MLI Pressure Sensor
Design Review 5

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Introduction

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Project Recap

Presenter: Ben Hallstrom

Background Information

- NASA Marshall Space Flight Center (MSFC)
- Advisors:
  - Dr. Wei Guo
- Sponsors:
  - Jim J. Martin, James W. Smith
- Pressure sensor must interfere as little as possible with its surroundings while measuring residual gas within an MLI blanket.

Multi-Layer Insulation (MLI)

- Cryogenic tanks use multi-layer insulation blankets to protect from thermal radiation during time in space
- Composed of 30 or more layers of alternating Double Aluminized Mylar and polyester fabric mesh placed in a cryostat.

Figure 1: Multi-layer insulation blankets

MLI Pressure Sensor

- Develop a pressure sensor that can measure the vacuum within interstitial areas.
- After vacuum, if residual gas still remains between each layer, sensor should read a pressure reading different than the pressure reading within the vacuum chamber.

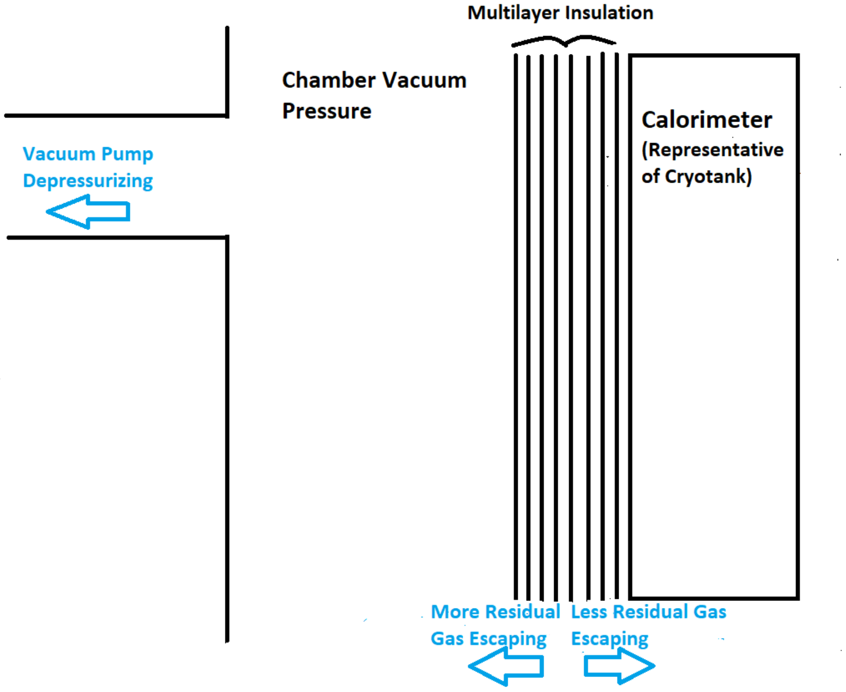


Figure 2: Pressure Gradient Illustration

Project Constraints

1. Measure from 10e-3 torr to 10e-5 torr.
2. Operate at temperatures as low as 77K.
3. Sample at least once every second.
4. Avoid interference with MLI components.

Electric Field in an CCG

- Electric field and magnetic field work together to trap electrons.
- Anode has a positive charge whereas the cathode has a negative charge.
- Electrons will be emitted and accelerated from the cathode to the anode.
- High initial voltage difference (at least 2,000 V) across the anode and cathode will produce a plasma.
- Ionized molecules will be attracted to the cathode and will be measured as current.

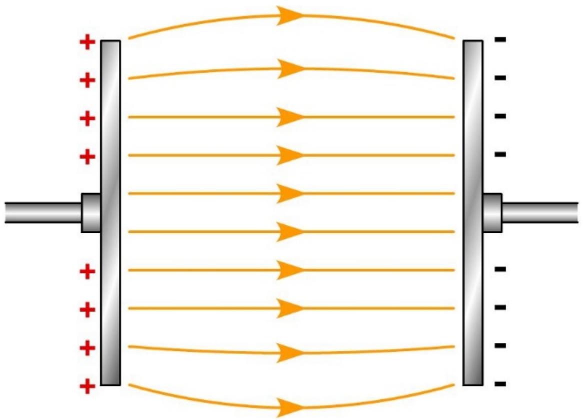


Figure 5: Behavior of electrons between plates.

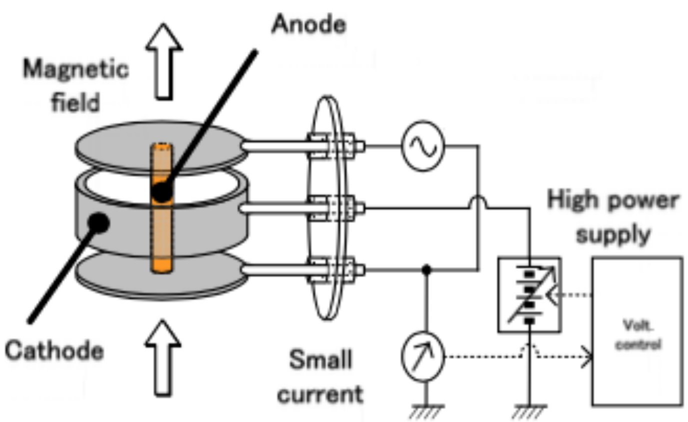


Figure 6: Diagram of Cold Cathode gauge theory.

Magnetic Field in a CCG

- Magnetic field typically used is 1-2 kG.
- Magnets are oriented so that the field it parallel to the orientation of the anode (perpendicular to the electric field).
- Will increase the path-length of electrons and thus the probability that they will collide with molecules and ionize them.

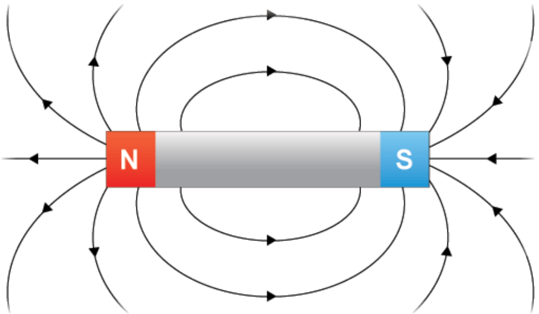


Figure 7: Magnetic field behavior.

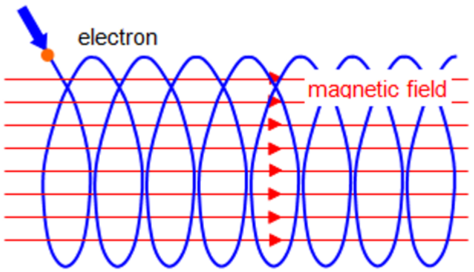


Figure 8: Behavior of an electron around a magnetic field.

Gauge Design

Presenter: Justin DiEmmanuele

Design Features

- Inverted magnetron ion gauge provided by NASA.
- Our design will mimic cross section of this sensor.
- We will likely lose sensitivity but not enough to make the data measured useless.

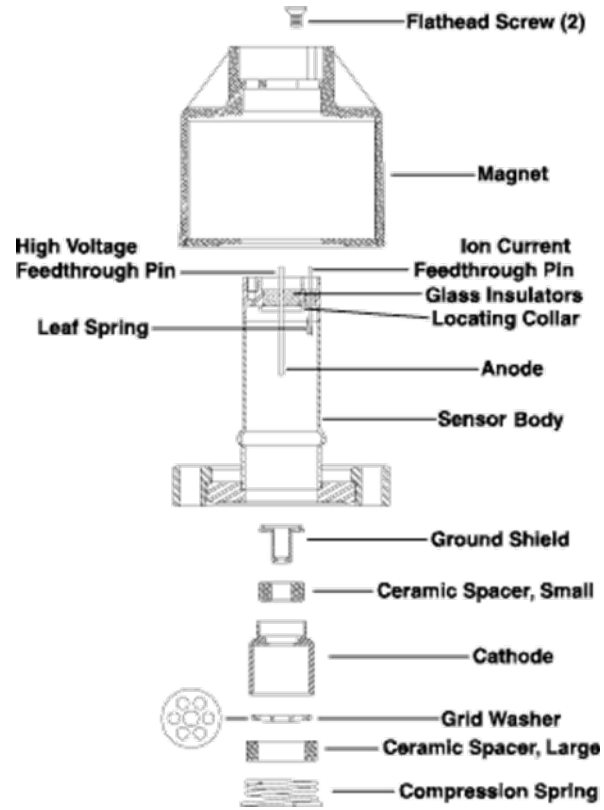


Figure 9: Exploded view of gauge supplied by NASA.

Design Features

- Electrons emitted from cathode.
- Two Neodymium magnets orientated to create a magnetic field.
- Wire clamped to anode provides voltage.
- Wire clamped to cathode returns current reading.

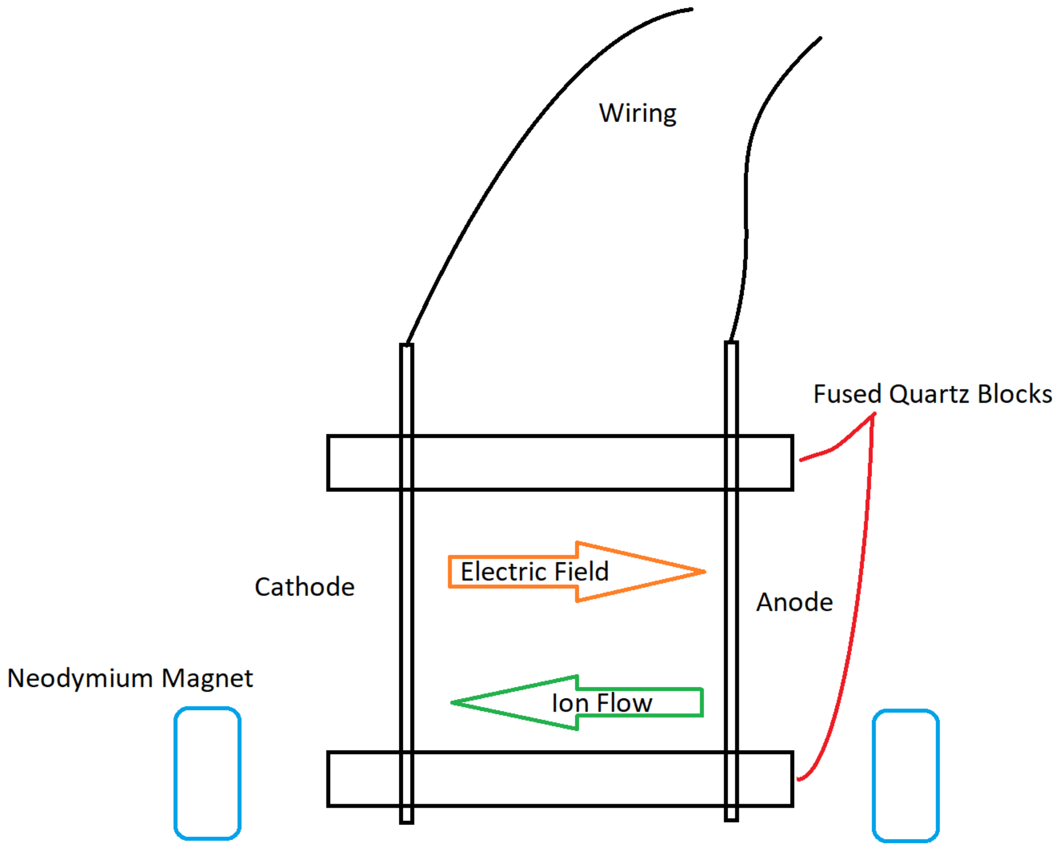


Figure 10: Schematic of the ion gauge assembly.

Theory

Presenter: Justin DiEmmanuele

Ion Gauge Equation

- I_c → Collector Current
- σ_i → Ionization Cross Section
- L → Length of ionizing space
- k → Boltzmann's Constant
- T → Temperature
- I_e → Electron Emission Current
- P → Pressure

$$I_c = \frac{\sigma_i L}{kT} I_e P$$

Field Emission

- I_e partially dependent on field emission from cathode
- Described by Fowler Nordheim Tunneling Equations
- Current Emitted is a function of:
  - Area of cathode
  - Work function of material
  - Voltage

Important to Note

- I_e Term is tricky for CCG
  - Includes field emission from cathode and electrons in plasma
- Testing at high Temperature
  - Decrease in sensitivity
- **In practice, I_c cannot be predicted easily**

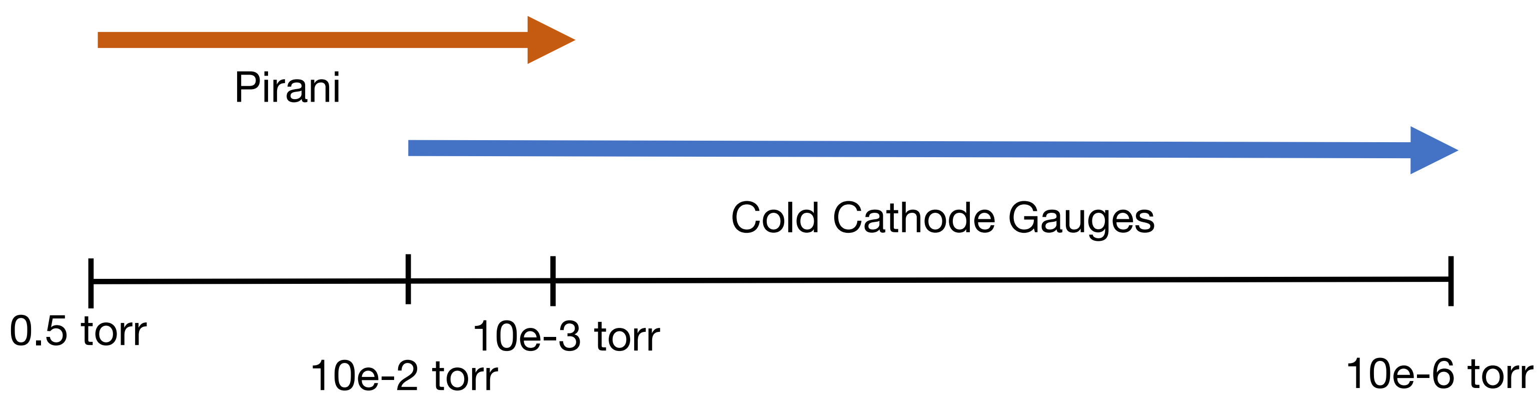
$$I_c = \frac{\sigma_i L}{kT} I_e P$$

Design of Experiment

Presenter: Marie Medelius

Design of Experiment

- Measurement devices used during test:
  - Our cold cathode gauge prototype
  - MSFC-supplied cold cathode gauge (control)
  - Pirani Gauge (higher pressures)



Design of Experiment

- Measured outputs:
  - Ion current vs. pressure
  - Compare control gauge with prototype gauge to calibrate prototype
  - Compare with expected behavior

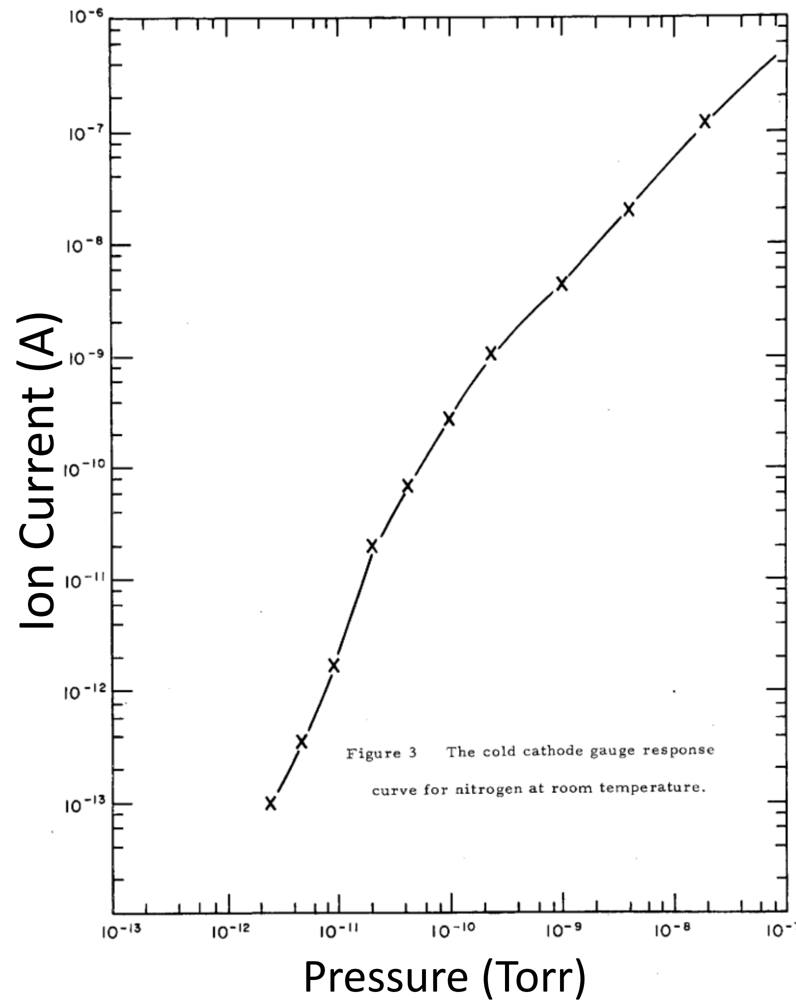
- Special considerations:
  - Goal - Obtain reliable signals even with noisy data
  - Run experiment 5+ times to minimize noise and make sure results are consistent

Expectation

- Because our design will have less space for a plasma cloud to form and sustain and lower electron emission, we predict we will have a lower value of I_e and therefore will measure a lower Ion current I_c but the measurement will still be proportional to pressure.

Expectation

- Should be able to reproduce same calibration curve over multiple tests
- May need to filter noise



Concerns

- Ion current may be too small to measure with available equipment
- Ion current may be so small that random current variations are large compared to real value
- Small space may inhibit sustainable plasma to form

Timeline

Table 2: Timeline

Major Tasks	Project Completed By: April 27, 2018													
Determine the Necessary Components and Materials	●													
Iterate CAD Designs		●	●	●	●									
Research Part Costs/ Create Bill of Materials				●	●									
Buy/Order Parts					●									
Build Prototype of Cold Cathode Ion Gauge						●	●	●	●	○				
Determine Where to Borrow LabView/ Modify Block Diagram for LabView					●				●	○				
Determine How to Acquire Supporting Hardware					●				●					
Final Testing/Prototyping										○	○	○	○	○
	21-Jan-18	28-Jan-18	4-Feb-18	11-Feb-18	18-Feb-18	25-Feb-18	4-Mar-18	11-Mar-18	18-Mar-18	25-Mar-18	1-Apr-18	8-Apr-18	15-Apr-18	22-Apr-18

- Building prototype
- Gathering supplies provided by Mag Lab in preparation
- Finalizing CAD drawings for dewar top plate machining
- Final testing will be done in next week