EML4551

Team 18: The Centennial Calendar

Design Review 5

Team Introduction

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PROJECT OVERVIEW

Overview

- Project Summary
  - Create a calendar that runs continuously for 100 years
    - Must utilize all-mechanical workings
    - No electrical input power
    - Annual maintenance allowed

Alyna Segura-Sanchez

Overview

➢ Project Scope

- Create an operational 100-year mechanical calendar prototype out of inexpensive materials that accounts for the day, month and year, with annual maintenance.

- The prototype developed is to simulate proper date keeping and will be utilized by future senior design teams to improve upon.

Alyna Segura-Sanchez

Overview

- Customer Needs
  - Mechanism powered mechanically.
  - Mechanism accounts for leap years and non-leap years.
  - Internal workings visible from a distance.
  - Usage of cost-effective materials while not sacrificing quality.
  - Compact mechanism that is self-sufficient for a year at a time.

Alyna Segura-Sanchez

Target Catalog

Table 1: Target Metrics

Metric	Measure	Target
Max allowable error	Time	1 day/year
Life span of mechanism	Time	100 years
Weather-proof rating	Durability	IP-55
Maintenance interval	Reproducibility	Annual
Max mechanism size	Dimensions	Door way
Furthest distance the date is legible	Visibility	3 meters
Organized design	Aesthetics	N/A
Amount of movements per day	Quantity	1
Tamper-proof rating	Durability	TL-40

Alyna Segura-Sanchez

Alyna Segura-Sanchez

OUR PROTOTYPE

Date Display

- Now utilizing the Clayton Boyer Perpetual Calendar as the core of the display
- Added an extra gear to track the years

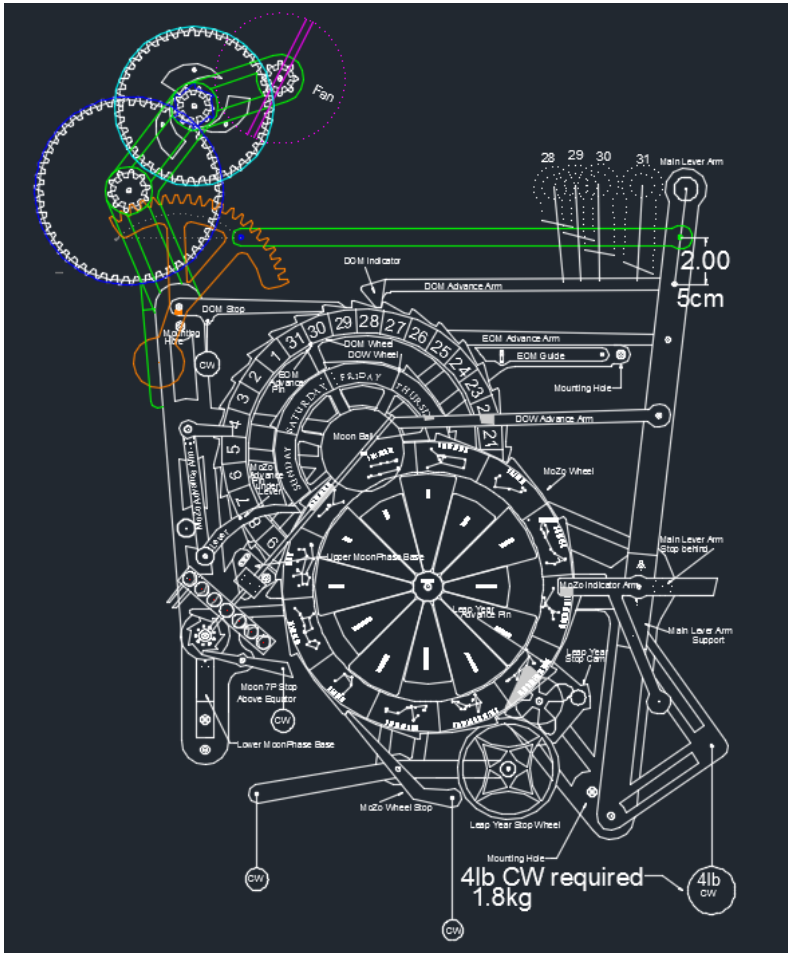

Figure 1: Clayton Boyer Perpetual Calendar AutoCAD drawing

Alyna Segura-Sanchez

Display Drawings

- Bought calendar drawing file
  - Not 3D
  - One page of drawings
  - Not all lines connected

- Prepared drawings for cutting
  - Placed same thickness on individual pages
  - Removed unnecessary labels

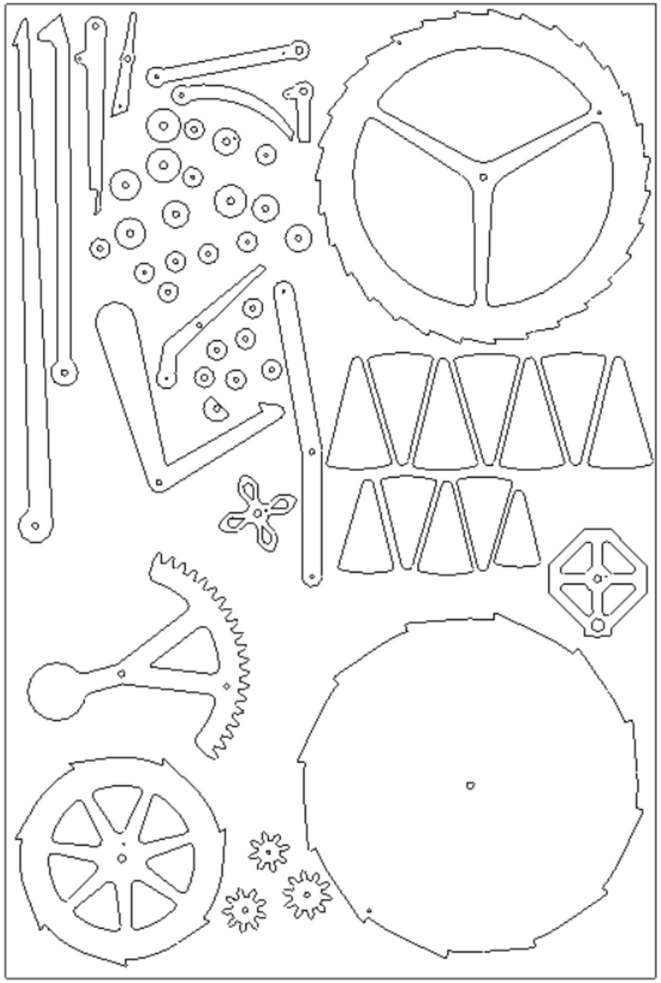

Figure 2: 3/8 in CAD drawings

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Display Material

- Material choices
  - Wood
  - Acrylic
  - Stainless Steel
  - Polycarbonate
- Why Polycarbonate?
  - Light
  - Weather resistant
  - Shatter resistant

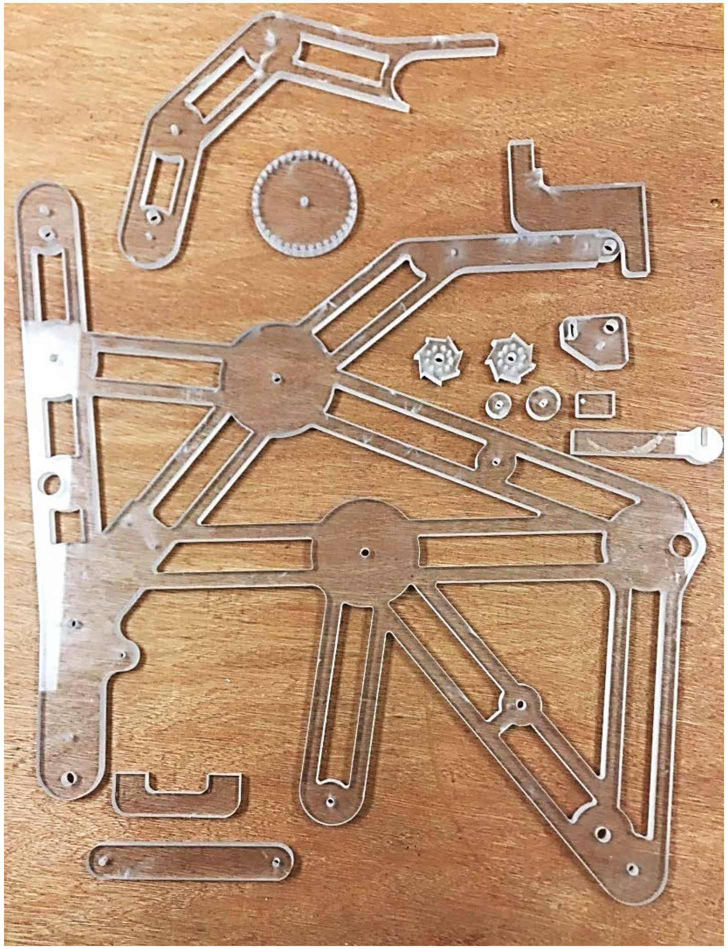

Figure 3: 3/4 in water jetted parts

Alyna Segura-Sanchez

Manufacturing Display Parts

- Considered multiple options
  - 3D printing
  - Laser cutting
  - Water jetting
- 3D printing required extruding
- Laser cutter not strong enough
- Decided on waterjet

Alyna Segura-Sanchez

Cutting Display Parts

- Water jetting
  - Looked at Engineering waterjet (too small)
  - Ended up using HPMI waterjet
- Water jetting of the display should finish by the end of the day
- Assembly of the display should finish by the end of the following week

Figure 4: HPMI waterjet

Jacob Williams

Display-Clock Connection

- Whitworth quick return
- Connects clock to main lever of display

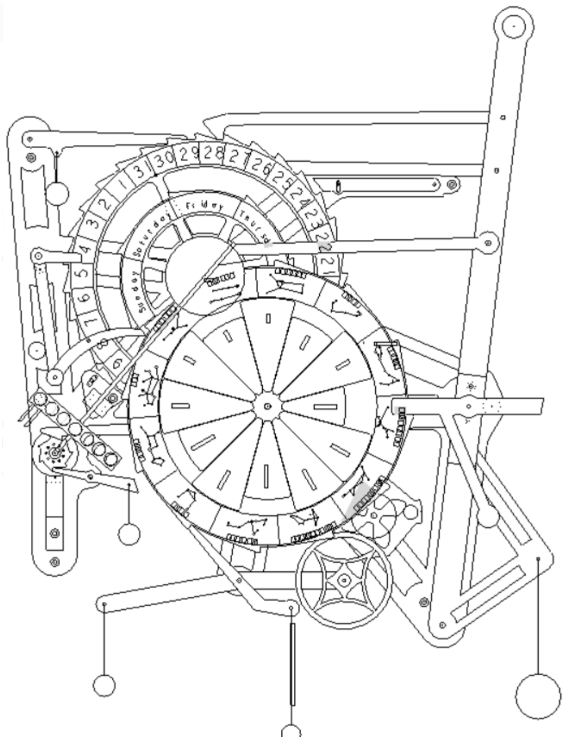

Figure 5: Calendar drawing

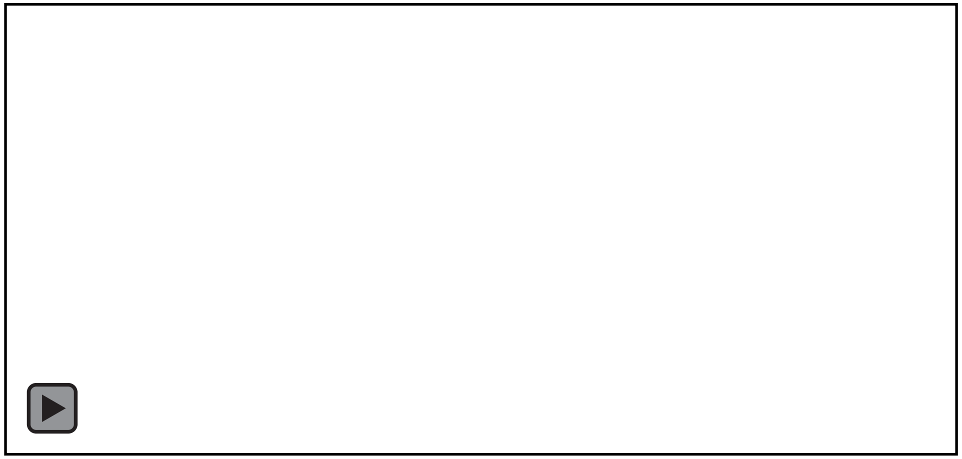

Figure 6: Whitworth quick return example

Jacob Williams

The Clock

- 1952 Kundo All-Mechanical, Torsional Pendulum Clock
- 400 day run time
- Simple, yet elegant
- Easy rewinding mechanism

Figure 7: Kundo All-Mechanical Torsional Pendulum Clock

Jacob Williams

Energy System

- Bellows modeled after those found on an Atmos clock
- Slight changes in temperature and pressure cause ethyl chloride gas to expand
- Utilizes most consistent environmental changes

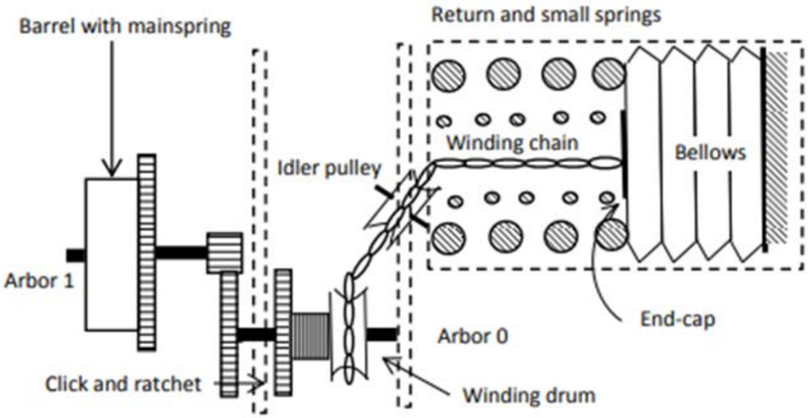

Figure 8: Atmos bellows

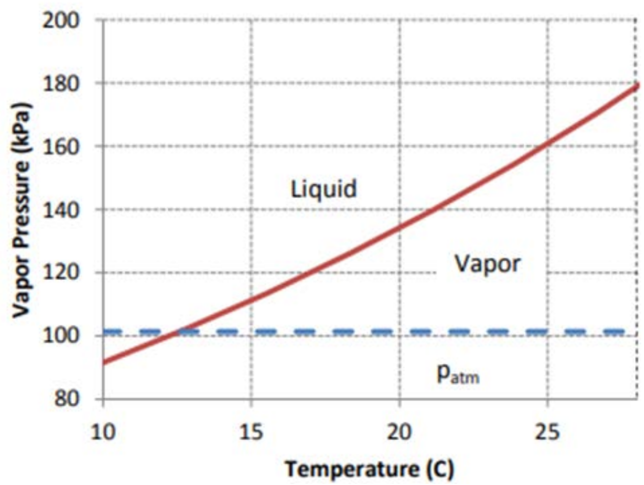

Figure 9: P-T graph of ethyl chloride

Jacob Williams

Bellows Motion

- Winding drum picks up slack when bellows expands
- When the bellows contracts, it pulls the winding chain and winds the mainspring through a click and ratchet system
- Atmos clock in Tallahassee will produce at least 36.1 days of power on average

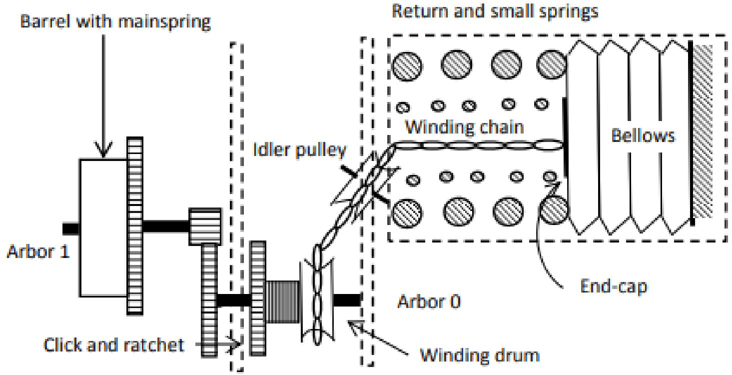

Figure 10: Atmos winding system

Jacob Williams

Bellows Test

- Analysis of Bellows will occur before implementation into the final prototype
- Maximum height differences will be compared throughout the day

Figure 11: Atmos bellows expanded (back) and contracted (front)

Jacob Williams

Next Steps

- Attach a stepper motor to the prototype to run at an accelerated rate.
  - Allows sponsors and following groups to see the flaws in our system.
- Design and manufacture an encasement able to withstand the Florida climate.
- Decrease overall size
- Increase aesthetic appeal

Jacob Williams

Gantt Chart

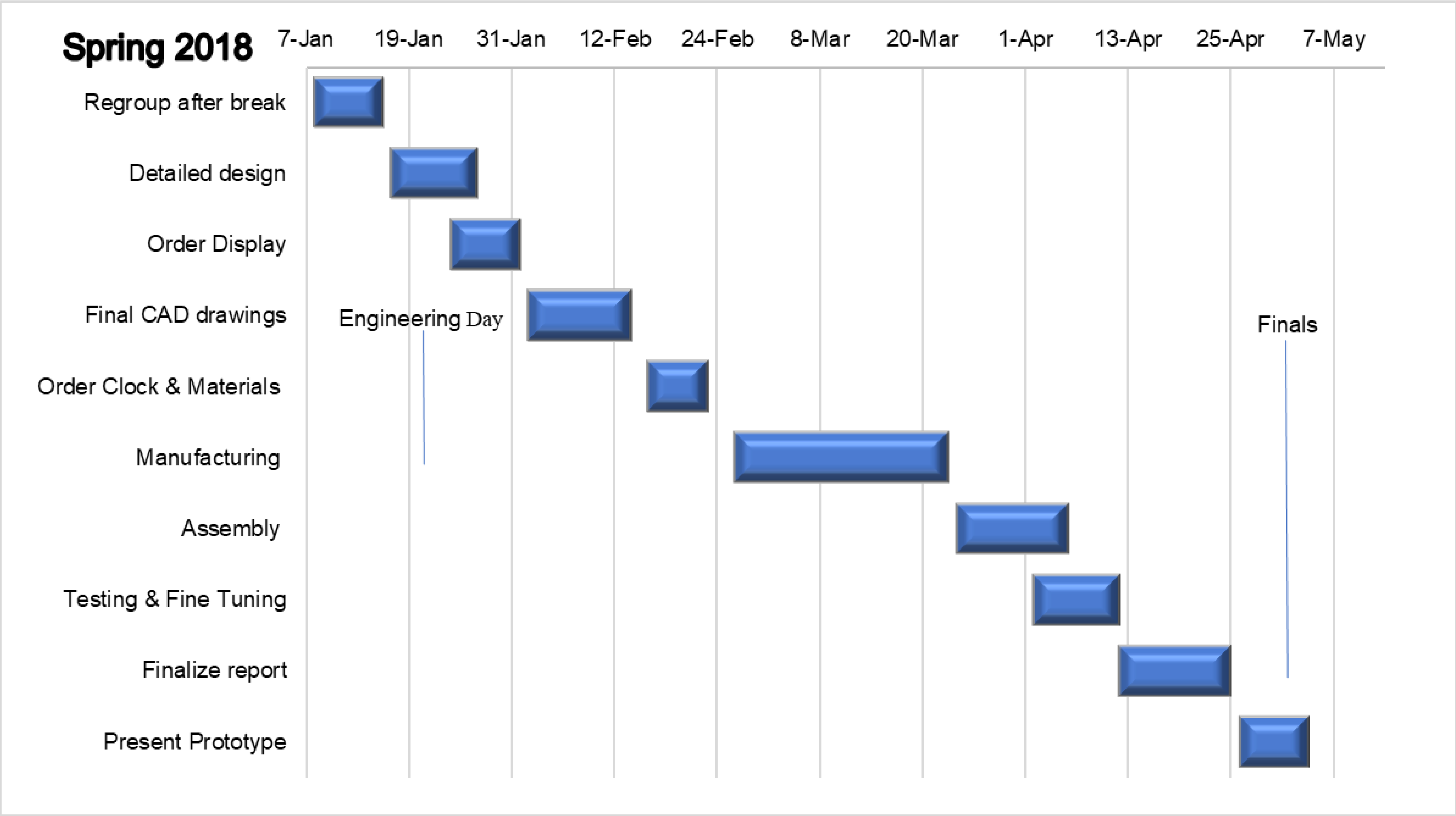

Figure 12: Gantt Chart

Jacob Williams

References

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Thank you for your time.

ANY QUESTIONS?

BACKUP SLIDES

Bellows Motion

- Pressure of ethyl chloride in the bellows creates a force, $f_b = a_b p_b$
- Two springs oppose bellow's force to recompress it, $f_s = k_s x$
- Winding drum picks up slack when bellows expands
- When the bellows contracts, it pulls the winding chain and winds the mainspring through a click and ratchet system

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Figure 9: Atmos winding system

Energy System (cont.)

- Temperature changes
  - The bellows on an Atmos clock generate about 4 days of power per °C
  - Minimum temperature change in Tallahassee on average is 15 °F (~8.34 °C)
  - Atmos clock in Tallahassee will produce at least 36.1 days of power on average

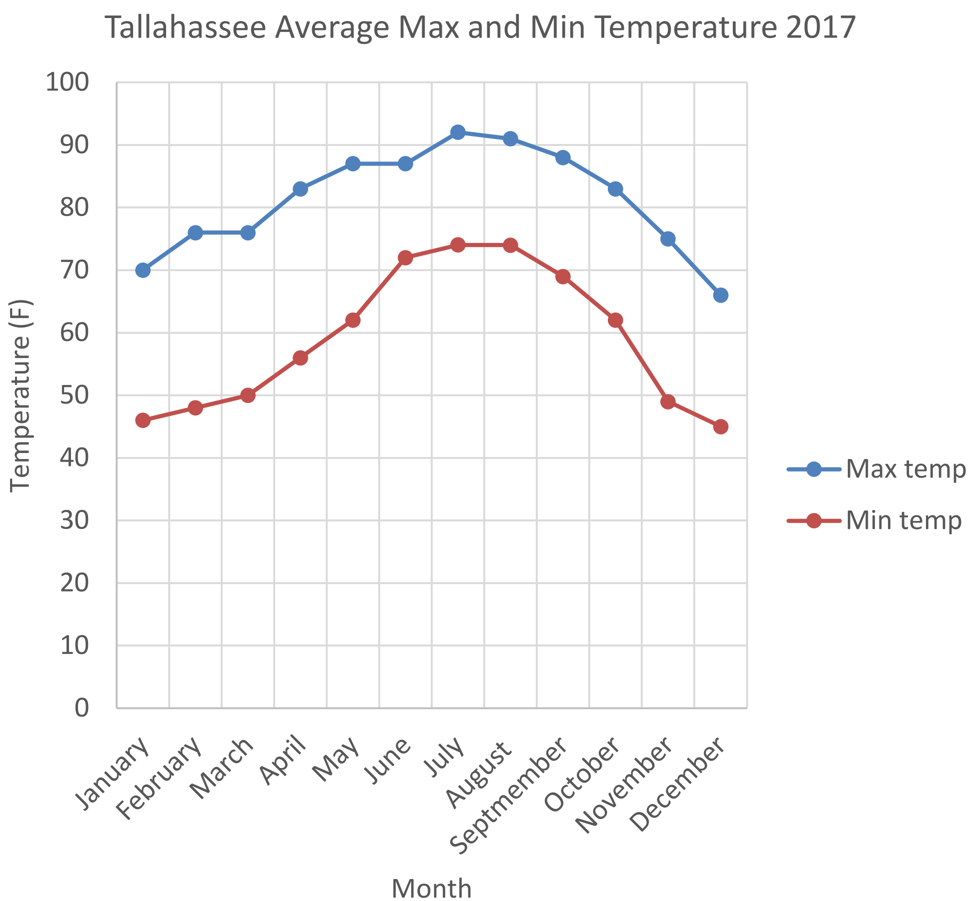


Figure 5: Temperature fluctuations per month in Tallahassee

Michael Patrick

Energy System (cont.)

- Air temperature vs. atmospheric pressure power contribution
  - 37 mmHg (1.46 inHg) is a comparable to a temperature change of 1 degree C
  - Max average pressure change = 1.45 inHg, min average pressure change = 0.33 inHg
  - Pressure differential will power Atmos clock between 4.33 and 0.953

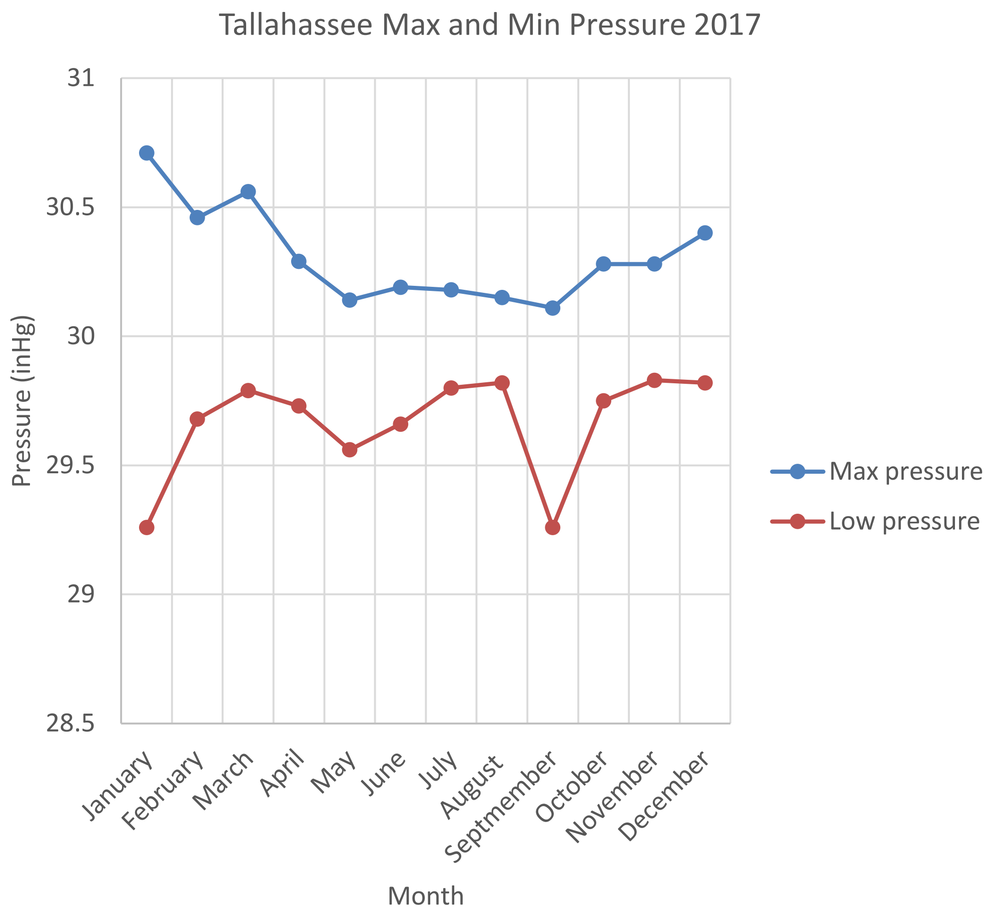
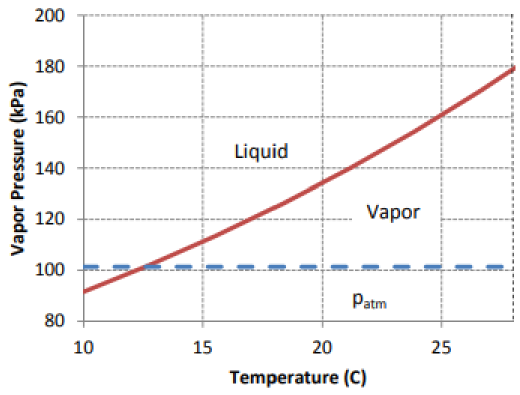


Figure 6: Pressure fluctuations per month in Tallahassee

Michael Patrick

Ethyl Chloride Gas

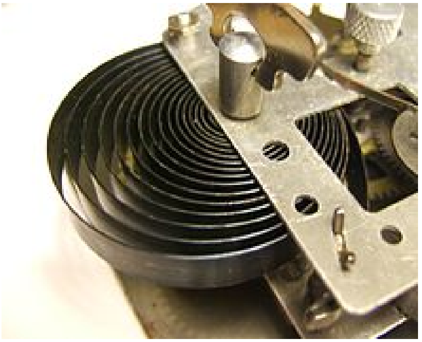
- At room temp. and atmospheric pressure, ethyl chloride is a vapor
- Bellows is at min. volume at vapor/liquid point (boiling point)
- Most of the gas is a vapor at atmospheric pressure, so the increase in pressure may follow the ideal gas law, $PV = nRT$



Pressure-temperature graph of ethyl chloride

Mainspring

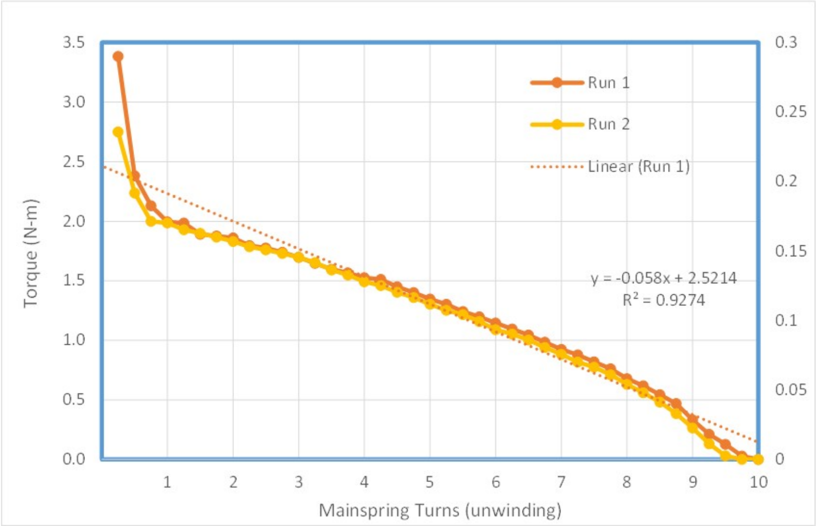
- Mainspring stores energy produced by bellows to drive the clock and the display
- Drive torque expressed as: $\tau = \frac{E b_{ms} h_{ms}^3 (\theta - \theta_0)}{12L} + \tau_0$ where E=modulus of elasticity, b_{ms}=mainspring width, h_{ms}=mainspring thickness, L=spring length
- $\tau_0 = Fd = (ma)d$
- Determine τ_0 by torqueing the mainspring



Mainspring example

Mainspring Torque Calculation

- $\tau_0 = Fd = (ma)d$
- Make a jig comprised of a clamp to hold the mainspring
- Attach rod to mainspring
- Fully load mainspring
- Measure distance that a mass holds rod in the equilibrium position (horizontal)
- Plot torque for every 360 degree unwinding



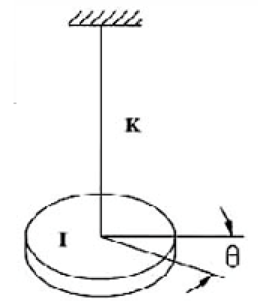
Mainspring torque

Clock Motion

- Use gear ratios to determine how long the clock can run
- $Gear\ ratio, R = \frac{N_{out}}{N_{in}}$
- In, out denotes input and output motions
- Need number of teeth for each gear in the gear train
- Determine how long the great wheel takes for a full rotation
- $runtime = time\ to\ turn\ great\ wheel\ one\ rev * number\ of\ revs\ to\ fully\ wind\ mainspring$

Torsional Pendulum

- The time base of the clock regulated by simple harmonic motion
- The natural frequency is expressed by, $\omega_n = \sqrt{\frac{k}{I}}$ where $I = mr^2$
- The period is, $T = \frac{2\pi}{\omega_n}$ where $T = 60s$
- k can be determined when the inertia is determined analytically
- Maintaining a 60s period is important because it keeps the timing of the clock



Torsional pendulum

Energy Analysis

- Power consumption
  - Determine the average torque produced
  - $W = \tau\theta = \tau_{mean}\frac{2\pi}{rev}$
  - $Power = \frac{W}{t}$
  - $P = \frac{W}{(time\ to\ turn\ great\ wheel\ 1\ rev)}$
  - For reference, an Atmos clock's average rate of power consumption is about $0.0327\ \mu W$
  - Losses due to pendulum, gear train, and escapement

Energy Analysis (cont.)

- Temperature changes enough to power clock?
  - From Atmos experiment:
  - At room temperature, the bellows moved 1.63 mm/C (0.036 in/F) on average
  - Circumference of chain winder is 34 mm
  - $\left(\frac{360°}{34\ mm}\right)\left(\frac{1.63\ mm}{°C}\right) = \frac{17.3°}{°C}$
  - 55:18 gear ratio from chain winder to mainspring
  - $\left(\frac{17.3°}{°C}\right)\left(\frac{55}{18}\right) = \frac{52.9°\ great\ wheel}{°C}$
  - For Atmos, full turn of great wheel takes 29.5 days
  - $\left(\frac{52.9°}{°C}\right)\left(\frac{29.5\ days}{360°}\right) = \frac{4.33\ days}{°C}$

Energy Analysis (cont.)

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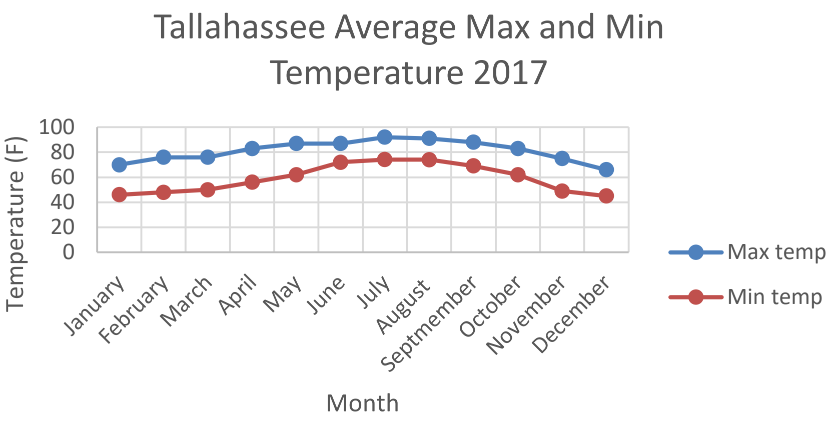
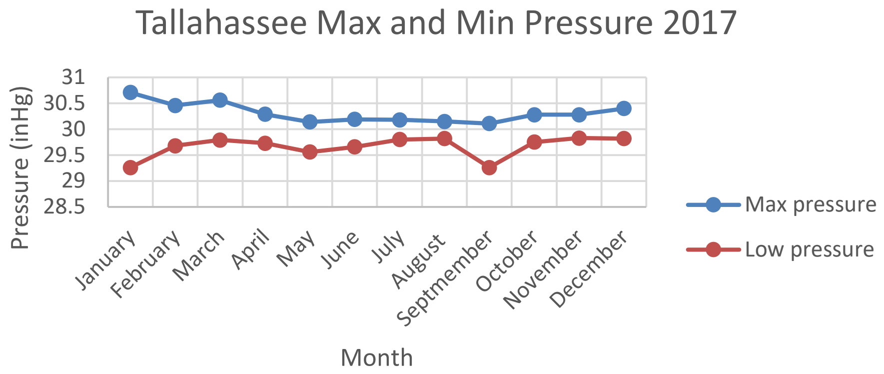
Energy Analysis (cont.)

- Temperature changes (cont.)
  - The bellows on an Atmos clock generates 4.33 days of power per degree C
  - Minimum temperature change in Tallahassee on average is 15 degrees F (~8.34 degrees C)
  - Therefore, an Atmos clock in Tallahassee will produce at least 36.1 days of power on average



Energy Analysis (cont.)

- Air temperature vs. atmospheric pressure power contribution
  - 37 mmHg is a comparable to a temperature change of 1 degree C
  - 37 mmHg = 1.46 inHg
  - Maximum average pressure change in Tallahassee is 1.45 inHg
  - Minimum average pressure change is 0.33 inHg
  - At best, pressure differential will power Atmos clock for 4.33 days
  - At worst, pressure differential will power Atmos clock for 0.953 days



Energy Analysis (cont.)

- Average temperature differential yearly = 21.5 degrees F = 12.0 degrees C
- Average pressure differential yearly = 2.64 inHg
- $\left(\frac{4.33\ days}{℃}\right)(12.0\ ℃) = 51.96\ days\ of\ power$
- $\left(\frac{1.46\ inHg}{℃}\right)\left(\frac{℃}{4.33\ days}\right)\left(\frac{1}{2.64\ inHg}\right) = 0.1277\ days\ of\ power$
- Pressure differential only constitutes 0.25% of power supplied
- Note: as long as power supplied per month exceeds the length of the month, power will not run out