtieth meridian), Eastern, Central, Mountain, and Pacific Coast Time, respectively, were kept running continually and corrected daily by the

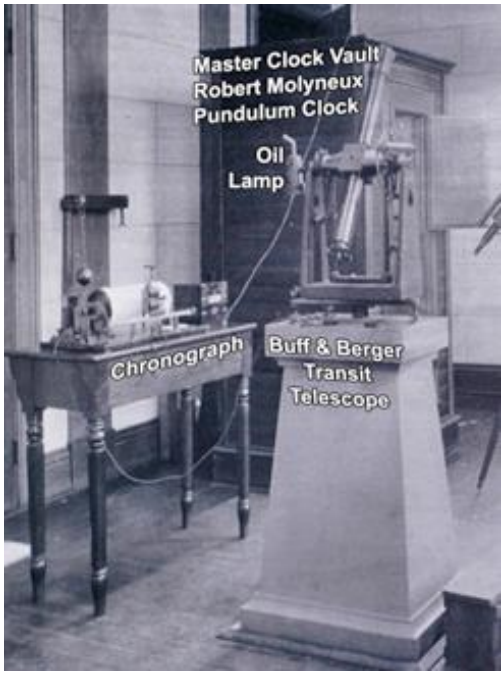
noon signal from the Naval Observatory.

To continue providing time to the citizens of Cincinnati from downtown, Shillito's Department Store in Cincinnati began using an Audichron talking clock in 1939, as reported by John Ventre. The device transmitted time to Cincinnatians via the telephone. Customers telephoned Parkway 1700, and a woman's voice gave a short advertisement for Shillito's before telling the time, hour, and minute. The telephone time service (plus weather) still functions today, sponsored by Cincinnati Bell. Give it a try by calling (513) 721-1700.

An Audichron talking clock announced the time, hour, and minute. Image from Wikipedia

The 167-year-old Robert Molyneux pendulum clock kept time for the city of

The first weather service in the USA was formed at the Cincinnati Observatory on 1 September 1869. Professor Cleveland Abbe, director of the observatory, telegraphed western points to get weather readings, and he noticed that similar weather showed up in Cincinnati two or three days later. Abbe published a weather bulletin of the Cincinnati Observatory that included trial 24-hour weather forecasts. Eventually, the network grew to more than 17 stations located mostly west and south of Cincinnati before merging with the Signal Service network in 1870. Washington, D.C., took notice and asked Abbe to start the National Weather Service!



Mounted on a stone pier near the chronograph in the transit viewing room, this Buff & Berger Transit Telescope features an oil lamp for illumination of the cross hairs. Image from COC

As an important detail in the history of the time ball, the copper-clad ball in Sidney, Australia, weighs over 265 pounds and is cushioned at the end of its fall by a soapy water shock absorber. An opening in the side of the ball allows a small person to enter and sit on a tiny wooden seat inside the ball, as reported in this video: *Sydney's Secrets*. Imagine the thrill experienced from the two-meter free fall before hitting the absorber!

The Going Time at the Observatory

Beginning in 1847, Professor Ormsby M. Mitchel purchased a transit

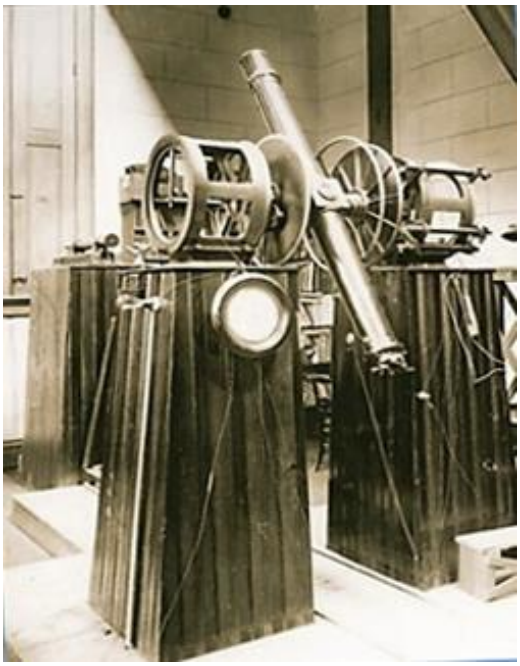
instrument for determining solar time at the observatory. (See the *Three-Inch Transit of the Cincinnati Observatory*.) Mean solar time at the Cincinnati Observatory was eventually determined by a 3-inch transit telescope, in use by 29 July 1878 and made by Buff & Berger from Boston, Massachusetts. It was synchronized to the Robert Molyneux master clock. The clock was a weight-driven pendulum mechanism manufactured in London during the mid-1840s with a mercury filled temperature compensating pendulum. This clock kept time for the city of Cincinnati from 1848 to 1873.

Mounted on a solid stone pier in the transit room, the clock was free of vibrations from the building. In 1880, a large wooden case, 3 feet 8 inches square on the outside, was built around the clock to prevent sudden changes of temperature and may be seen in the background of the Buff & Berger Transit Telescope picture. The case was constructed with double walls. As reported in *The Cincinnati Observatory, Birthplace of American Astronomy* (2006), a window of 3 panes of 3/8 inch plate glass, with air spaces between the panes, enabled the observer to see the face of the clock and the thermometer hung within, without opening the air-tight case.

The clock remained at a stable temperature while the observing room that housed the transit telescope followed the temperature outdoors. As the outdoor temperature varied, so did the temperature of the telescope. This practice of always keeping the scope at the outdoor temperature minimized sudden thermal changes for the lens and mechanism.

As the pendulum swung back and forth on the Robert Molyneux clock, a needle attached to the bottom of the pendulum contacted a pool of mercury that opened and closed an electric connection to a sounding device in the transit room; hence clock time was communicated by the click of the sounder to the astronomer viewing the stars through the Buff & Berger telescope.

Occasionally, the astronomer adjusted the clock to match exact solar time observations at the observatory. More often, the astronomer noted the clock was going fast or slow and recorded that error rate in an observatory time log.



The Fauth & Co. Meridian Circle Telescope, located in the transit viewing room, is mounted to cast iron piers and features the Hipp Observatory (slave dial) clock attached to the front left-hand pier. Image from COC

Note that to the left of the Buff & Berger stellar Transit Telescope pictured in the viewing room rests a chronograph on the small table. Ormsby M. Mitchel developed probably the first working chronograph for automatically recording the beats of a clock, a necessity for exact timing observations. The chronograph also served a larger program to automatically transmit time and observational information in "real time" over telegraph wires. (See page 4 in *The American Method of Transits*.)

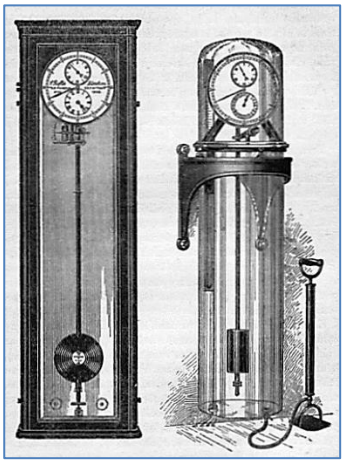
The Fauth & Co. Meridian Circle Telescope with the sliding bench is shown prior to shipment from the factory. Image from

As reported by the Cincinnati Observatory Center, in 1873, when the observatory moved from Mt. Adams to Mt. Lookout on four acres of land donated by board member John Kilgour, the master clock for the observatory was upgraded to a pendulum clock manufactured by James Ritchie & Son, Edinburgh, Scotland.

In September 1888, an upgrade to the transit telescope was enjoyed by the astronomers following the installation of the Fauth & Co. meridian circle telescope manufactured in Washington, D.C. The telescope was located in the transit viewing room.

The Hipp Observatory (slave dial) clock from Peyer Favarger & Co. was controlled by the Riefler slave clock in the master clock vault and was visible to the astronomer operating the Meridian Circle Telescope.
Photo by L. Hite

An astronomer reclined on a bench, mounted on sliding rails, under the eyepiece for the telescope and observed the crossing of the sun at its highest point in the day. That observation of time was then synchronized with a Hipp Observatory (slave dial) clock from Peyer Favarger & Co., Neuchatel, Switzerland, mounted on the meridian telescope. The slave dial clock was synchronized with the master clock.



Located in the master clock vault, the Riefler clock system comprised the slave cabinet clock and the master tank clock with the attached hand-operated air/vacuum pump. Image from Clock Systems of the Cincinnati Observatory

Between 1904 and 1906, electricity was installed at the observatory. The master clock was again upgraded in 1909 using the system of Riefler pendulum clocks, accurate to about 10 milliseconds per day. The Riefler master tank clock, SN 225, and the Riefler slave cabinet clock, SN 212, are pictured later in the photo gallery and are located in a temperature-stabilized vault in the basement of the observatory. Pages 344 through 351 in *Popular Astronomy*, Vol. XIX (1911), reported that wood was not used in the construction for the glass-enclosed clock made in

Germany by Clemens Riefler, thereby eliminating expansion or contraction of clock parts caused by the presence of moisture.

Corrections to the slave clock used the traditional pendulum length adjustment; however, corrections to the Riefler tank master clock required adding or removing air on the inside of the sealed glass tank using a hand air/vacuum pump.

Looking through a double glass viewing window into the clock vault, the astronomer observed both the master clock and the slave clock without entering the room. Every 35 to 40 seconds, the master clock battery-powered winding mechanism activated. An occasional visit to the inside of the vault was necessary to adjust the air pressure in the glass-enclosed master clock or to change batteries.

Master clock time was communicated to the astronomer, upstairs in the transit viewing room, using the slave clock in the vault. The slave clock was synchronized to the Hipp Observatory (slave dial) clock mounted on the support pier for the meridian circle telescope. This arrangement allowed for convenient viewing of the master clock time by the astronomer.

The Western Electric Company 1.5 Volt carbon battery was a typical power source for the Riefler clock system. (See the photo gallery.)

Solar time is measured by the apparent diurnal motion of the sun. Cincinnati noon in solar time is the moment when the sun is at its highest point in the sky (exactly due south or north depending on the observer's latitude and the season). The average time taken for the sun to return to its highest point is 24 hours. When the observatory moved from Mt. Adams to Mt. Lookout, OST was 19.1 seconds later.

A sidereal day is about 23 hours, 56 minutes, 4.091 seconds, corresponding to the time it takes for the earth to complete one rotation relative to the vernal equinox. During the time needed by the earth to complete a rotation around its axis (a sidereal day), the earth moves a short distance (approximately 1°) along its orbit around the sun; therefore, after a sidereal day, the earth still needs to rotate a small extra angular distance before the sun reaches its highest point. A solar day is nearly 4 minutes longer than a sidereal day.

Historian and former director of the Cincinnati Observatory Center, John Ventre demonstrates to a group of visiting engineers the vintage 1845 Merz and Mahler refractor telescope, located in the Ormsby M. Mitchel building.
Photo by L. Hite

Leap year is based on the sidereal year, the period that it takes the earth to orbit (revolve around the sun) in reference to a distant star. The period is 365.25636 days; hence, every four years, the earth's place in reference to the first point of Aries is off by one day, which is the ascending node of the intersection of the celestial equator and the ecliptic. To keep the astronomical year in sync

with the calendar year, an extra day is necessary on 29 February every four years, with a few exceptions on the century years.

People govern their daily lives via solar time, and the observatory's telescopes run on sidereal time.

Acknowledgments

I thank John Ventre, historian and former director of the Cincinnati Observatory Center, for providing valuable details, technical editing, and important documents, along with an enlightening perspective on history.

I thank Dr. Robert T. Rhode for his important assistance with editing. Check his site, www. roberttrhode.org, where you find fascinating "Books and eBooks from the HeartLand" and several free documents to enjoy, including original portraits of famous authors painted in the sumi-e tradition, greeting cards, and suggestions for writers.

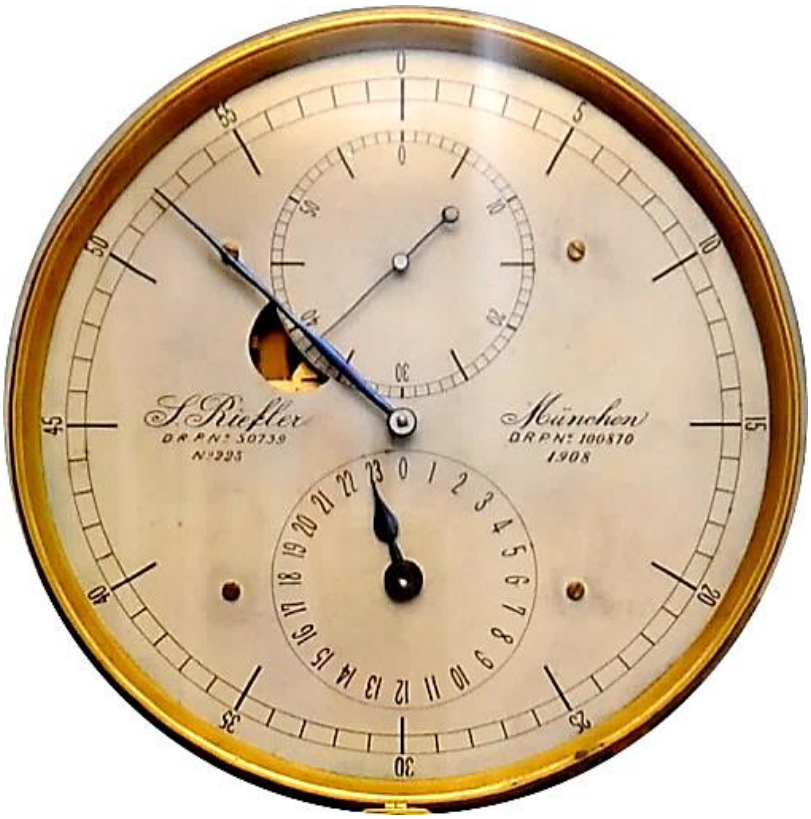
I thank Klause Huelse, from Germany, for making available to all of us his wonderful collection of pictures for time balls, time flaps, and time guns. Please see his site at: http://www.leuchtturm-welt.net/HTML/TIMEBPK/TIMEBALL.HTM for additional collections of historical pictures.

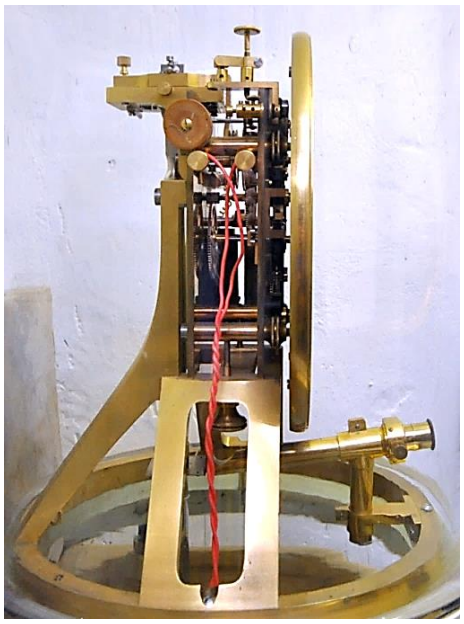
The Ormsby M. Mitchel building at the Mt. Lookout Observatory is situated next to a circular brick patio featuring wrought iron benches. Photo by L. Hite

Photo Gallery

The Riefler & Company Master Tank Clock, mounted on a 3-inch thick marble stone located in the clock vault, is shown with the hand air pump used to evacuate the glass sealed clock chamber.

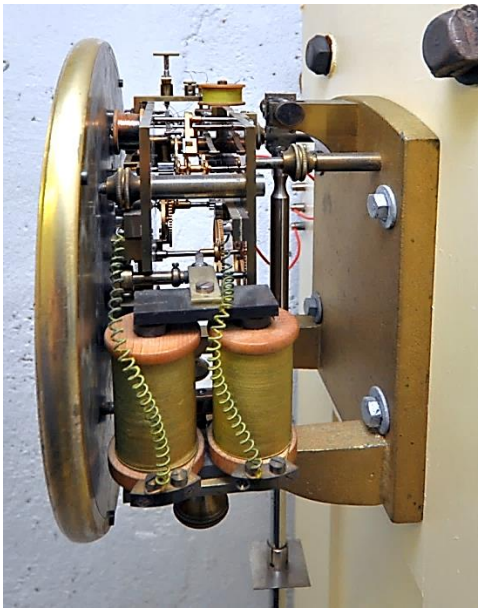
Corrections to the Riefler tank master clock required adding or removing air on the inside of the sealed glass tank using a hand air/vacuum pump shown below. Every 35 to 40 seconds, the master clock battery-powered winding mechanism activated.

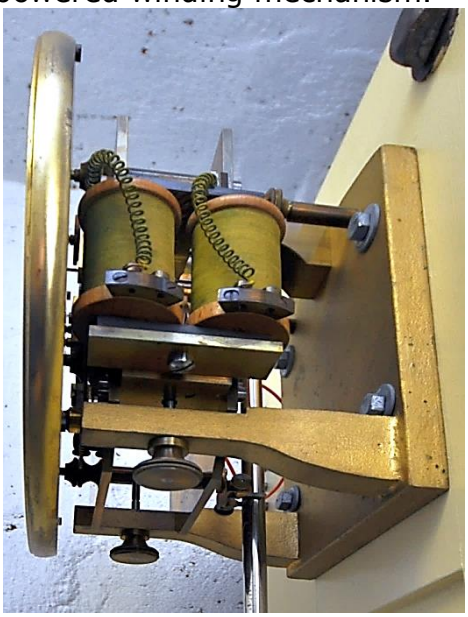




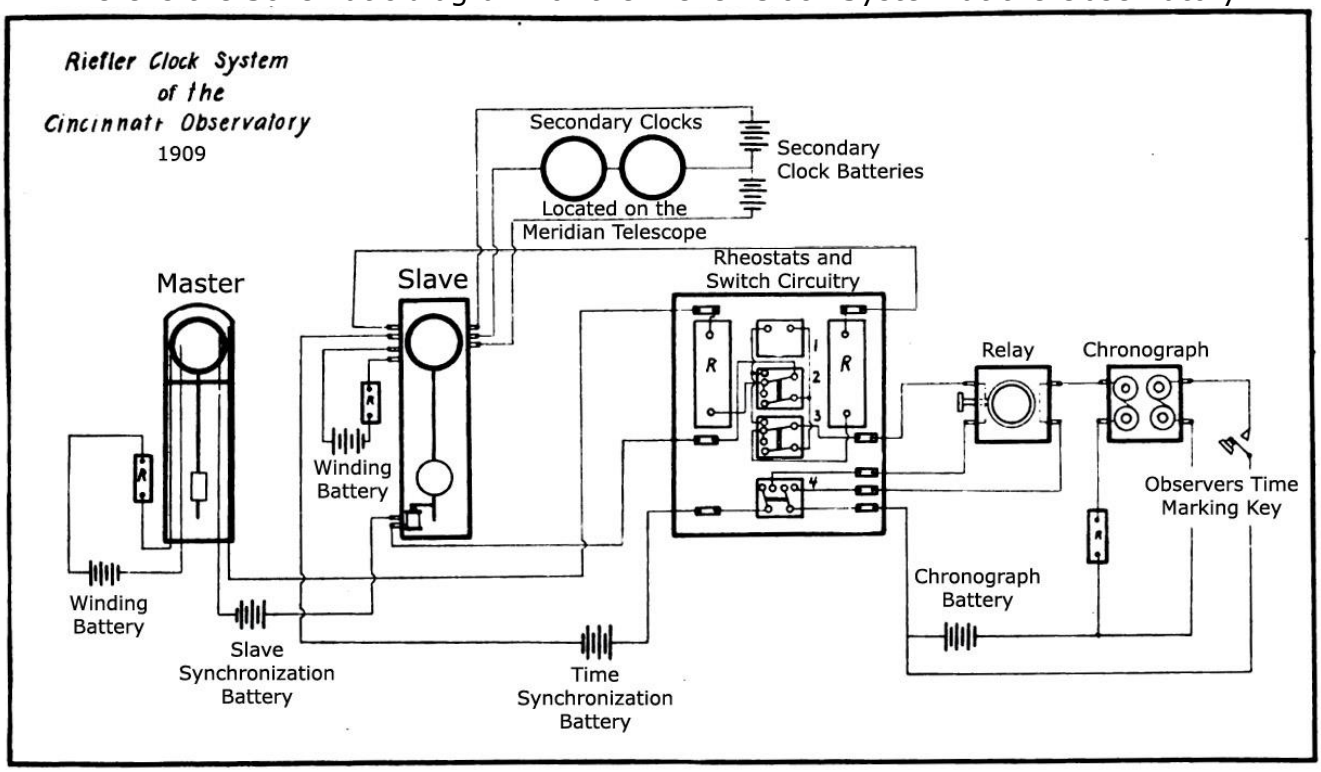
The Riefler Slave Clock is in the clock vault.

Here is the Riefler Slave Clock battery-powered winding mechanism.

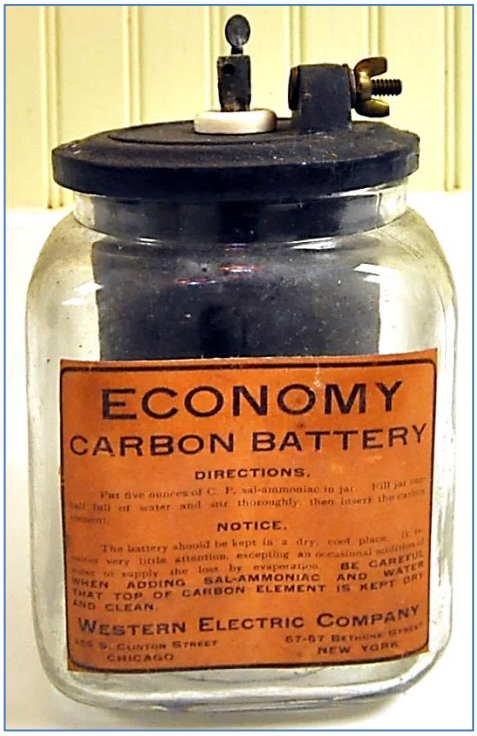


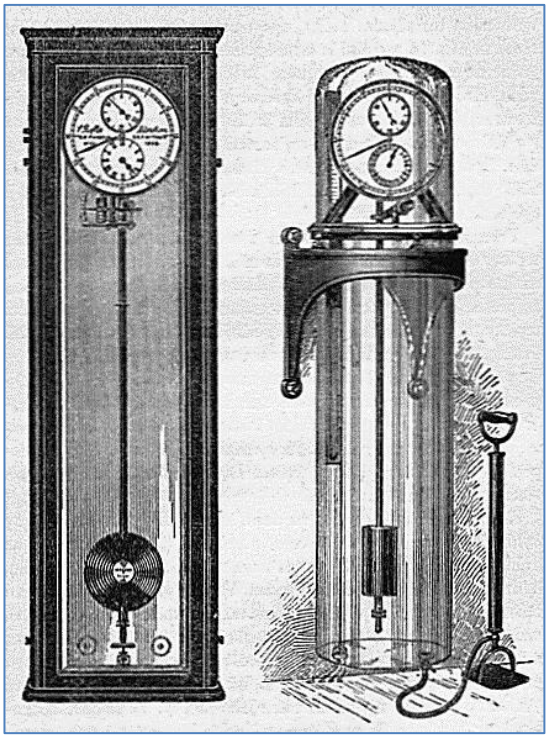


Here is the Schematic diagram for the Riefler Clock System at the Observatory.

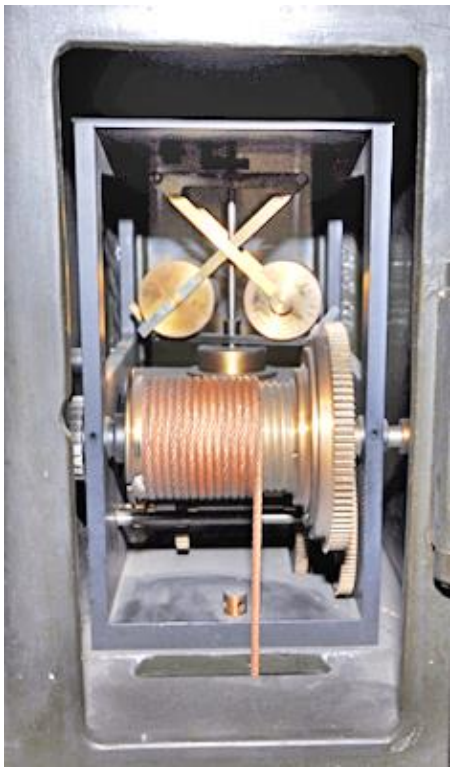


The Western Electric Company 1.5 Volt carbon battery shown below was a typical power source for the Riefler clock system pictured beside the battery including the hand operated air/vacuum pump. Also shown is the rheostat used to control current flow to the slave and master clock.



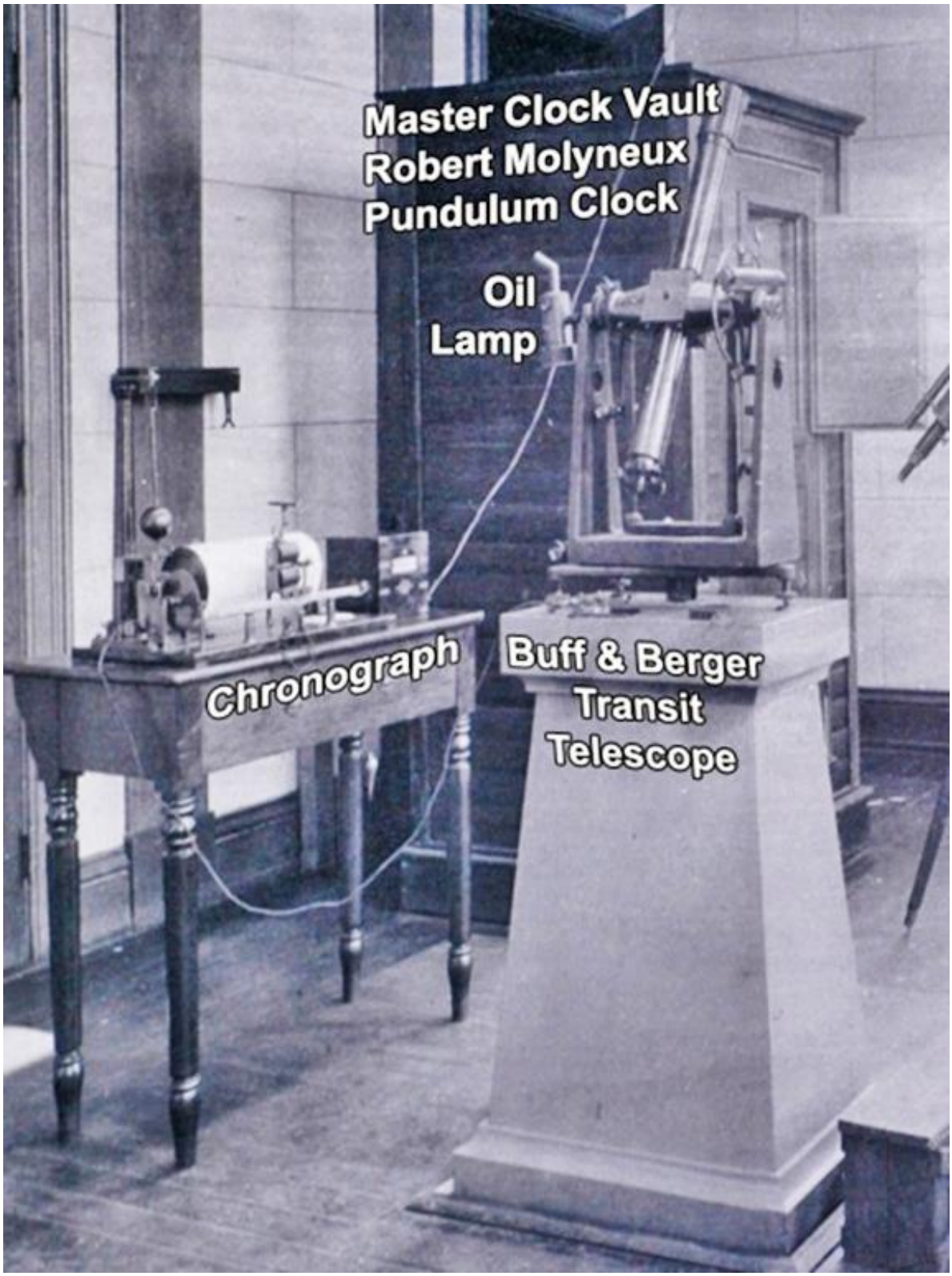


Here is the Warner and Swasey Co. Drum Chronograph made in Cleveland, Ohio.

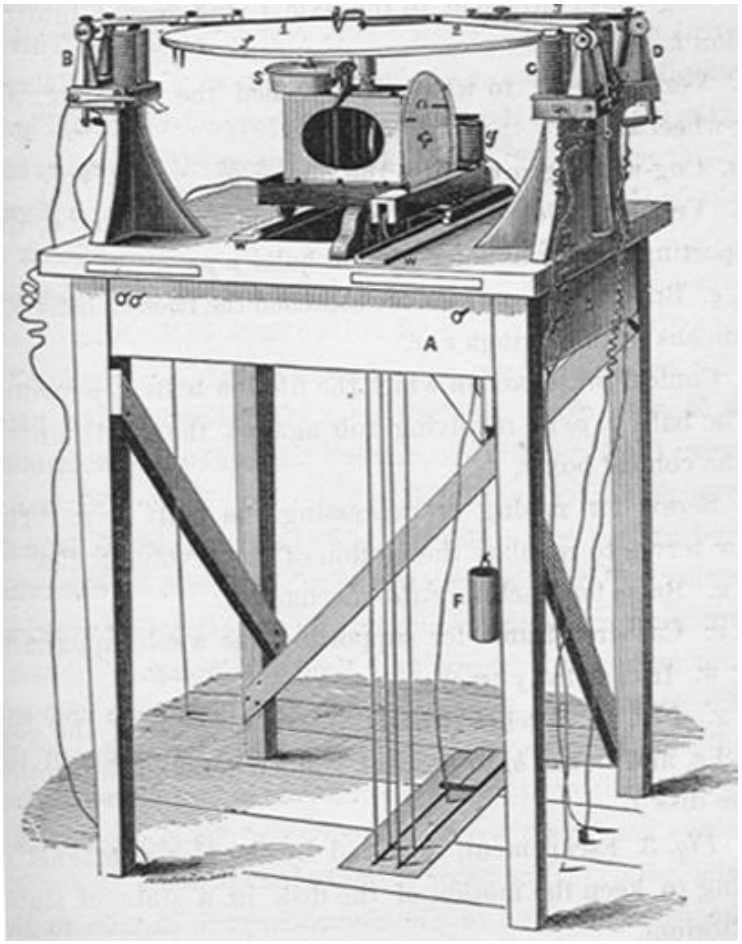


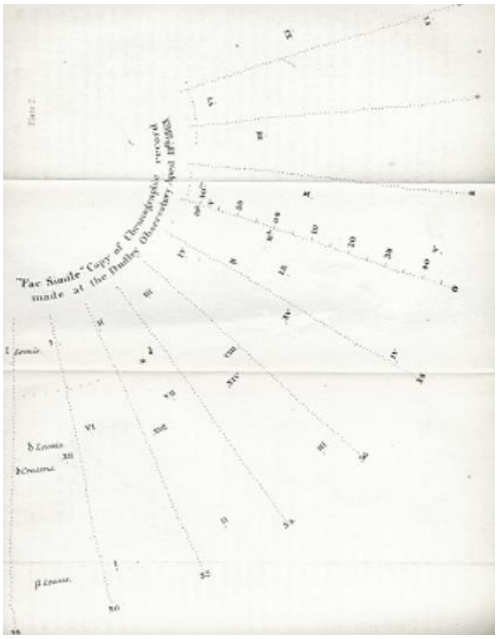
The transit viewing room is now a classroom. Note the center viewing window in the far wall and in the ceiling.

The Buff & Berger transit telescope mounted on a stone pier, the drum chronograph, and the vault for the Robert Molyneux master clock are shown in the transit room below.

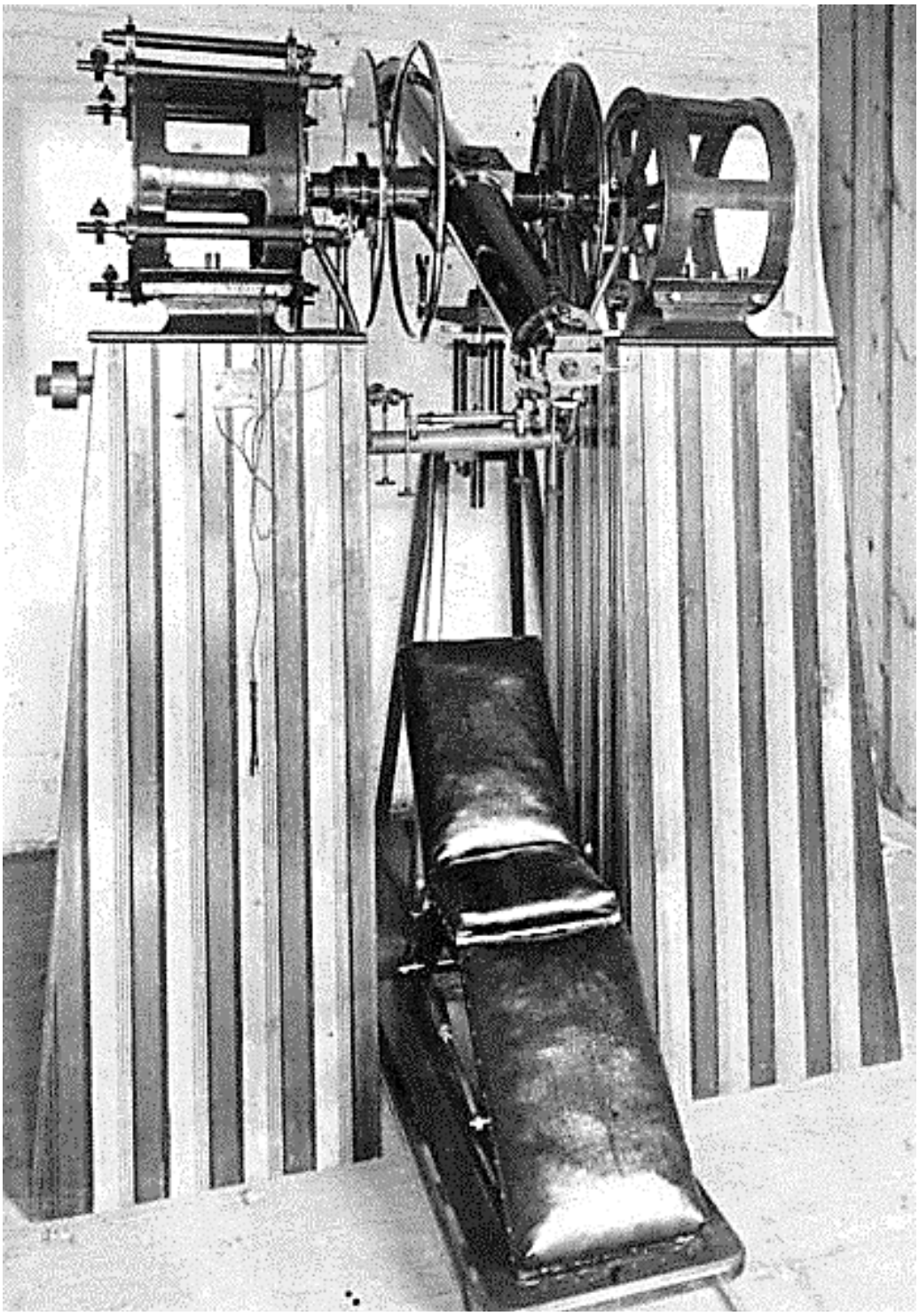


The revolving-disk chronograph with its accompanying disk-chart, developed by Ormsby MacKnight Mitchel in 1849, was probably the first working chronograph for automatically recording the beats of a clock. A flat disk 22 inches in diameter—made by pasting a dampened sheet of paper over a circular wooden hoop, which dried to become as taut as a drumhead—revolved horizontally once per minute. A make-circuit clock marked every other second with a tiny dot. At the end of every revolution, the disk's position was shifted by 0.07 inch. Two hours of observations were recorded on each flat circular sheet, on which alternate seconds appeared as radial dotted lines and observations as dots irregularly in between.





Here is the Fauth & Co. Meridian Circle Telescope with an aperture of 5 ¼ inches, a focus of 70 inches, and circles of 11 inches.



Here is the Hipp Observatory (slave dial) clock from Peyer Favarger & Co., Neuchatel, Switzerland, that hung on the Fauth & Co. meridian circle telescope in the transit room.

These images feature the Hipp Observatory (slave dial) clock working details.

This view of the Master clock vault at the Mt. Lookout Observatory shows the outside-wall entrance door, the inside-wall entrance door, and the outside viewing window.

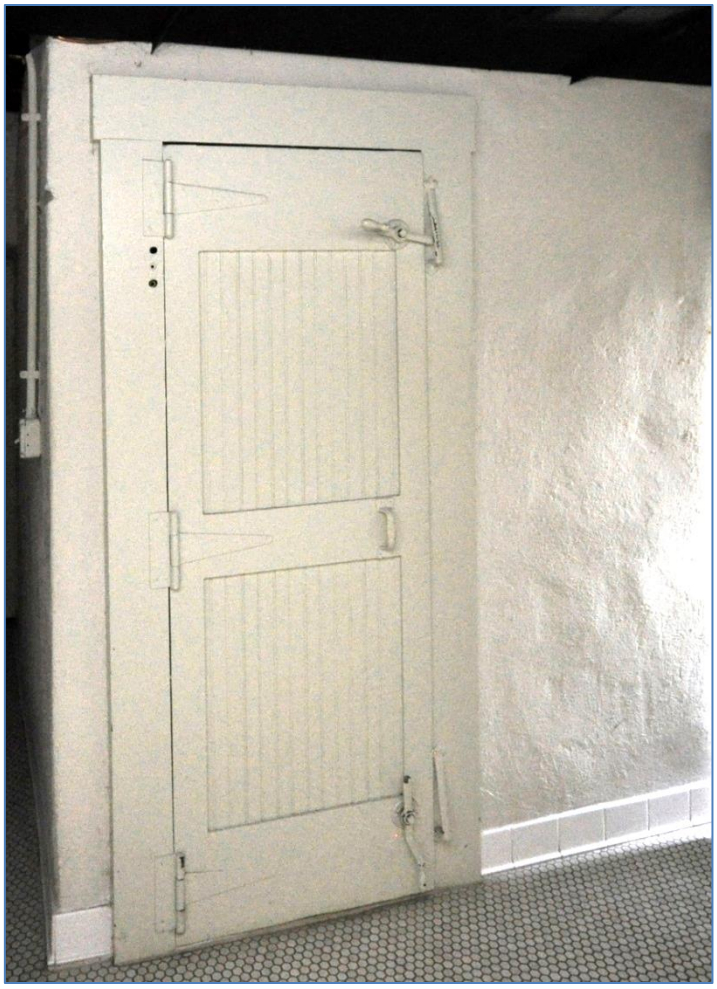


Table 1, Time Balls, Partial Worldwide Listing

Country	City	Place	Type	Operation
Angola	St. Paul de Loanda	Observatory	Time ball	
Argentina	Buenos Aires	Hydrograph. Office?	Cylinder, red	1901–?
Argentina	Mar del Plata	Mitteldock nacelle	Time ball, basket	1893–?
Ascencion	Ascencion I	Flagstaff at the Master's Cottage	Time ball	1860–1865
Ascencion	Ascencion II	Staff on Hayes Hill	Time ball	1865–?
Australia	Adelaide, SA	Signal Station, semaphore	Time ball	1875–1932
Australia	Brisbane I, Queensland	Wickham Terrace Observatory	Time ball, black	1861–1966
Australia	Brisbane II, Queensland	Wickham Terrace Observatory	Time ball, black	1894–1955
Australia	Cookstown, Queensland	Grassy Hill	Time ball, black	
Australia	Devonport, TAS	Post Office	Time ball	
Australia	Fremantle, WA I	Semaphore	Time ball	1876–1901
Australia	Fremantle, WA II	Arthur Head, Mast Head	Time ball	1901–1937
Australia	Fremantle, WA III	Arthur Head, Mast Head	Time ball	1998–?
Australia	Geelong, VIC	Telegraph Station	Time ball	1862
Australia	Hobart, TAS	Fort Mulgrave	Time ball	
Australia	Newcastle, NSW	Custom House	Time ball, golden	1877
Australia	Port Phillip, Victoria		Time ball	
Australia	Sydney, NSW	Observatory	Time ball, black	1858
Australia	Williamstown, Victoria	Fort Gelibrand	Time ball	1861
Belgium	Antwerp	Hanseatic House	Time flap	1883–?
Bermuda	Ireland Island	Dockyard	Time ball	1886–1905
Brazil	Bahia	Fort San Marcello do Mar	Time ball, red	1906–1907
Brazil	Rio de Janeiro	Tower Observatory Mount Castello	Time ball, red	1880–?
Burma Myanmar	Rangoon II	Pagoda	Time ball	
Burma Myanmar	Rangoon I	Mayo Sailors'Home Tower	Time ball	1893–?
Canada	Halifax	Citadel	Time ball, black	1904–?
Canada	Montreal	Harbor Commissioners' Building	Time ball, black	
Canada	Quebec	Citadel	Time ball, black	1852
Canada	St. John, NB	Custom house	Time ball, black	1870–?
Chile	Coquimbo	Pilot School	Time ball, black	
Chile	Coquimbo	Pilot School	Time ball, black	
Chile	Valparaiso	Escuela Naval, Monte Artilleria	Time ball, black	1908–?
China	Chefoo	Signal point Yantaihügel	Time ball	

Country	City	Place	Type	Operation
China	Hong Kong I	Blackhead Point, Point Chinsalchui	Time ball, red	1908–1933
China	Hong Kong Il	Marine Police HQ, Kaulung Point	Time ball	1881–1908
China	Newchwang	Custom House Flagstaff	Time ball	1887–?
China	Shanghai I	Semaphore	Time ball	1884–1907
China	Shanghai II	Tower Quai de France	Time ball	1907
China	Swatau	Port Authority	Time ball, black	
China	Tsingtao I	Observatory	Time ball	1898–?
China	Tsingtao II	Time ball system	Time ball, black	1909–?
Croatia	Losinj (Lussinpiccolo)	SW quay fronting the public square	Discs 2	1886–?
Croatia	Pola	SW bastion of the Harbor Castle	Time ball	1872–1910
Croatia	Rieka (Fiume)	Tower Molo Ammiraglio Cagni	Time ball, black	
Cuba	Havana II	Tower Treasury	Time ball, black	
Cuba	Havana l	Morro, Hafen Kapitanat Building ?	Time ball	1900–?
Denmark	Copenhagen I	Nicolai Kirke	Time ball	1869–1909
Denmark	Copenhagen II	Silo warehouse, free port	Time ball	1909–1941
Denmark	Elsinore	Pilot Station, S–Mole	Time ball	
Egypt	Alexandria	Fort Napoleon (Caffarelli), Kom el Nadura	Time ball, black	1885–?
Egypt	Port Said	Lighthouse	Time ball, black	1897–?
Egypt	Suez		Time ball	
Finland	Helsinki	Observatory	Time ball, black	
Finland	Turku	Navigation School at old Observatory	Time ball, basket	1907–Today
Finland	Turku	Observatory	Time ball, black	1849–1936
France	Brest	Signal mast Observatory navigation school	Time flap	1887?
France	Cherbourg	Fort l'Onglet, Quai Napoleon	Time flap	1887?
France	Dunkerque	Lighthouse in Leughenaer	Time ball, black	1902–?
France	Fouras	Near Marine Observatory Tour of Rosier	Time ball	
France	Lorient	Harbor Marine Tower	Time ball, black	
France	Rochefort	La Tour St. Louis	Time ball	
France	Toulon	Observatoy de la Marine	Time ball	1880–?
Germany	Bremen	Free Haven Port Authority	Time ball	1895–1928
Germany	Bremerhaven	Column Weser beach	Time ball	1876–1928
Germany	Cuxhaven	Tower, signal station, semaphore	Time ball	1875–1929
Germany	Emden Nettle	Tower outer harbor nettle Ander lock	Time ball	1911–?

Country	City	Place	Type	Operation
Germany	Hamburg	Kehrwiederspitze, Kaiserspeicher	Time ball	1876–1934
Germany	Kiel I	Observatory	Time ball	1884–1886
Germany	Kiel II	Imperial. Shipyard	Time ball, black	1886–?
Germany	Kiel Wik	Artillery Magazine, shipyard entrance	Time ball, black	1908–?
Germany	Wilhelmshaven I	Observatory east tower	Time ball	1878–1905
Germany	Wilhelmshaven II	Harbor entrance tower	Time ball	1905–1931
Gibraltar	Gibraltar	Naval Signal Station, Windmill Hill	Time ball	1903–?
Greece	Piraeus	Mast Mole S Kai	Time ball, black	
Guyana	Demerara, Georgetown		Time ball	
India	Bombay I	Churchgate	Time ball	
India	Bombay II	Colaba Observatory	Time ball	1893–?
India	Bombay III	Dock Offices, Princes Dock	Time ball	
India	Bombay IV	Bombay Castle, Clock Tower	Time ball	
India	Calcutta	Semaphore Tower, Fort William	Time ball	
India	Madras	Semaphore, Port Office	Time ball	
Indonesia	Batavia I	Building Inner Harbor	Time ball ?	1879–?
Indonesia	Batavia II	New Harbor, Tanjong Priok	Time flap	1885–?
Indonesia	Forth Point (Cikoneng)	near coast	Time ball	1879–?
Indonesia	Soerabaya	Landingpier, West Mole	Time flap	1879–?
Ireland	Dublin I	Ballast Office, Carlisle Bridge, Westmoreland Street	Time ball	1874?–1915
Ireland	Dublin II	Watchtower Rogerson Quay	Time ball	1915–1948
Italy	Catania	Observatory Benedictine	Time ball, black	
Italy	Genoa	Semaphore; North of Cape San Benigno	Time ball, black	1905–?
Italy	Messina	Tower of the Observatory	Time ball	?–1908
Italy	Naples I	Hydrographic Office, South Vincenzo Molo Flagstaff	Time ball	1902–1904
Italy	Naples II	New Castle (Castello Nuovo)	Time ball	1904–?
Italy	Taranto	Naval Shipyard signal mast		
Italy	Taranto	St. Angelo Castle	Cone, black	1898–?
Italy	Trieste	Lighthouse ?	Time ball	
Italy	Venice	Observatory Patriarcale, Hydrology office	Time ball, red	1907–?
Jamaica	Port Royal	Dockyard Flagstaff	Time ball	?–1895

Country	City	Place	Type	Operation
Japan	Kobe	Courtyard Port Authority	Time ball, red	
Japan	Kure, Hiroshima		Time ball	?–1907
Japan	Moji (Shimonoseki)	Observatory	Time ball	
Japan	Sasebo, Nagasaki		Time ball	?–1907
Japan	Yokohama	Eastern Hatoba	Time ball, black	1903–?
Japan	Yokosuka		Time ball	
Latvia	Riga	Seemannshaus	Time ball, black	1885–?
Lebanon	Beirut	American tower. School	Time ball	
Lerttland	Libau	Telegraph building	Time ball	
Malta	La Valetta I	Palace Tower	Time ball, black	?–1906
Malta	La Valetta Il	Custom House / Port office	Time ball, black	1881–1906
Malta	La Valetta Ill	Auberge de Castille	Time ball	1906–1923
Mauritius	Port Louis I	Observatory, Signal station	Time ball	
Mauritius	Port Louis II	Port Tower, Clock Tower	Time ball	1909–?
Mozambique	Lourenco Marques	Port Captain's office, Delagoa Bay	Time ball	1903–1910
Netherlands	Den Helder	Navt Dock Yard	Time flaps	1855–?
Netherlands	Amsterdam	Meteor Institute	Time flaps	
Netherlands	Amsterdam	Tower Navigation School	Time flaps	1881–?
Netherlands	Flushing I	Tower, Telegraph	Time flaps	
Netherlands	Flushing ll	Arsenal, Rijksvverf (Vlissingen)	Time flaps	1854–?
Netherlands	Hellevoetsluis I	Hospital	Time ball?	
Netherlands	Hellevoetsluis II	Marine Establishment Office	Time ball?	?–1905
Netherlands	Nieuwediep	Roof Directiegebouw (Den Helder)	Time flap	
Netherlands	Rotterdam l	Meteor. Institut	Time flap	
Netherlands	Rotterdam ll	Water Tower Ruige Plaat, Delfshaven	Time ball	1910–?
New Zealand	Auckland I	Port Oftico Flagstaff	Time ball	1902–1904
New Zealand	Auckland II	Ferry Building Clock Tower	Time ball	1912–?
New Zealand	Dunedin, Otago I	Telegraph Office	Time ball	1868–?
New Zealand	Dunedin, Otago II	Port Chalmers Signal Station Flagstaff	Time ball	
New Zealand	Lyttelton	Christchurch	Time ball, black	1876–1934
New Zealand	Queenstown ?		Time ball	
New Zealand	Timaru	Post Office and Telegraph Office	Time ball	
New Zealand	Wellington I	Port Nicholssen, Battery Hill Observatory	Time ball	1864–?
New Zealand	Wellington II	Customs Building, Queens Wharf	Time ball, black	
Norway	Bergen	Sjomandsskole, Nordnæs	Time ball, brown	1922 ?

Country	City	Place	Type	Operation
Norway	Oslo, Christiania	Glasmagasin Stortorvet (marketplace)	Time ball, gold plated	1909–?
Norway	Trondheim	Flagpole at Customs House	Time ball, black	
Pakistan	Karachi l	Beacon Sandy Spit Merewether Pier	Time ball	1907–?
Pakistan	Karachi ll	Waterfront Kiamari	Time ball	1905–?
Pakistan	Karachi lll	Observatory Manora	Time ball	1905–?
Philippines	Manila I	Tower Meteorological Office, Fort seawall	Time ball	1885–?
Philippines	Manila II	Port Kavite (Cavite), Water tower	Time ball	1906–?
Poland	Danzig l	Neufahrwasser Lighthouse	Time ball, basket	1894–1929
Poland	Danzig ll	Neufahrwasser Lotsenturm	Time ball, basket	1876–1894
Poland	Stettin	Government Buildings	Time ball, black	1908–?
Poland	Swinoujscie I	Lotsenturm, root Westmole	Time ball, zinc sheet	1879
Poland	Swinoujscie II	Column	Time ball, black	1879–1928
Portugal	Lisbon I	Navy Yard	Time ball, black	1858–1914
Portugal	Lisbon II	Ballon Observatory	Time ball	1914–?
Russia	Arkhangelsk	Mast Marine Depot Solombala	Time ball, black	
Russia	Kronstadt	Telegraph building	Time ball, basket	
Russia	Vladivostok	Port Authority, Maritime Authority	Time ball	
Scotland	Edinburgh	Nelson Monument	Time ball	1852–?
Senegal	Dakar	Barracks on Dakar Point	Cylinder	1906–1909
Singapore	Singapore I	Fort Canning Hill	Time ball	1893–?
Singapore	Singapore II	Pulo Brani	Time ball	1893–?
South Africa	Cape Town I	Royal Observatory	Time ball	1836–?
South Africa	Cape Town II	Signal Hill	Time ball	?–1894
South Africa	Cape Town III	Table bay, Victoria & Alfred Waterfront	Time ball, red & white	1894–1934
South Africa	Durban l	Sandy Point, Entrance Port Natal	Time ball	1885–?
South Africa	Durban ll	Port Natal Bluff Lighthouse	Time ball	1904–?
South Africa	East London		Time ball	
South Africa	Port Alfred		Time ball	
South Africa	Port Elizabeth	Algoa Bay lighthouse	Time ball	1865–1930
South Africa	Simon's Town	Telegraph office, Observatory	Time ball	
Spain	Cadiz	San Fernando Observatory	Time ball, Sschwarz	
Spain	Vigo, Spain		Time ball	
Sri Lanka	Colombo	Semaphore, Master Attendant's Office	Time ball	

Country	City	Place	Type	Operation
St. Helena	St. Helena I	Observatory, Ladder Hill	Time ball, white	1834–?
St. Helena	St. Helena II	Time Office Jamestown	Time ball, white	
St. Lucia	Port Castries I	Harbor Master's Offices	Time ball, black	1894–?
St. Lucia	Port Castries II	Lighthouse Vigies, local time ball	Time ball, black	1894
Suriname	Paramaribo	Fort Zeelandia Paramaribo, noon disk	Time disk, B&W	1838–1913
Sweden	Gothenburg I	Navigation School Kvarnberget	Time ball	1864–1915
Sweden	Gothenburg II	Navigation School, Kvarnberget	Time ball	1915–?
Sweden	Karlskrona	Naval Shipyard	Time ball, brown	1885–?
Sweden	Malmö	Navigation School	Time ball	1884–1935
Sweden	Stockolm	Navigation School, Stigberget	Time ball, black	1907–1936
Trinidad	Port of Spain	Wharf, pier	Time ball	
UK	Blackburn	Clock Tower	Time ball	1878–1931?
UK	Bolton	Jewelers shop Prestons of Bolton	Time ball	
UK	Brighton	Clock Tower	Time ball	1887
UK	Chatham	Royal Naval Barracks, tower of the wardroom	Time ball	1907–?
UK	Deal, Kent, England	Terrace Timeball Tower Museum	Time ball, black	1855
UK	Devonport	Mount Wise	Time ball, black	1888–1933
UK	Edinburgh	Nelson's Monument, Calton Hill	Time ball	1852
UK	Falmouth	Pendennis Castle	Time ball, black	1897–1920?
UK	Glasgow	Sailor's Home	Time ball	1858–1864
UK	Greenwich	Royal Observatory	Time ball, red	1833–?
UK	Leeds	John Dyson ball Time Building, 26 Briggate	Time ball	1910
UK	Liverpool I	Electric Telegraph Company Office	Time ball, red	1853–?
UK	Liverpool II	Observatory, Waterloo Dock	Time ball	1845–?
UK	Liverpool III	Victoria Tower, Salisbury Dock	Time ball	1860–?
UK	London I	Telegraph Company's, Charing Cross	Time ball	1852–?
UK	London II	J. French's premises Cornhill	Time ball	1860–?
UK	Margate	Clock Tower	Time ball	1906–?
UK	Norwich	Norwich Castle, Norfolk	Time ball	1900–?
UK	Portland	O-Mole	Time ball	1907–1933
UK	Portsmouth I	Robert Wauchope, first Time Ball test	Time ball	1829–?
UK	Portsmouth II	Dockyard Semaphore Tower	Time ball, black	1833–1913
UK	Rosyth, Forth	Shipyard	Time ball	1918–?

Country	City	Place	Type	Operation
UK	Sheerness	Garrison Fort, Flagstaff	Time ball, black	1895–1933
UK	Southampton I	South Castle, God's House Tower	Time ball	1888–1904
UK	Southampton Il	South Western Hotel	Time ball	1904–?
UK	Wolverhampton	Queen Square	Time ball	1887–?
Ukraine	Nikolayev	Observatory, roof of the Rotunda	Time ball, black	1875–?
Ukraine	Odessa	Steam Company Office, yellow house	Time ball, black	1900–?
Ukraine	Sevastopol	Commander-in-Chief's House	Time ball	1904–?
USA	Anapolis, MD	United States Naval Observatory	Time ball, black	1845
USA	Baltimore, MD l	Maryland Casualty Company Tower	Time ball	1912–?
USA	Baltimore, MD ll	Hydrographic Office	Time ball	
USA	Baltimore, MD lll	Offices of the B. & O. Railroad	Time ball, black	1885–?
USA	Boston, MA I	Equitable Life Building	Time ball, 4-foot diam., copper, 400 pounds	1878–?
USA	Boston, MA II	Post Office	Time ball	?–1893
USA	Boston, MA III	Ames Building	Time ball	1903–?
USA	Buffalo, NY	Hydrographic Office	Time ball, black	1901–?
USA	Chicago, IL l	Hydrographic Office	Time ball	
USA	Chicago, IL ll	Government Building, Columbus Fair	Time ball	
USA	Chicago, IL lll	masonic temple (Masonic Temple)	Time ball, red	1899–?
USA	Cincinnati, OH l	Observatory	Time ball, black, 5-foot diam.	1879?–1885?
USA	Cincinnati, OH ll	Carlisle Building	Time ball, 3-foot diam.	1880? –1882
USA	Cincinnati, OH lll	Washington Park, Centennial Exposition	Time ball, black	1888-?
USA	Cleveland, OH	Hydrographic Office, arcades building	Time ball, black	1899–?
USA	Crete, NB	Merrill Hall, Doane College	Time ball	1883-? 1999-2000
USA	Detroit, MI	Morgan and Wright Building	Time ball, black	
USA	Duluth, MN	Hydrographic Office, Torry Building	Time ball, red	1902–?
USA	Galveston, TX	Levy Building; Hydrographic Office	Time ball, black	1901–1919
USA	Hampton Roads, VA	Fortress Monroe	Time ball	
USA	Hampton, VA	Old Point Comfort Hygeia Hotel E-Tower	Time ball	1885–?
USA	Hartford, CT	Telphon Comp.	Time ball	
USA	Honolula, Aloha, HI	Aloha Tower	Time ball	1926–?

Country	City	Place	Type	Operation
USA	Jamestown, VA		Time ball	
USA	Kansas City, MO		Time ball	
USA	Key West, FL	Naval Station Equipment Building	Time ball	1907–?
USA	Mare Iceland, CA	Observatory, Navy Yard	Time ball, black	1885–?
USA	Mystic Seaport, CT		Time ball	
USA	New Haven, CT		Time ball	
USA	New Orleans, LA I	Cotton Exchange	Time ball	1883–1910
USA	New Orleans, LA II	American Sugar Refining Co.	Time ball, black	
USA	New York, NY I	Seamen's Church Institute	Time ball	1913–1967
USA	New York, NY II	South Street, Seaport Titanic memorial park	Time ball	1976
USA	New York, NY lll	Western Union Telegraph building	Time ball, black	1877–1914
USA	New York/, NY llll	Times Square	Time ball	1907
USA	Newport News, VA	Silsby Building, Hampton Roads	Time ball, black	1902–1910
USA	Newport, RI	Machinens	Time ball, black	
USA	Newport, RI		Time Ball	
USA	Norfolk, VA	National Bank of Commerce, Citizens Bank	Time ball, black	1904–?
USA	Philadelphia, PA		Time ball	
USA	Philadelphia, PA l	Maritime Exchange-buildig, Bourse	Time ball	1885–1895
USA	Philadelphia, PA ll	Hydrographic Office	Time ball	
USA	Portland, Maine	Pioneer Courthouse/ Pioneer Post Office	Time ball, black	1877–1885
USA	Portland, OR	Custom House	Time ball, red	1906–?
USA	San Francisco, CA I	Telegraph Hill, Observatory, German Castle	Time ball	1885–1898
USA	San Francisco, CA II	Tower Ferry House	Time ball	1898–1909
USA	San Francisco, CA III	Fairmont Hotel	Time ball, black	1909–1937
USA	Sault St. Marie, MI	Hydrographic Office, Ashmon Street	Time ball, black	1900–?
USA	Savannah, GA	Cotton Exchange	Time ball, black	?-1908
USA	St. Louis, MO	E. Jaccard Jewellery Co.	Time ball, 4' Diam.	1881–?
USA	St. Paul, MN		Time ball	
USA	Woods Hole, MA	U.S. Fish Commission	Time ball	?–1902
Vietnam	Haiphong	Observatory	Time ball	1886–?
Vietnam	Saigon	Quays, semaphore?	Time ball	1908–?

Table 2, Time Guns (Partial Worldwide Listing)

	Country	City	Place	Type	Operation
1	Afghanistan	Kabul	Noon	Time Gun	1924
2	Australia	Fremantle		Time Gun	1995
3	Australia	Sydney		Time Gun	?
4	Australia	Victoria	Warrnambool	Time Gun	1888
5	Canada	Halifax, N.S.	1:00 PM	Time Gun	1856
6	Canada	Montreal		Time Gun	?
7	Canada	Nanaimo Bastion, B.C.		Time Gun	1853
8	Canada	Newfoundland	St. John´s	Time Gun	?
9	Canada	Ontario	Fort Henry	Time Gun	1938
10	Canada	Ottawa	Noon	Time Gun	1869–?
11	Canada	Vancouver	9:00 AM	Time Gun	?
	Chile	Coquimbo		Time Gun	1909
12	Chile	Santiago		Time Gun	?
13	China	Hong Kong	Noon	Time Gun	1947
14	Croatia	Zagreb		Time Gun	?
15	Cuba	East Havana	9:00 PM	Time Gun	?
16	France	Nice	Noon	Time Gun	1860–?
17	France	Paris		Time Gun	1846–?
18	Gambia	Banjul		Time Gun	?
19	Germany	Cuxhaven	Fort Grimmerhörn	Time Gun	1905–1922
20	Germany	Keel	Midday Gun	Time Gun	1890 ?
21	Iceland	Kangaroo Island		Time Gun	1999
22	Ireland	Gilleen		Time Gun	1847
23	Italy	Naples		Time Gun	?
24	Italy	Roam	Noon	Time Gun	1847
25	Italy	Sicily	Messina	Time Gun	?
26	Japan	Osaka	Osaka Casle, Noon	Time Gun	?
27	Madras	Observatory		Time Gun	?
28	Malta	Valletta	Fort Rinella, Grand Harbor	Time Gun	1884
29	Poland	Aldershot		Time Gun	1860
30	Russia	St. Petersburg		Time Gun	?–1934
31	Russia	Vladivostok		Time Gun	
32	Scotland	Edinburgh	Edinburgh Castle	Time Gun	1861
33	South Africa	Cape Town	Noon	Time Gun	1806
34	UK	Dundee		Time Gun	?
35	UK	England	Birkenhead, 1:00:00 PM	Time Gun	1867
36	UK	England	Whitehaven, 1:00 PM	Time Gun	2005
37	UK	Guernsey	Cornet Castle, Noon & 9:30 PM	Time Gun	1974
38	UK	Jersey	Elizabeth Castle	Time Gun	?
39	UK	Liverpool	Observatory	Time Gun	1845
40	UK	Malta	Valletta, Grand Harbour, Noon	Time Gun	?
41	Ukraine	Sevastopol	Noon	Time Gun	1819–Today

Tables: Klaus Hülse, *Maritime Time Signals* and Leland L. Hite.