Team 18: The Centennial Calendar

Design Review 4

Team Introduction

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Zachary Brower

PROJECT OVERVIEW

Recap

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

Zachary Brower

Recap

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

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Recap

- Adjusted 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.

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Recap

- Adjusted 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.

Target Catalog

Table 1: Adjusted 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

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Michael Patrick

OUR PROTOTYPE

The Clock

- 400 Day Anniversary Clock
- All-mechanical, torsional pendulum timekeeper
- Runs for around 400 days on a full wind

Figure 1: Kundo 400 Day Anniversary Clock

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The Clock (cont.)

- High quality, affordable clock
- Great device for us to analyze
- Cons:
  - Most range from 65-75 years old
  - Requires substantial maintenance when components fail

Figure 2: Torsional pendulum of Kundo 400 Day Anniversary Clock

Michael Patrick

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

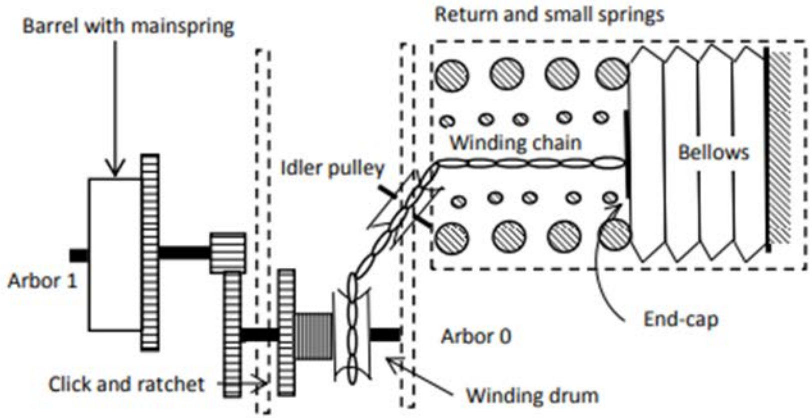

Figure 3: Atmos bellows

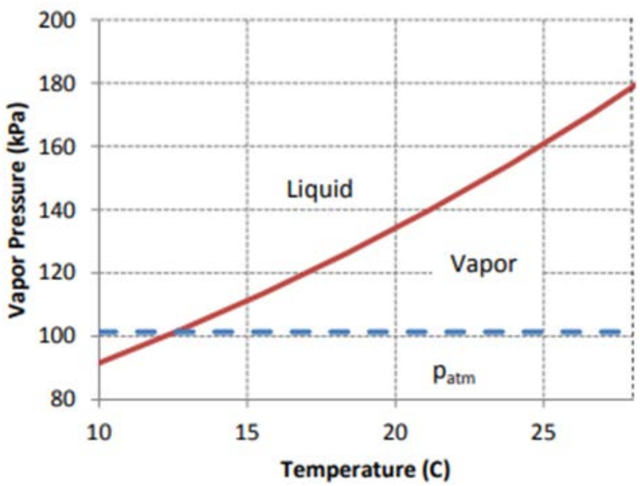

Figure 4: P-T graph of ethyl chloride

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Energy System (cont.)

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

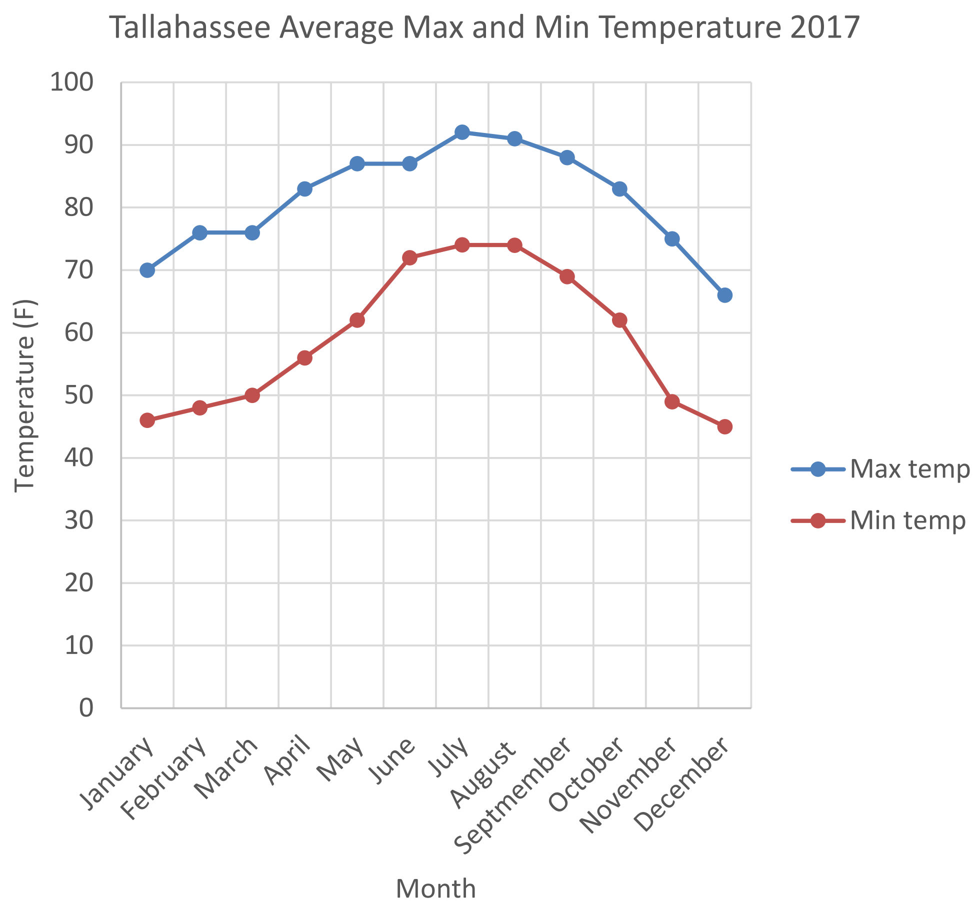

Figure 5: Temperature fluctuations per month in Tallahassee

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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

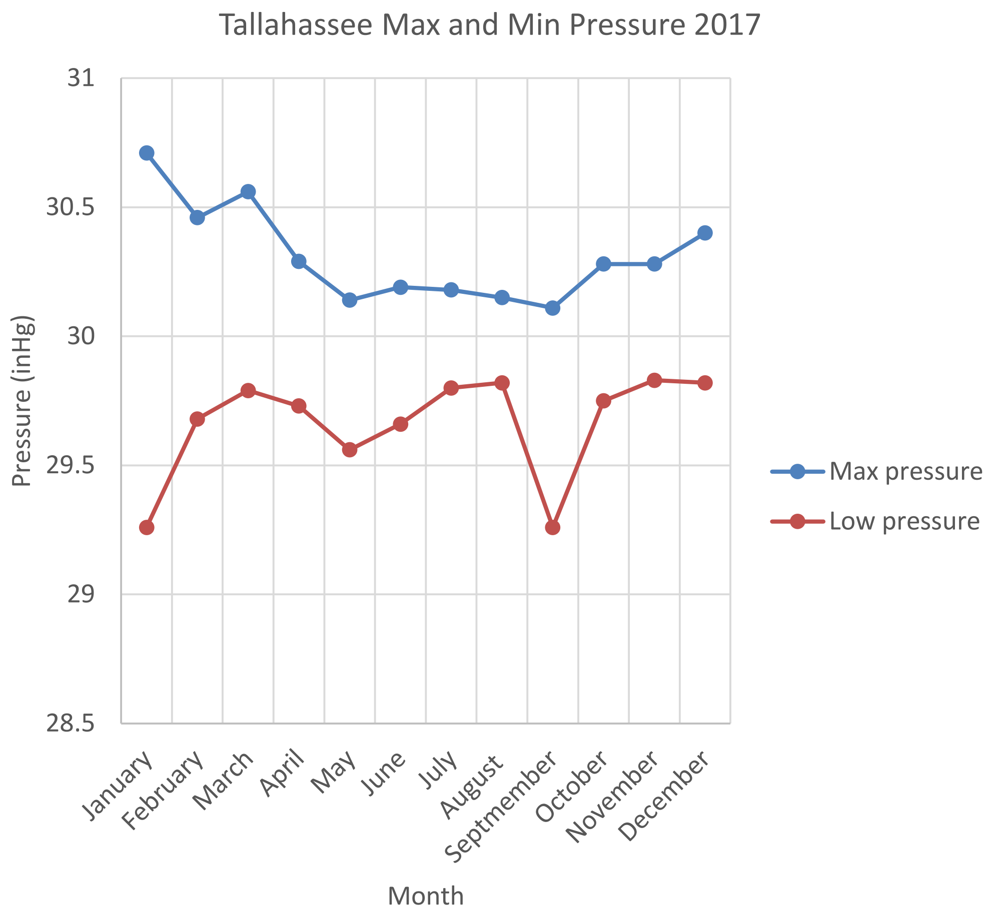

Figure 6: Pressure fluctuations per month in Tallahassee

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Date Display

- Had original display design hashed out
- Ordered a nice, wooden "clock"
- Rolling with the mistakes

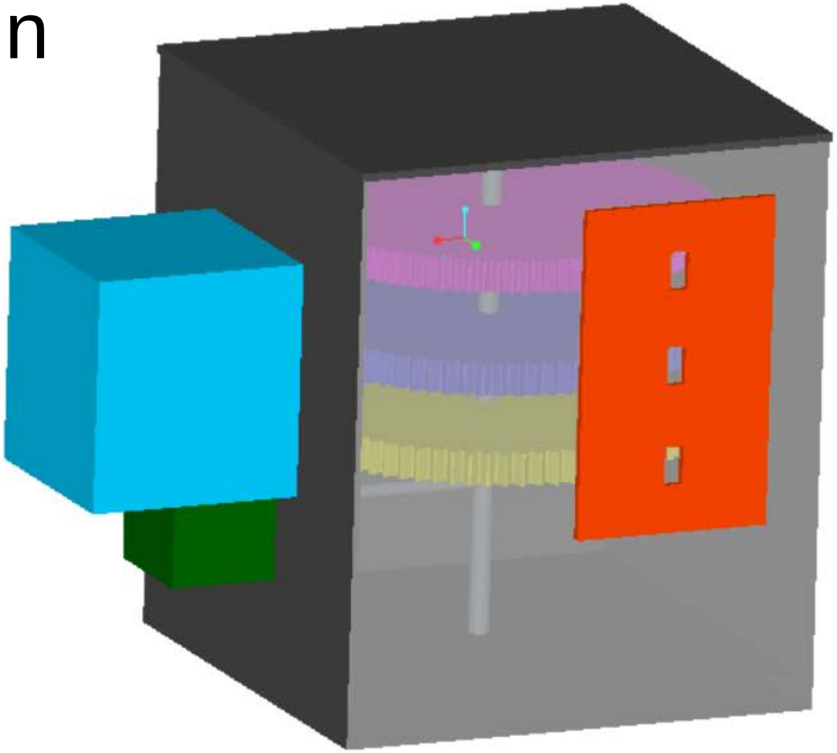

Figure 7: Preliminary display design

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Date Display (cont.)

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

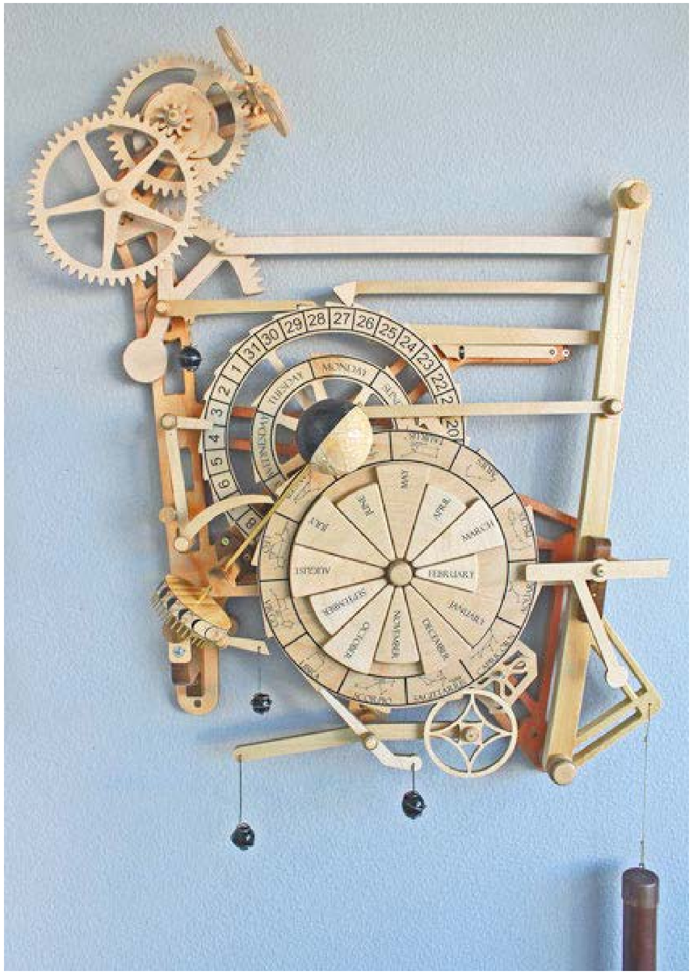

Figure 8: Clayton Boyer Perpetual Calendar

Date Display (cont.)

- Calendar will be made from acrylic
- Reduces weathering effects seen on wood
- Allows for lighter design, less power needed

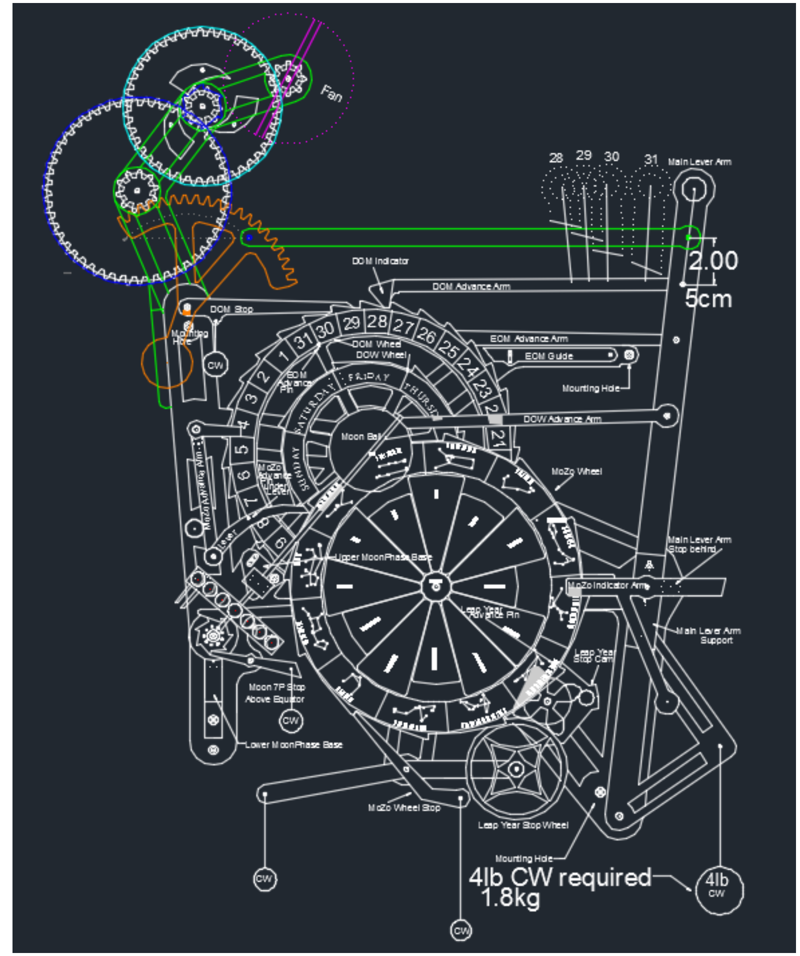

Figure 9: Clayton Boyer Perpetual Calendar AutoCAD drawing

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Prototype Simulation

- Once complete, the prototype will be set to run at an accelerated pace
- Allows for flaws in the design to be found
- Lets future teams analyze our design to make further improvements

Michael Patrick

Overview

- Current Focus
  - Time-keeping mechanism and date display
  - Energy system design
  - Connection of the subsystems
- Building Prototype
  - Ordering Parts
  - Setting up CAD files
  - Found available waterjet

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Gantt Chart

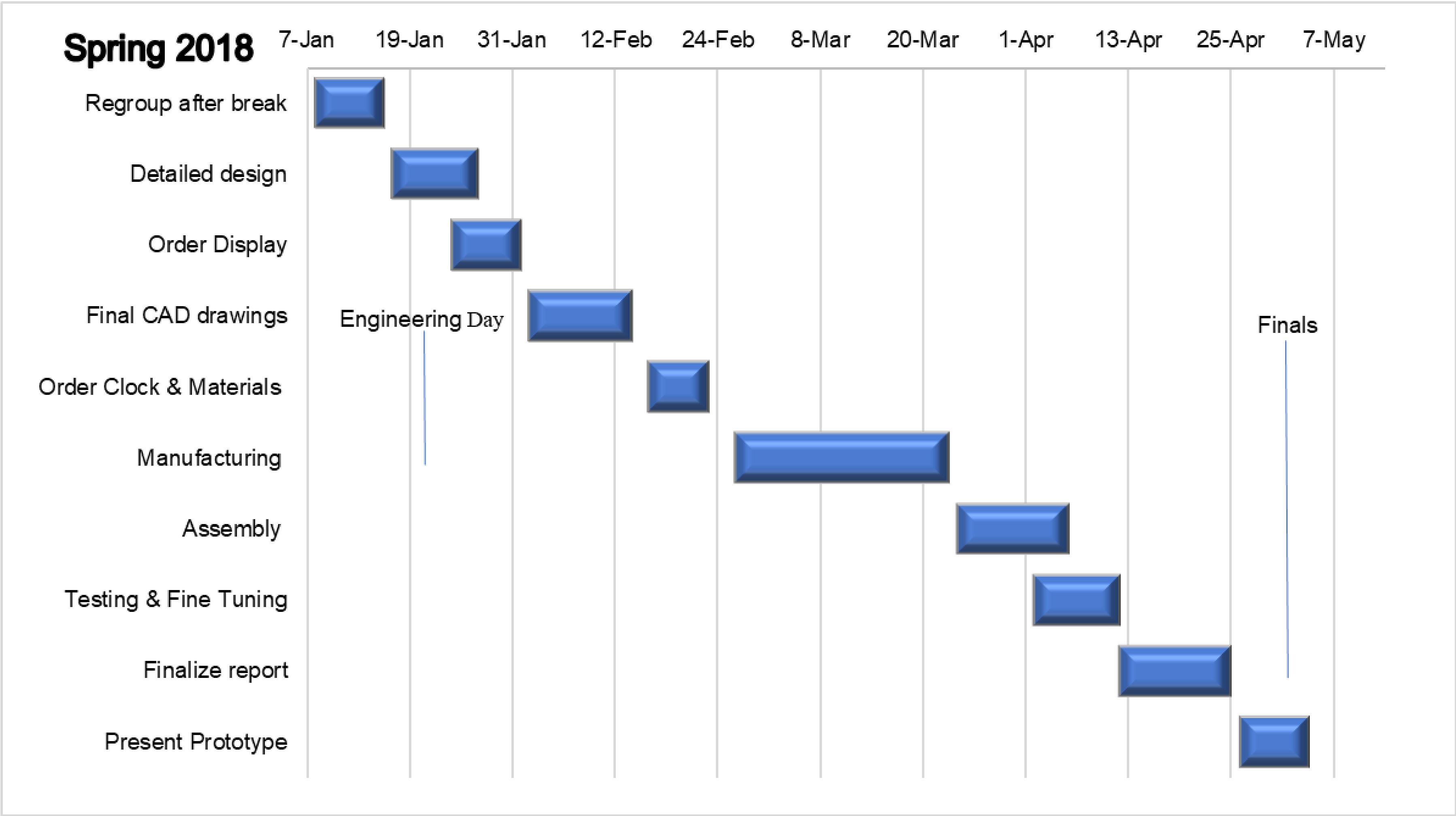

Figure 10: Gantt Chart

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References (ADD NEW ONES)

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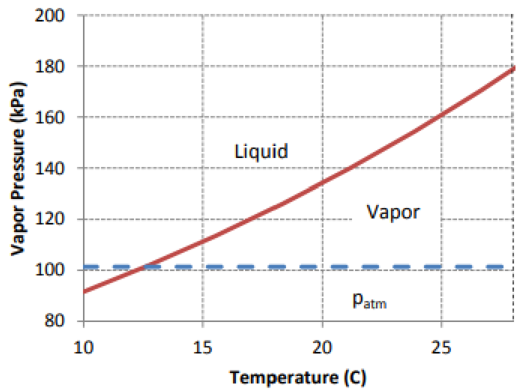
Thank you for your time.

ANY QUESTIONS?

BACKUP SLIDES

Ethyl Chloride Gas

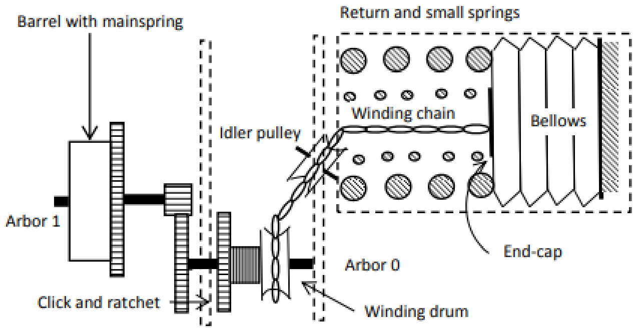
- At room temp. and atmospheric pressure, ethyl chloride is a vapor
- Bellows is at min. volume at vapor/liquid point (boiling point)
- Most of the gas is a vapor at atmospheric pressure, so the increase in pressure may follow the ideal gas law, $PV = nRT$



Pressure-temperature graph of ethyl chloride

Bellows Motion

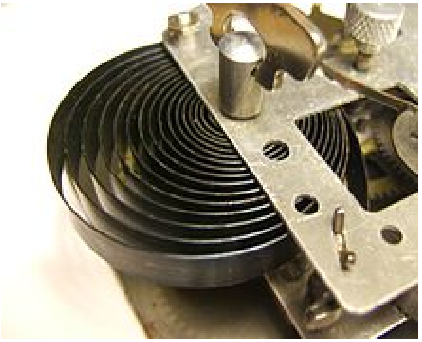
- Pressure of ethyl chloride in the bellows creates a force, $f_b = a_b p_b$
- Two springs oppose bellow's force to recompress it, $f_s = k_s x$
- Winding drum picks up slack when bellows expands
- When the bellows contracts, it pulls the winding chain and winds the mainspring through a click and ratchet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



Atmos winding system

Mainspring

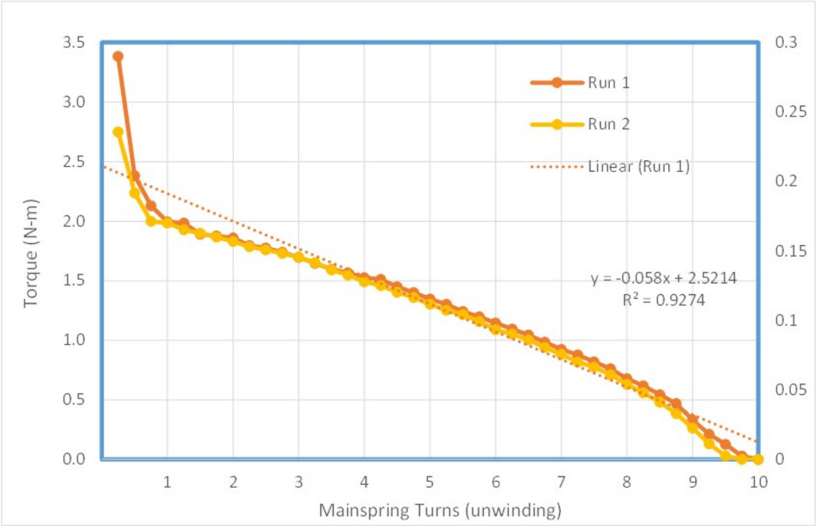
- Mainspring stores energy produced by bellows to drive the clock and the display
- Drive torque expressed as: $\tau = \frac{Eb_{ms}h_{ms}^3(\theta-\theta_0)}{12L} + \tau_0$ where E=modulus of elasticity, b_{ms}=mainspring width, h_{ms}=mainspring thickness, L=spring length
- $\tau_0 = Fd = (ma)d$
-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



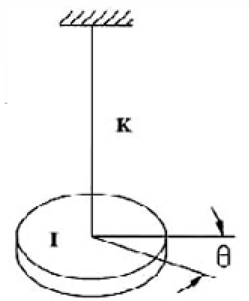
Mainspring torque

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
  - $\left(\frac{360°}{34\ mm}\right)\left(\frac{1.63\ mm}{℃}\right) = \frac{17.3°}{℃}$
  - 55:18 gear ratio from chain winder to mainspring
  - $\left(\frac{17.3°}{℃}\right)\left(\frac{55}{18}\right) = \frac{52.9°\ great\ wheel}{℃}$
  - For Atmos, full turn of great wheel takes 29.5 days
  - $\left(\frac{52.9°}{℃}\right)\left(\frac{29.5\ days}{360°}\right) = \frac{4.33\ days}{℃}$

Energy Analysis (cont.)

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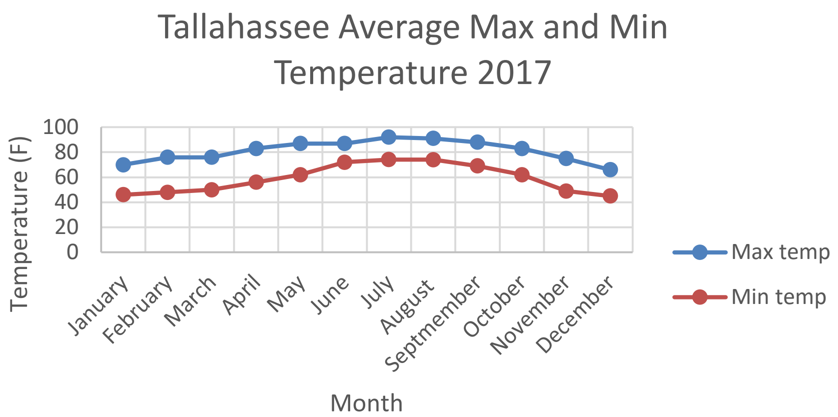
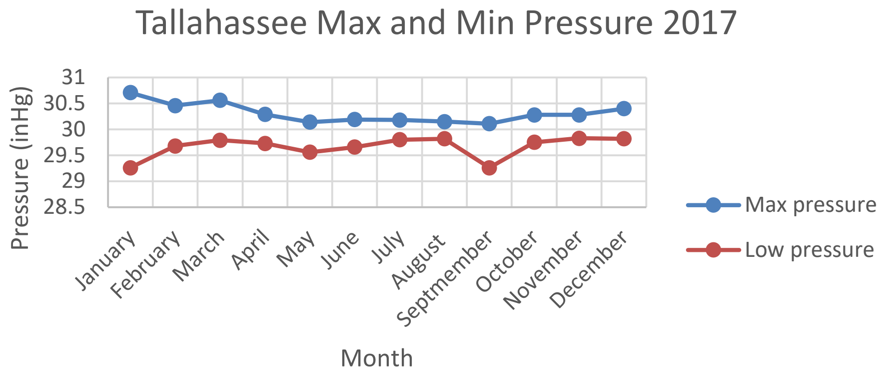
Energy Analysis (cont.)

- 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