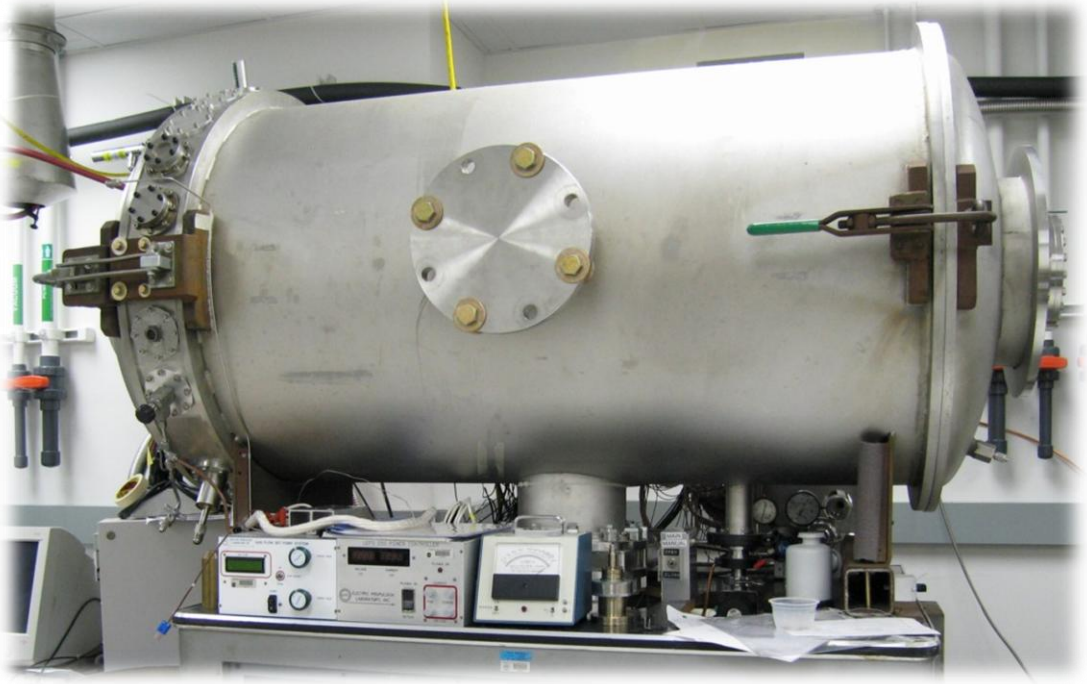

Control Systems for Thermal Vacuum Chambers

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NASA Space Grant

Caltech Student-Faculty Programs

Thermal Vacuum Chambers

- Flight hardware needs to be tested in a thermal vacuum chamber to mimic the vacuum and temperature of space.
- Some tests conducted at the Reliability Assurance Technology Test Laboratory (RATT Lab).

Cassini in the 25 ft Space Simulator.

Objectives

- Chamber currently used to develop instruments.
- A vacuum fail-safe device is to be built for one of the chambers to increase the margin of safety.
- Installation of thermal actuators.
- Goal of flight certification.

Vacuum Systems

- **Knudsen Number (Kn): mean free path of molecules divided by pipe radius.**
- **“Rough” vacuum:**
  - **Up to 10^{-3} Torr (mm Hg), Kn<0.01.**
  - **Air is viscous and pulled with a pressure difference (rough pump).**
- **“High” vacuum:**
  - **up to 10^{-10} Torr (mm Hg), Kn>1.**
  - **Air acts like particles and pushed with momentum transfer (turbomolecular pump).**

Turbo pump.

Heat Exchanger Systems

- **Heat exchanger plate used to change the temperature of the chamber.**
- **Resistance heaters and cryogens (liquid nitrogen, LN_2) used for heating and cooling.**

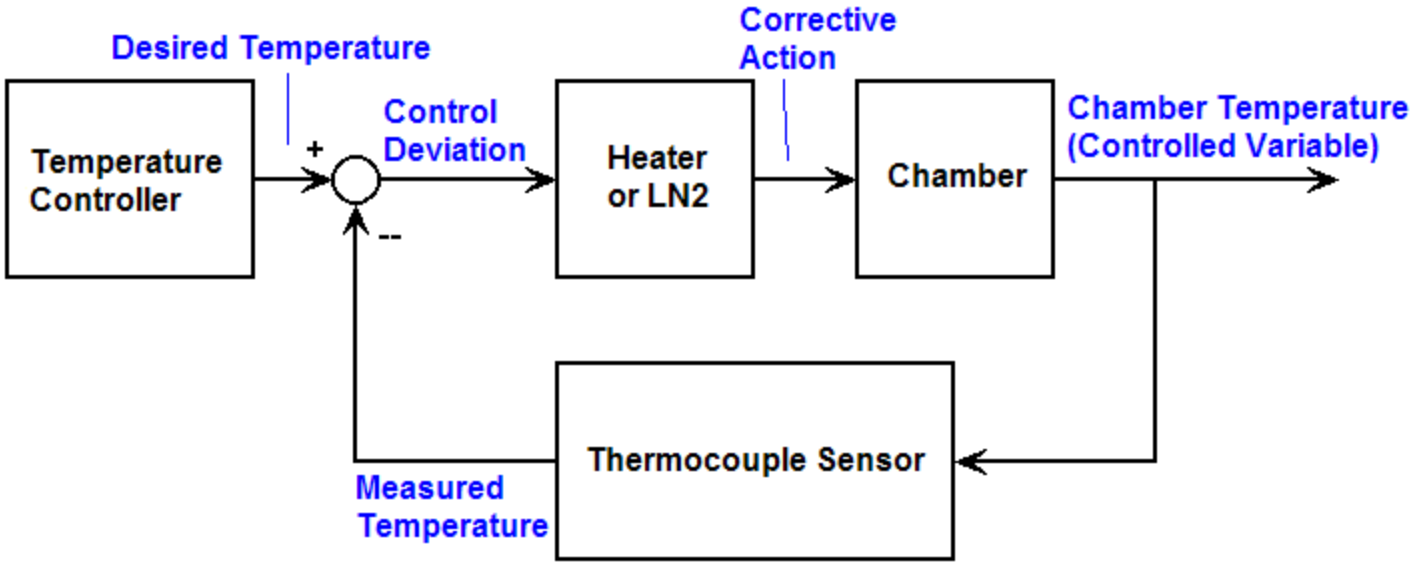
LN_2 dewar flasks that supply the RATT Lab.

Sensors

- Thermocouples monitor temperature.
- Thermocouple gauges to measure the vacuum up to “rough” vacuum (10^{-3} Torr).
- Bayard-Alpert ionization gauges for up to “high” vacuums (10^{-10} Torr).
- A multi-gauge controller is used to measure the output of the two vacuum gauges.

Bayard-Alpert ion gauge.

Control Systems

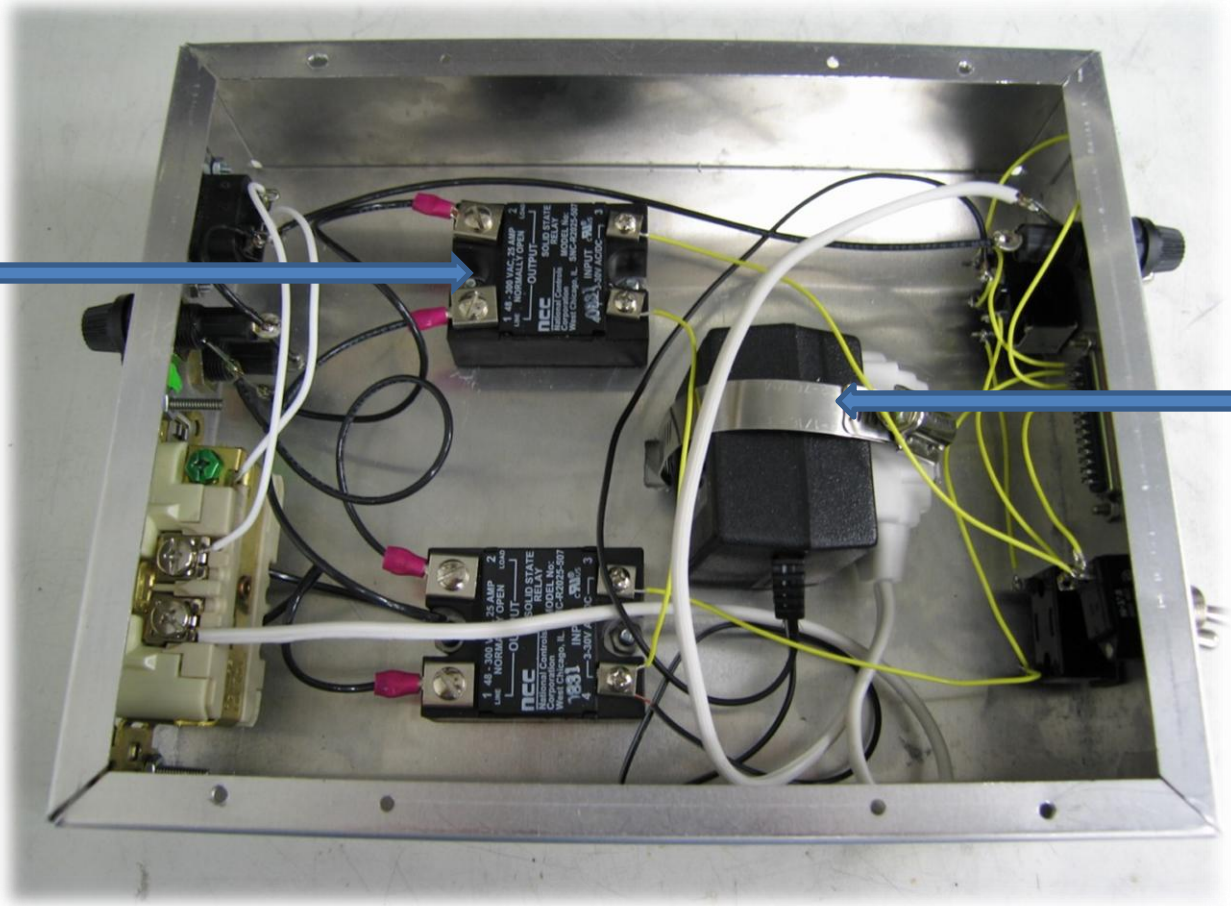


- Control systems maintain a constant vacuum and temperature environment by integrating sensors and actuators.
- Overall system consists of three components:
  - Temperature controller: maintain preset temperature.
  - Temperature fail-safe: backup for extreme temperatures.
  - Vacuum fail-safe: backup for loss of vacuum.

Fail-safe Mechanisms

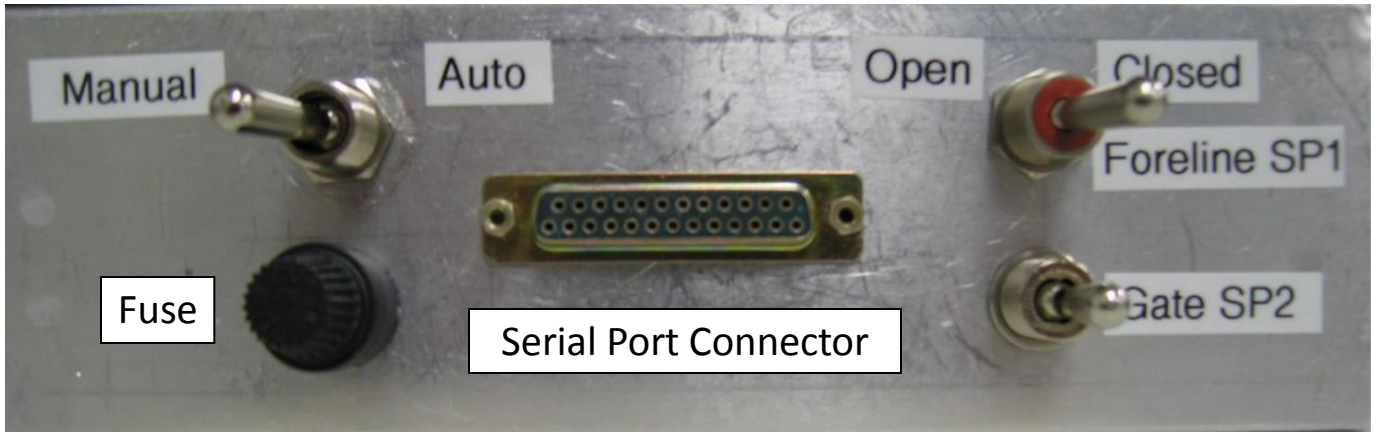
- **Temperature fail-safe:**
  - **High temperatures: heaters shut off.**
  - **Cold temperatures: solenoid valves shut off the flow of LN_2.**
- **Vacuum fail-safe:**
  - **Loss of vacuum: isolate the chamber to protect the instruments and close foreline to protect turbo pump.**
- **Actuators and sensors to be installed for the temperature controller and temperature fail-safe.**
- **Vacuum fail-safe needs to be built.**

Vacuum Fail-safe



Inside of the vacuum fail-safe box.

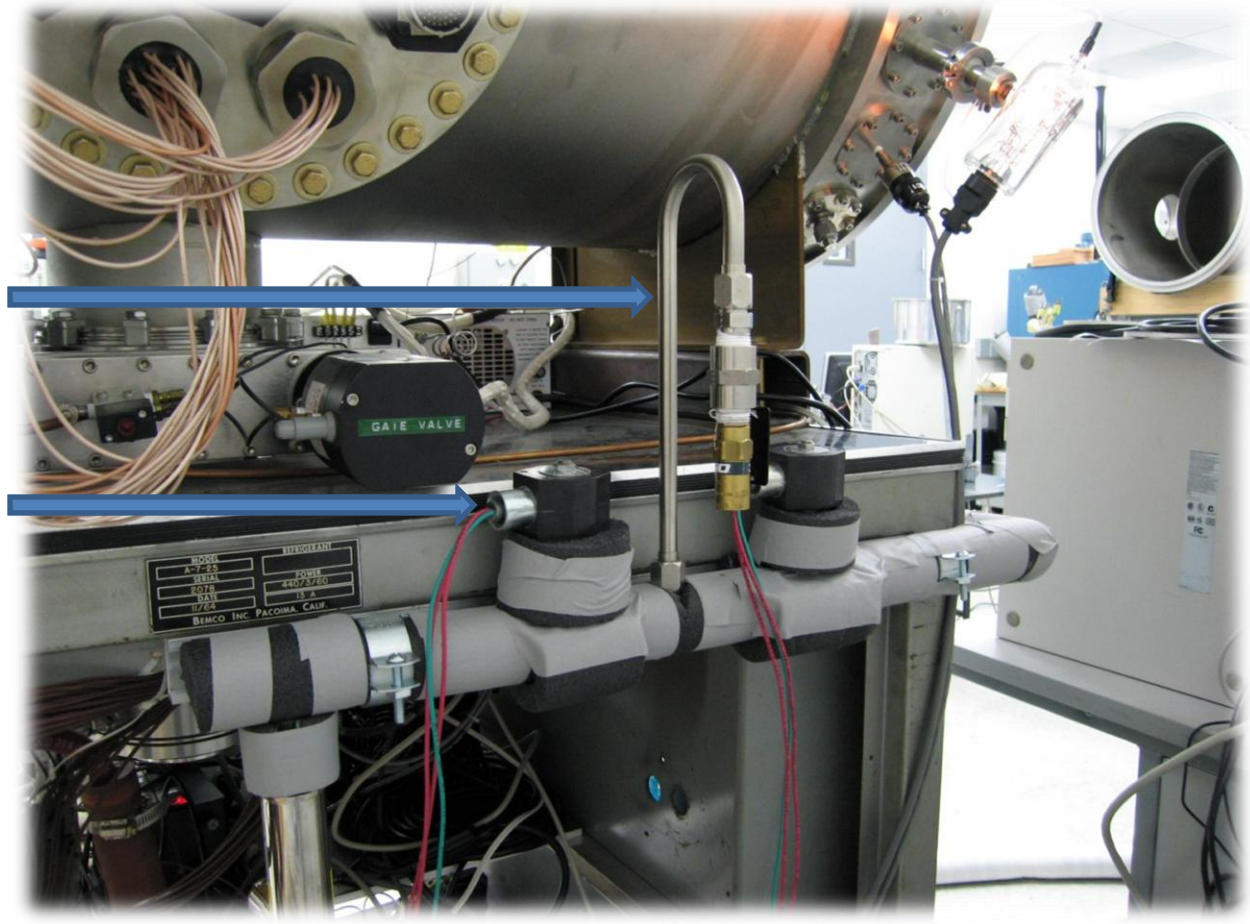
Vacuum Fail-safe



Front view of the vacuum fail-safe box.

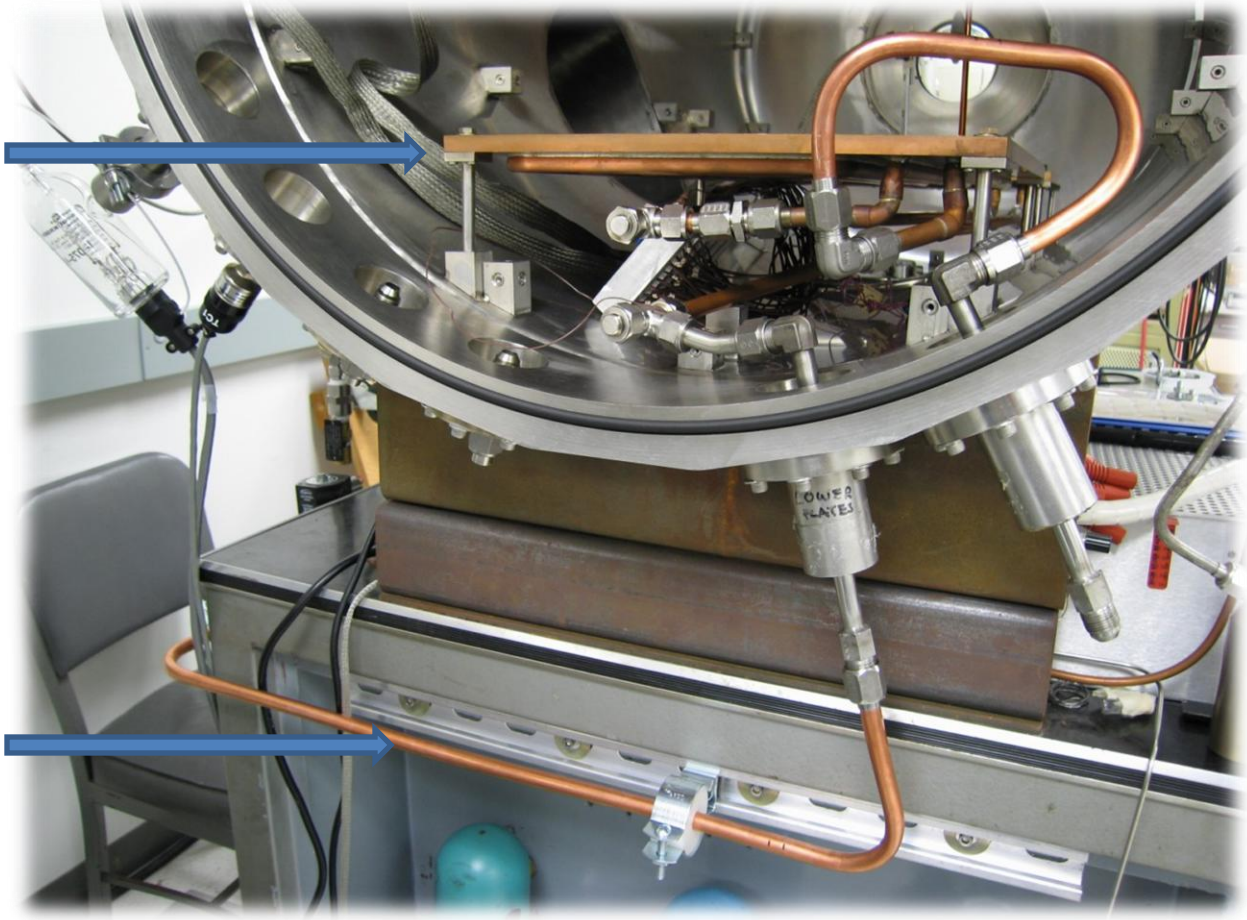
Back view of the vacuum fail-safe box.

LN_2 Solenoid Valves



Solenoid valve setup. One valve controlled by controller, one by fail-safe.

Heat Exchanger Plate



LN_2 and resistance heaters for cooling and heating inside the chamber.

Controllers and Fail-safes

Multi-gauge Controller

Vacuum Fail-safe

Turbo Pump Controller

Turbo Pump

Temperature Controller

Temperature Fail-safe

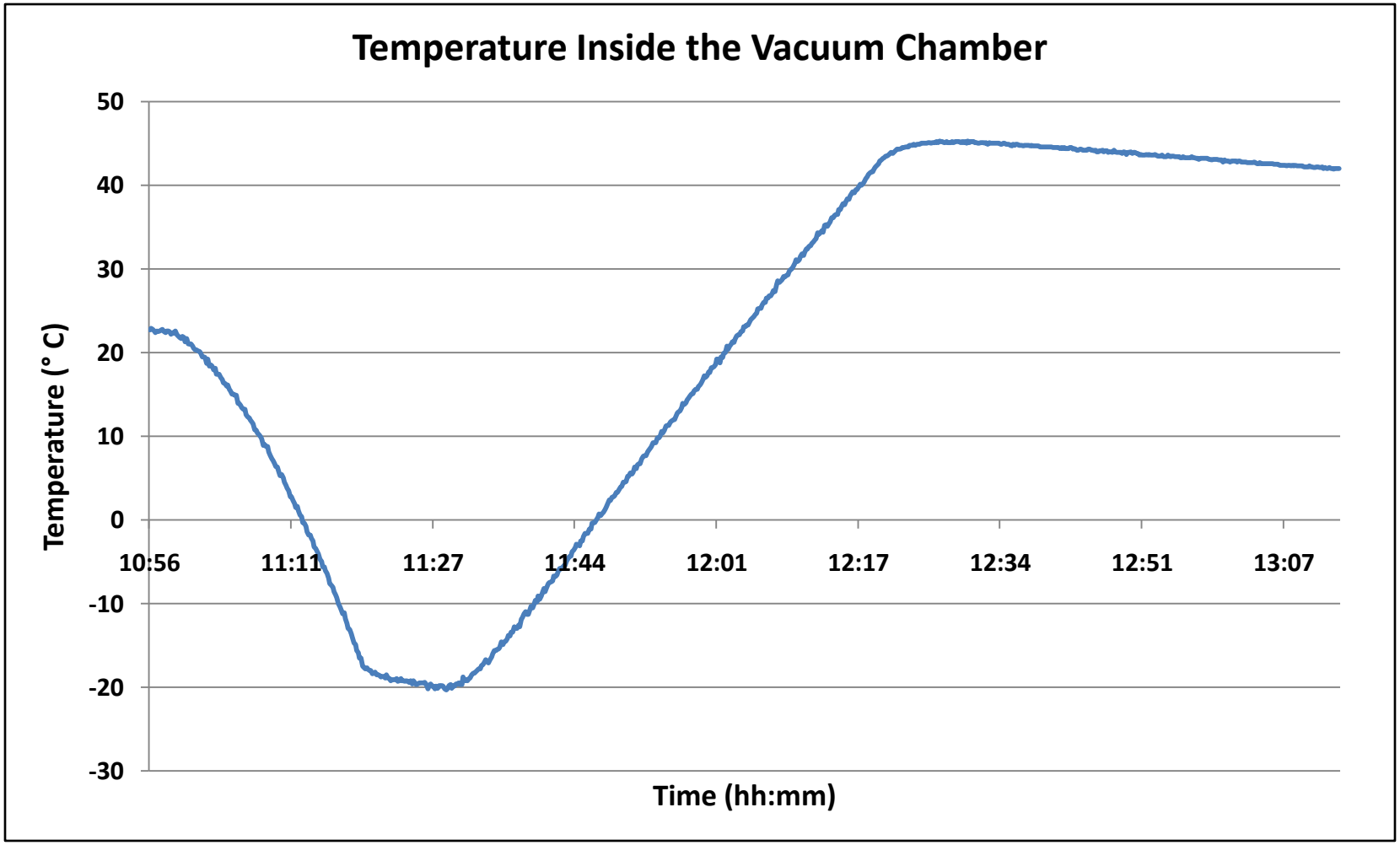
The control and fail-safe units.

Results

- Vacuum leak simulated to test the vacuum fail-safe.
- Fail-safe correctly latched on to “safe” mode.
- Thermocouples connected to data acquisition device to record temperature during test.
- Simulated hot and cold temperatures.

The data acquisition system.

Temperature Test



Graph of temperature over time. The fail safe was set to -20°C and 40°C.

Discussion

- Vacuum and temperature fail-safes work.
- Some overshoot of temperature, but negligible:
  - Location of the thermocouples.
  - Thermal inertial of heat exchanger plate.
  - Cold gas remaining in piping.
- Updated existing operating procedures to include procedures for the vacuum fail-safe.

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