ASEN 2002 Design Lab

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General Purpose

General Purpose: To design a functional zero-pressure balloon and understand the fundamental thermodynamic principles governing its behavior

Zero-Pressure Balloons

- Open at bottom
- Vents on side
- Limited duration

Super-Pressure Balloons

- Long distance
- No openings
- Low gas loss

Introductions and Outline

Design Requirements $\longrightarrow$ **Haotian Chen**

Design Specifications $\longrightarrow$ **Sunny Sarkar**

Design Research $\longrightarrow$ **Cole Sechrist**

Design Analysis $\longrightarrow$ **Isaac Timko**

Design Deliverables $\longrightarrow$ **Ricardo Lopez-Abadia**

Design Requirements

Purpose

- Carry a 500 kg research instrument
- Maintain altitude of 25 kilometers $\pm$ 800m for at least one day

Pre-Lab

- Force Analysis, Volume Analysis, and Mass Analysis
  - Free Body Diagram
  - Equilibrium Equations for Full-Scale Design
- Thermal Analysis
  - Effect of Radiation and Heat Transition

Free Body Diagram

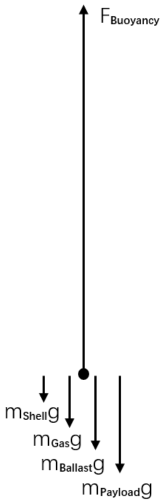

Figure: Free Body Diagram of Balloon Mass System

Design Requirements

Full-Scale Design

- Gas
  - Density, Safety......
- Material
  - Density, Strength, Safety......
- Computer Science
  - Matlab code for calculation which considers all factors that affect Volume and the balloon's mass
    - Thermal radiation, Gas, Material, Safety redundancy......

Finally......

- THE BEST TEAM OF ASEN2002 !

Zero Pressure Balloon

- Gage Pressure
- Pressure Depends Heavily on Temperature
- Vents on Sides
- Limited Run Time

Assumptions

Perfect Sphere

$$\frac{dE}{dt} = 0$$

- $0 = \dot{Q}_{in} - \dot{Q}_{out}$
- $\dot{Q}_{balloon} = \dot{Q}_{solar} + \dot{Q}_{earth}$
- $T_{balloon\ min} = \sqrt[4]{\frac{\alpha_{eb} \cdot q_{earth}}{4\varepsilon_b \cdot \sigma_{SB}}}$ $\qquad T_{balloon\ max} = \sqrt[4]{\frac{\alpha_{sb} \cdot q_{sun} + \alpha_{eb} \cdot q_{earth}}{4\varepsilon_b \cdot \sigma_{SB}}}$

Assumptions

- Ideal Gas

$$PV = mRT$$

- Pressure Constant at the initial altitude and temperature

$$V_{He} = \frac{mRT}{p} \; gives \; value$$

- Radius of Shell is Negligible

$$V_{He} = V_{system} \qquad \rho_{system} = \frac{m_{system}}{V_{system}}$$

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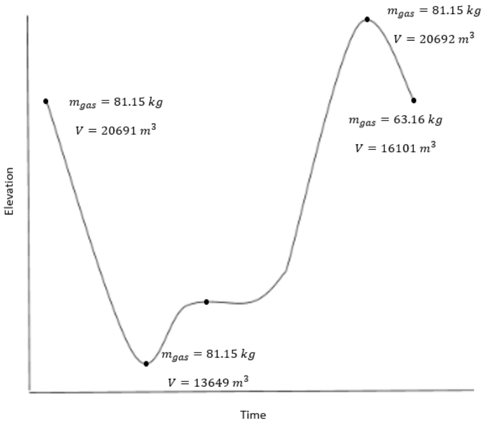
Design Specifications



$$V_{system} = \frac{mRT}{p}\ gives\ value \qquad \rho_{system} = \frac{m_{system}}{V_{system}}$$

Design Research

Potential Materials

- Honeywell Capran Emblem 2500M M-Coated Bi-Axially Oriented Nylon Film
  - Lowest tensile strength at break is 207 MPa
  - Thickness of 25.4 microns
- Honeywell Capran Emblem 1200 Bi-Axially Oriented Nylon Film
  - Lowest tensile strength at break is 193 MPa
  - Thickness of 12.2 microns
- Honeywell Capran Emblem 1500 Clear Bi-Axially Oriented Nylon Film
  - Lowest tensile strength at break is 200MPa
  - Thickness of 15.2 microns

Selected Material: Honeywell Capran Emblem 2500M M-Coated Bi-Axially Oriented Nylon Film

Design Research

Potential Gases

- Helium
  - Non-combustible
  - Density at STP (1 atm and 0°C) is 0.179 g/L
  - Price: $58/125L
- Hydrogen
  - Very flammable
  - Density at STP is 0.090 g/L
  - Price: $5.50/kg

Selected Gas: Helium

Data on materials is from matweb.com

Design Analysis

Mass Budget

Item	Mass (kg)	Fractional Percent of Total
Balloon Shell	3.387	0.471%
Helium Gas	81.15	11.28%
Ballast	135	18.76%
Payload	500.0	69.49%
Total	719.5	100.0%

- Factor of Safety: 2
- Volume: 16810 m^3

Volume Calculations

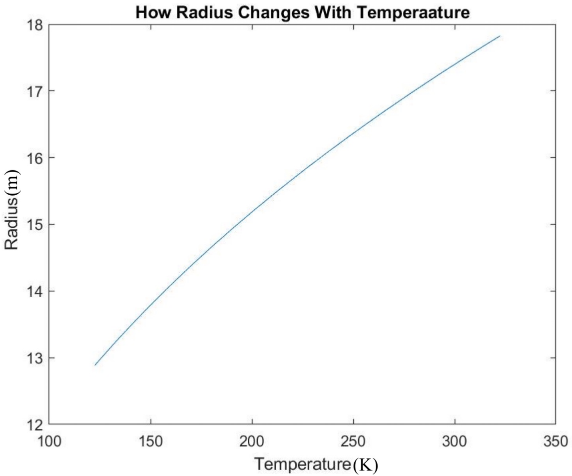
$$Volume_{Balloon} = \frac{4}{3} * \pi * (r + thickness)^3$$

$$thickness = \frac{k_{safe} * P_{Guage} * r}{2 * \sigma_u}$$

$$Volume_{He} = \frac{4}{3} * \pi * (r)^3$$

$$Volume_{Balloon} = \frac{4}{3} * \pi * (r + thickness)^3$$

Design Visulzation



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Design Deliverables

- Mass
  - 81.2 kg - Gas of Balloon
  - 3.4 kg - Shell of Ballon
- Released Balast
  - 140kg - Released Payload
  - 18 kg - Released Gas
- Volume
  - 13650 m^3 - volume during night
  - 20700 m^3 - volume during day
- Height
  - 24250 m - height during night
  - 25750 m - height during day

Design Deliverables

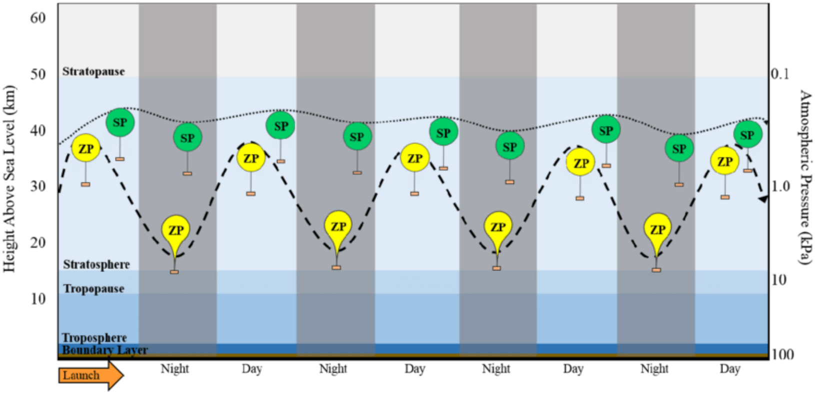

Figure: https://www.researchgate.net