First Congregational Church Steeple Clock Maintenance and Info

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Figure 1: Picture from: http://www.my-time-machines.net/howard_no1_detail.htm

The First Congregational Church Clock Tower Clock, Williamstown, MA.

The clock in the First Congregational Church clock tower is an **E. Howard and Co. model #1 clock Serial Number 3020**. It was installed in 1914. From the figure 1 website: “Beginning in 1842 and continuing for nearly 100 years, E. Howard & Co. made around 4000 tower clocks. E. Howard is widely considered one of the finest American clock makers and is very sought after by collectors, especially in the United States.”

The same website has some description: “Single train, cast iron, plate and spacer frame construction. Graham deadbeat escapement. Harrison style maintaining power. Eight day duration. 25"w x 50"h x 22"d. 56"h including top lead off gear nest. Top of base 14"w x 12"d.”

Understanding the Clock

Mechanical clocks are typically described in four sections. The driving mechanism can be a weight or spring that provides power to run the clock. The transmitting mechanism distributes this power to indicating mechanism at the pace set by the controlling mechanism. The controlling mechanism is where the pendulum keeps time. The indicating mechanism is the actual hands of the clock face. Each section has a job to do. Understanding the clock in this way can help demystify the mechanics and purpose of the various clock parts. It is important for anyone who provides care for the clock to know the nature of the design and function of the clock works apparatus. For a visual intro, see a 7 and a half minute film on this clock at youtube:
http://www.youtube.com/watch?v=Dr5XYle5PMc

The Four Parts of the Clock

1. Driving Mechanism

The driving mechanism: supplies power to the transmitting mechanism of the clock. It runs as fast as possible and doesn’t care about regulation. The power comes from a weight on a pulley rope (figure 2) that wraps around a drum or axle connected by means of a ratchet and click. The driving wheel is not rigidly attached to the ratchet and click so that the weight can be wound up after it runs down. The weight is wound up with a key which has a square hole which fits over the square end of the axis/arbor to which the drum is fastened (see figures 4 and 5.) Take a good look at the square end of the axis/arbor and you will see that the winding over the years has gradually twisted the end. This is a one week clock, but one week clocks actually are set to run 25% longer than the specified time. This means that if you wind the clock up fully, you actually get a little more than 8 days. If you wind the clock once a week, you can come on any time that 7th day without fear that the clock will have stopped. The weight has to overcome friction caused by thickening oil and dirt in pivots. Too much weight is bad as it adds undue stress on the mechanism. The driving mechanism is the weight, cord, drum, ratchet and click, click spring (to keep the click against the ratchet), main driving wheel, and arbor.

> *“All accurate clocks used for astronomical purposes or where correct time is essential are weight driven.” Willis Milham.*

The wire rope when wound up forms 1 layer on the drum. The wire rope is sure to wear out and break. There should therefore be some arrangement to avoid danger and damage when the weight drops. A box of broken stone or sand can perhaps be kept at the place where the weight will strike. The pulleys should be well oiled to prevent friction. Wire rope should be oiled to keep from rusting. Mineral oil is good for this.

Figure 2: The weight that drives the clock. 224.8 pounds on 6/16/2011.

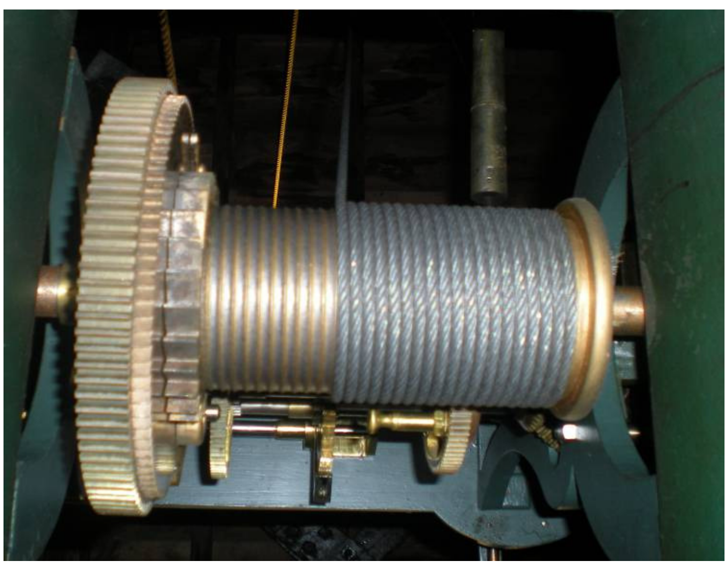

Figure 3: The drum with one layer of pulley cable on it. On the left are first the ratchet and click and then the larger main driving wheel. One winding of steel cable is good for about 8 days.

Figure 4: The square end of the axis/arbor of the drum. This is where the key fits to wind the clock.

Figure 5: The key for winding the clock.

2. Transmitting Mechanism:

The transmitting mechanism transmits the motion to the controlling mechanism. It consists of a series of cogged wheels working on one another. It is also called the time train. The larger cogged or toothed wheels always do the driving and are called wheels. Driving wheels have teeth. Smaller wheels are called pinions and are driven by the driving wheels. They are wider and have horizontal serrations/cogs called leaves. On each axle or arbor there is a rigidly fastened wheel and a pinion. Wheels are of brass. Pinions and arbors are of steel. The ends of the arbor are called pivots and these run in holes in the frame or plates which hold the clock mechanism. The great toothed wheel of the driving mechanism drives the pinion on the first axle. Its wheel drives the next pinion and so on until the wheel on the last axle drives the pinion on the axle of the escape wheel which is a part of the controlling mechanism. Each axle turns faster than its predecessor and with less power. The weight is 224.8 pounds. At the axle that drives the hands of the clock, it is down to 48 pounds. When it finally gets to the escapement, it is only at half a pound. Using Newtons for force, we start with 1000N with the weight. The force is 214 for the axle that drives the hands of the 4 clock faces. At the escapement wheel, it is at only 2.3N.

Figure 6: A pinion on top with the wider leaves being driven by a wheel with teeth below. On the other end of these two arbors are a wheel on top and an arbor on the bottom one.

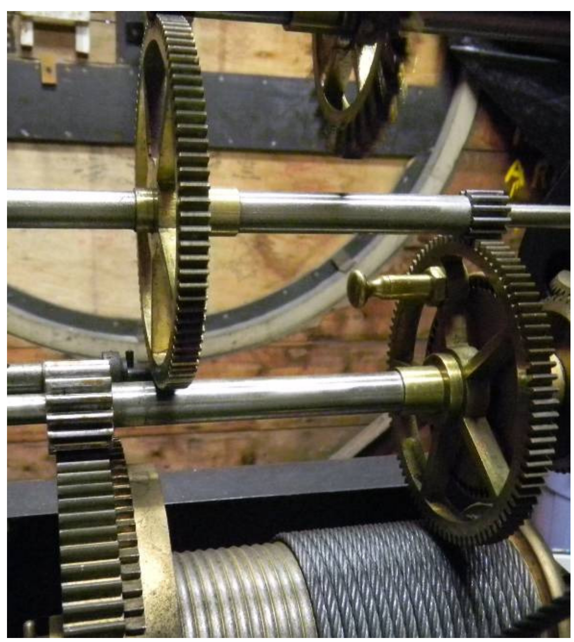

Figure 7: On the bottom we have the main driving wheel of the driving mechanism turning the pinion of the transmitting mechanism. This in turn rotates the arbor that has a driving wheel that acts on another pinion on a second arbor.

3. Controlling Mechanism.

The controlling mechanism allows the clock to run just so fast and no faster. The controlling mechanism is sometimes called the regulating mechanism. The last wheel in the time train drives the pinion on the escape wheel arbor. The escape wheel has rather long pointed teeth inclined at an angle. Over a certain number of these teeth extends the anchor and it is attached the pendulum. As the pendulum swings to the right, a tooth on right side escapes, but the escape wheel is not free to turn rapidly as a tooth at the other side will strike the other horn of the anchor. As the pendulum swings to the left the tooth on the left side escapes but another tooth is caught by the other side of the horn on the right hand side. Each swing of the pendulum allows one tooth to go past. First the release happens on one side of the anchor, and then at the other side. It is the action of the escape wheel and anchor which causes the ticking of the clock. As a tooth escapes it gives a little push to the pendulum which keeps it swinging. It is not the pendulum which makes a clock go, but the weight on the clock which keeps the pendulum going. This push is achieved through the crutch, a small metal rod or wire (our clock has a rod, see figure 11) which is rigidly attached to the anchor and loosely attached to the pendulum. The crutch ends in a pin which works in a slot in the pendulum rod.

The rate of running is controlled to run at the rate of one tooth for the full time of one swing of the pendulum. Escape wheels are made of brass. The number of teeth can be anything, but it depends on the time of swing of the pendulum and ration of wheel to pinion in the time train. 30 is common. The pendulum swing is 1 second.

The anchor escapement is either recoil or deadbeat. Our clock has a deadbeat anchor escapement. The deadbeat escape wheel does not move backwards. It remains stationary when not moving forward. The swing of a pendulum depends on its length, the value of gravity and the length of the arc through which it swings. T = π times the square root of l over g where π is 3.14159, l is the length of the pendulum, and g is the acceleration of gravity. The formula assumes the swing arc is very small.

Here are some sample pendulum lengths and the period of their swings:

13feet and ½ inch = 2 seconds

7 feet 4 inch = 1.5 seconds

39.1 inches = 1 second (what we have)

9.8 inches = ½ second

2.5 inches = ¼ second.

If the pendulum were a heavy ball suspended by a rod without mass, then the length would be point of support to the center of the ball. On a normal pendulum with mass, the pendulum length is the point of support to a small distance above the center of the bob. The Pendulum has a screw thread and nut to change the length an inch or more. In practice the value of g, arc, and length are all found by experiment. Here is how much the clock loses per day at different arcs compared with infinitesimal movement:

1°= 1.65s

2°= 6.59s

3°=14.80s

4°=26.35s

5°=41.15s

Oil thickens, dust collects, and friction changes. The power supplied to the pendulum and arc of swing will change. Drop from 4° to 3° of arc and you gain 11.55s per day.

Also escapement changes as power changes. So keep power and arc as constant as possible. Pendulum support = firm and rigid. Changes in temperature change the length of a pendulum and the time of swing. This results in a gain time in the winter and a loss of time in the summer when it is warm.

The coefficient of expansion of wood is small. At 180° the pendulum length changes by a factor of 0.0004.

Wood is ideally white pine or mahogany straight grained well baked and shellacked to exclude moisture.

If the bob is large, made of lead or zinc and supported at the bottom, it is possible to overcome the effects of temperature changes on the clock time. A Zinc or lead bob would have to have a radius of 6 to 7 inches to compensate for temperature changes. As the pendulum lengthens, the bob expands. The amount the pendulum moves the center of mass down is the amount the bob expanding moves the center of mass up making no change. They compensate for each other.

More important than pendulum length is the temperature induced change in friction over the whole system, but I haven’t quantified that. More weight sometimes needs to be added in the winter to keep the clock going, so it is a factor.

3a. Regulating the clock:

When the clock runs slow or fast, you can regulate it.

The screw on top of the pendulum (figure 10) lets you change the pendulum length by up to an inch. You must unscrew the clamp from the pendulum spring first. However, this may not be the best way to regulate the clock unless you need to change it more than 2 seconds a day. The finer scale adjustment is possible by putting weights on the pendulum above the bob. Since the weights will be above the center of gravity of the pendulum, adding small weights will make it go slower. Pennies may be used or small pieces of lead wire nails.

Determine how much difference one wire nail in a pan makes the running of the clock this way: Let the clock run 1 week. Determine how much time was lost or gained. Put 10 nails on and determine how much difference occurs the following week. This gives the effect of 10 nails and thus 1 nail. Perhaps a nail is 1/3 a second a day. Now regulation is easy because one knows the # of nails to use to get the desired effect.

There are several approaches to regulating a clock. They all work. Pick one that works for you.

- Let the clock run alone. Change it when it is 20 seconds off.
- Add the proper amount of weight on the bob and leave alone. Use a log to keep track.
- Regulate each time it is set and add or remove weight.
- Only use one weight and add it on when the clock needs to go slower and take off the weight to speed it up.

Figure 8: The anchor escapement: The escape wheel is underneath the anchor with horns on each side that alternately let teeth go by as the pendulum swings.

Figure 9: The pendulum (in red). The wood box below is there to catch the pendulum when the brass fitting that holds it up breaks (and it will break) so that it doesn't destroy any of the rest of the clock. The bob can sometimes rub against the wood box which would be bad.

Figure 10: The dial for lengthening or shortening the pendulum. (located above the pendulum.)

Figure 11: The clutch arm that gives the pendulum a kick to keep it going can be seen entering the pendulum toward the bottom of the photo.

4. Indicating Mechanism

The indicating mechanism consists of the hands and dial and the under the dial mechanism which is often called the motion work. One axle in the time train turns in just one hour. This axle acts on a vertical axle that distributes the once-an-hour rotation to 4 other axles, one for each clock dial (figures 12 and 13.) Each of these axles extends through their clock dial and carry the minute hand for that dial. Just behind the clock dial is a cogged wheel set dials down the speed such that it is 12 times slower and this outer sleeve carries the hour hand. These two caps and 4 wheels are called the under the dial mechanism since that is their location (figure 14.)

Dial proportions used to be quite formal. The diameter of the dial is 1/10th the height of the clock dial. The figures and minutes are 1/3 of the clock dial radius.

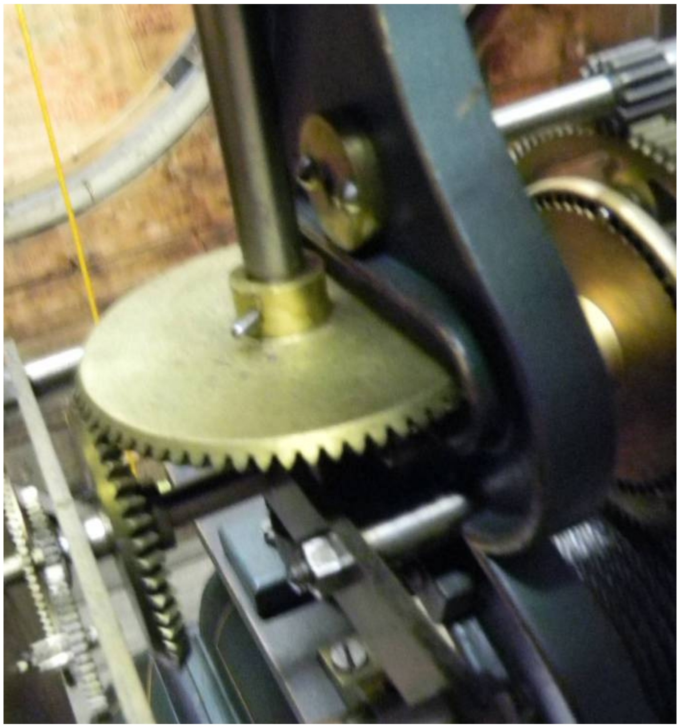

Figure 12: Here you see the arbor that turns once an hour sticking out of the frame and connecting to an arbor that heads straight upwards.

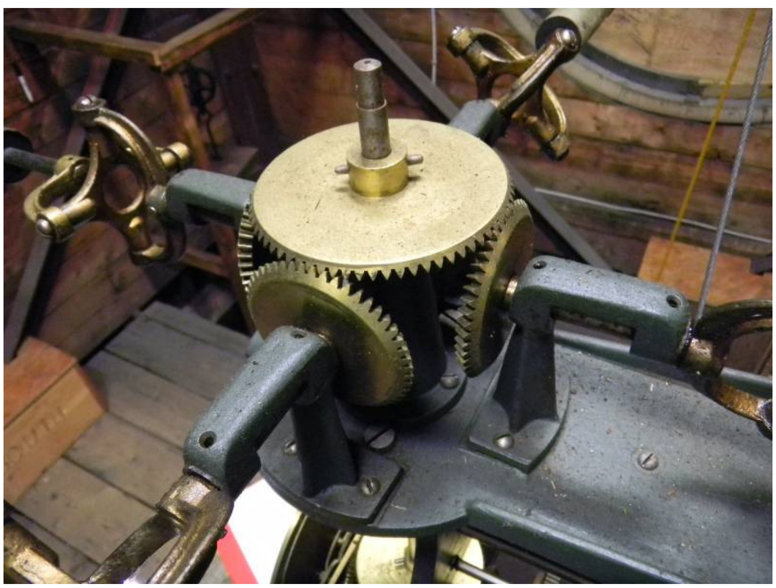

Figure 13: This straight upwards arbor then transmits the one rotation an hour to the for dials of the clock.

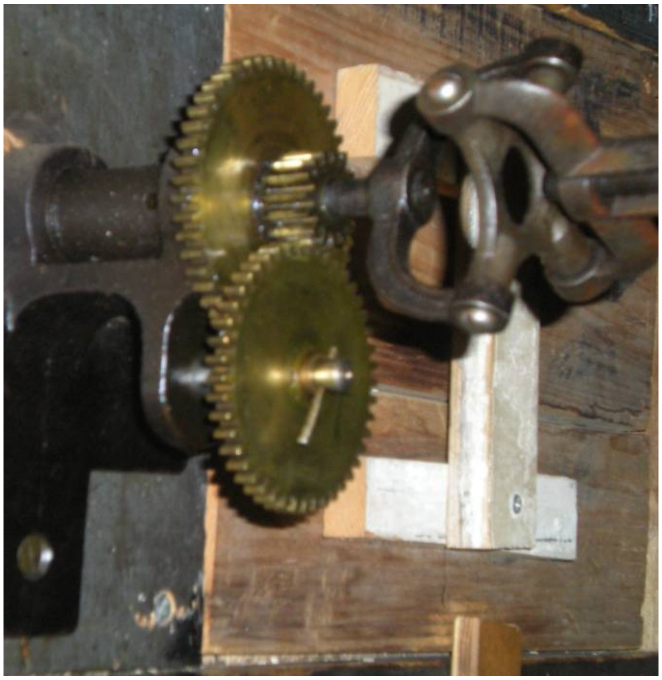

Figure 14: The behind the dial mechanism that transmits the one rotation an hour to the hour hand and the wheels and arbors you see make the minute hand move 12 times faster.

General Care

The clock is set by pulling the plug out (figure 15), manually rotating the axle rod that extends to one of the clock dials until the time is correct, and then putting the plug back in. This peg is of a softer metal that will sheer off if the clock dial hands get stuck so the tension will be released rather than break cog wheels or such. You can look out the windows on the clock dials to check the time. Then set the internal dial (figure 16) on the mechanism itself by manually moving the minute hand so you can visually see how much you are moving the clock hands on the exterior dials.

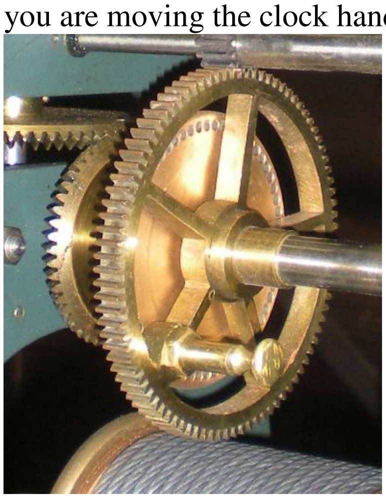

Figure 15: The peg can be seen on the one rotation an hour arbor. You pull this peg out when changing the time on the dials.

Figure 16: The internal dial. Set this clock face by manually moving the minute hand to what the outside dials are at so you can see what the dials outside are doing as you adjust the time.

Well oil pulleys and wire ropes. Mineral oil for ropes. This prevents friction and rusting.
No oil where beat pins touch the pendulum.
Oil pivots once a year.

Regulate length and weights in pans. Add weight to go slower.
Frost is bad. Rust is bad
Record date error and rate.

Watch out for helpful people who ADD WEIGHTS without consulting with anyone. For this reason, extra weights are stowed below the clock with the oil where no one can see them.

Add a sandbox for the weight to land in when the cable carrying the weight breaks. Willis Milham is certain that every cable will eventually break. It would be good if it didn't end up landing on the first floor.

Williams College has a Machinist/Model Maker who could be an asset if parts needed to be ordered:

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Trevor Murphy and Cecil Harvey, Summer 2010.