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FLOATING PRESSURE CONVERSION AND EQUIPMENT

UPGRADES OF TWO 3.5 kW @20K, HELIUM REFRIGERATORS

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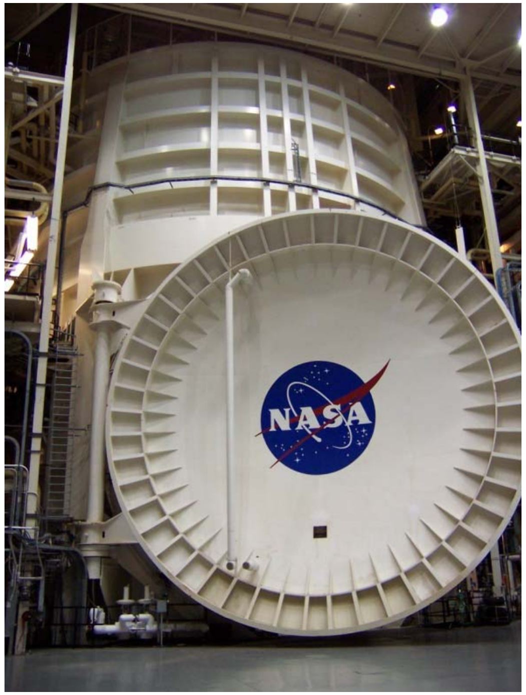
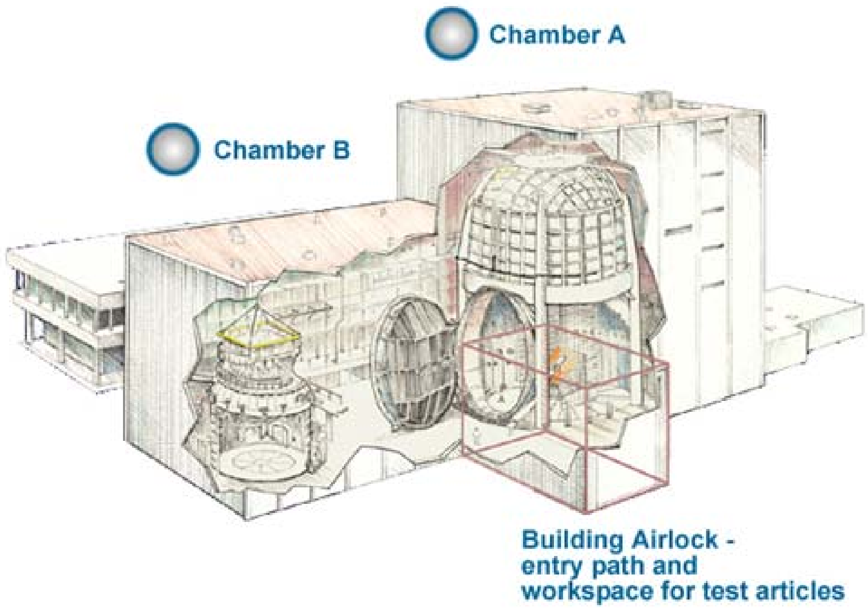




FLOATING PRESSURE CONVERSION AND EQUIPMENT UPGRADES OF TWO 3.5 kW @20K, HELIUM REFRIGERATORS

Brief History of SESL use of Helium Refrigeration

» 1960's Five CVI refrigerators of 1.75 KW @20K were installed for chamber cryo-pumping

Chamber A was supported by four and one for Ch-B

» 1990's Combined all units with common transfer line

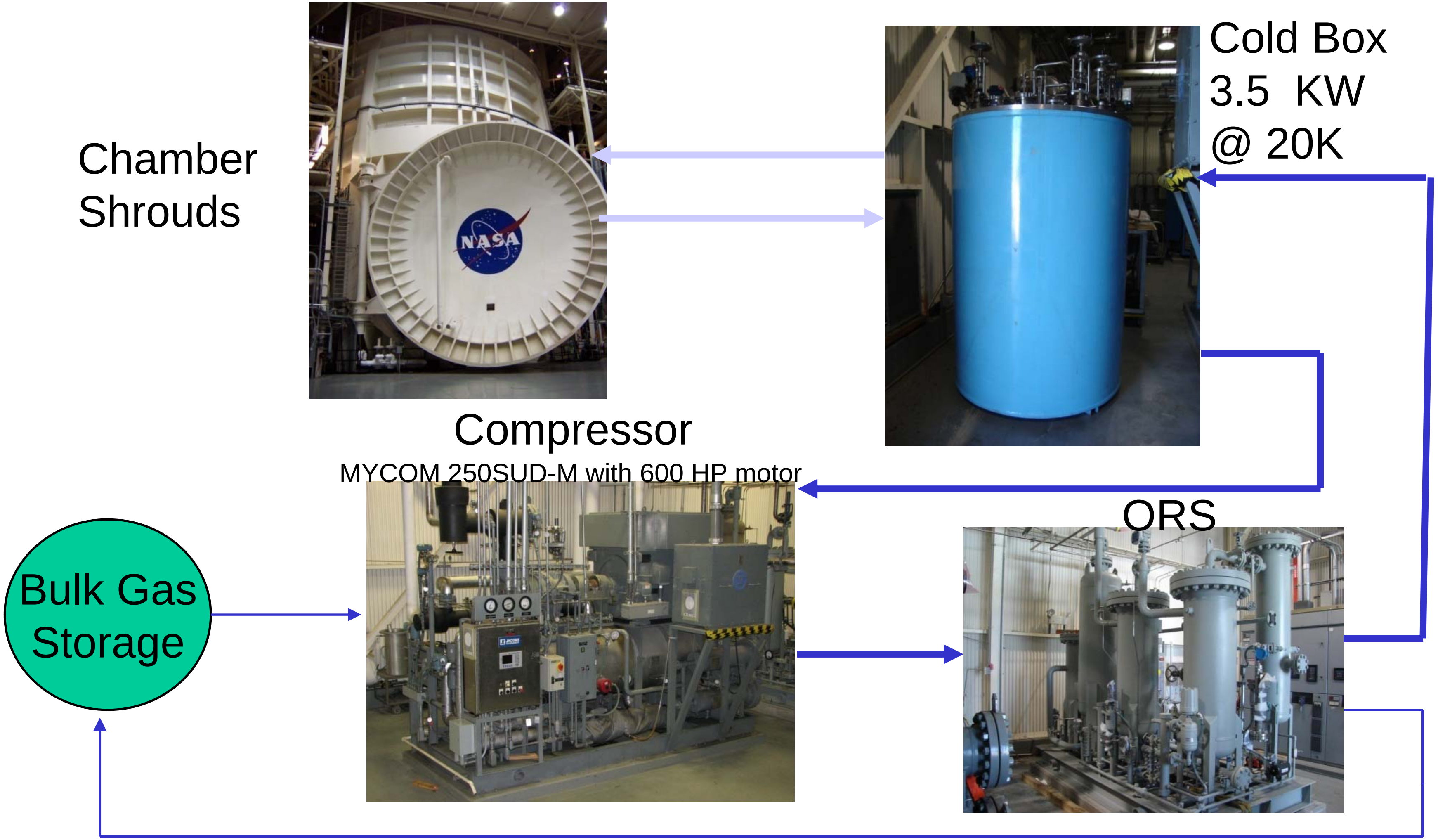
- Very beneficial to have the ability to use refrigerators on different chambers through common manifold

» 1997 Commissioned two Linde modified TCF50 units rated at 3.5 KW @20K each to redundantly support testing in either Chamber A or B

Future:

» Preparing to add a new 12.5 KW @20K refrigerator to support JWST testing in Chamber A

Since the initial commissioning of SESL (1965), large scale helium refrigerators and helium shrouds within Chambers A & B have been used to provide cryo-pumping to high vacuum conditions



Why did JSC go away from the original CVI units?

» In the late 1980's realized the CVI units were no longer maintainable

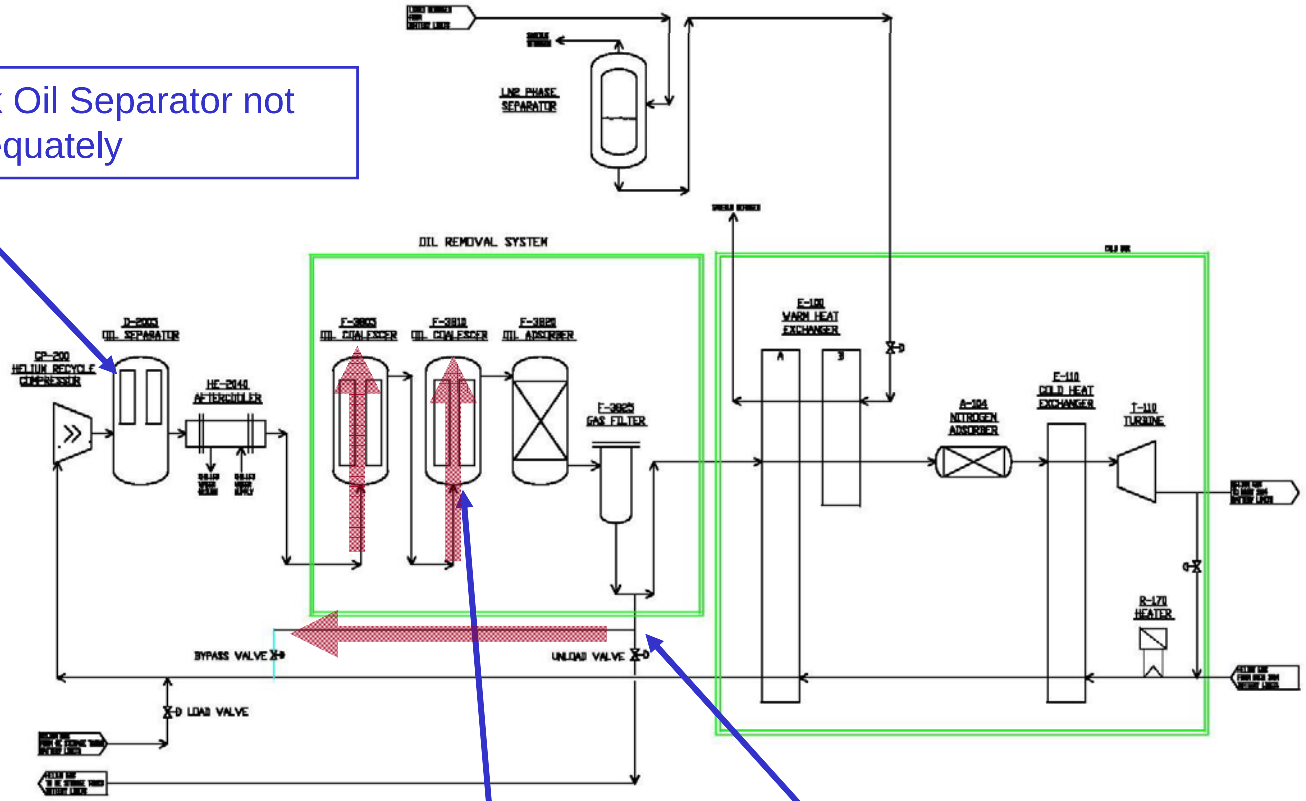
» Moved to newer technology of turbine expanders and oil-injected screw compressors

» Issued a contract through NASA's Construction of Facilities (CoF) program to procure two new helium refrigerators, a building wing, and utilities to support the upgrade

- **The system performance was good once up and running, but three problems lead to much headache**
  - » Oil Carry-over past the oil removal system
  - » Controls system lock-up with no discernible cause
  - » The chamber panel temperatures varied by 2.5K
- **As a result of the oil carryover, the cold boxes were contaminated**
- **The problem was partially mitigated by the compressor contractor, but not corrected**
- **Linde Cryogenics of Tulsa was contracted to determine the cause of oil carryover, and implement solution**

Original system arrangement and issues:

Horizontal Bulk Oil Separator not performing adequately



Flow through coalescers was bottom to top

Compressor recycle valve downstream of ORS

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Cold Box 80K Charcoal Adsorber
Contaminated with compressor oil

Cold Box VJ Bayonet to load
Compressor oil found downstream of turbine

Modifications / refurbishment project (Linde):

Changes made to the ORS

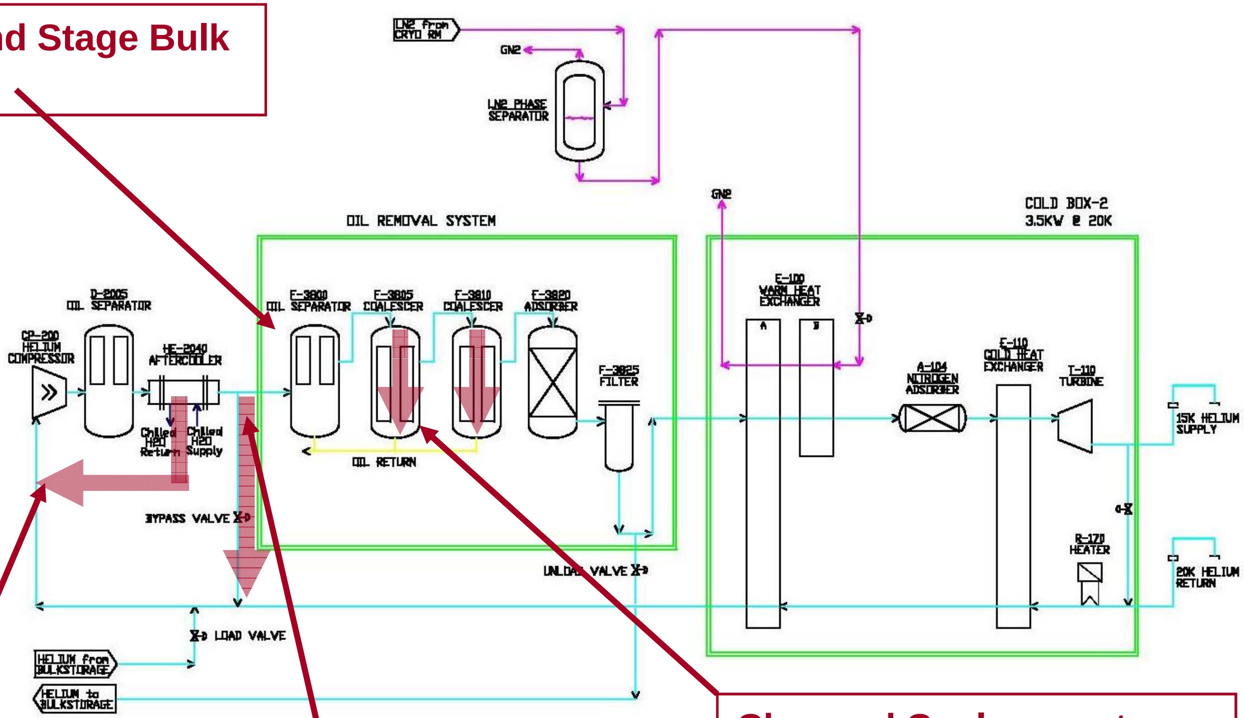
- Replaced the coalescing elements to Monsanto type elements
- Modified helium flow path to flow from top to bottom and center to out through the side of the coalescing element
- Added a new vertical bulk oil separator between the helium after-cooler and the two downstream coalescer vessels
- Added a check valve on the line from helium buffer tank to reduce possibility of oil contamination of the helium buffer tank
- Changed the compressor bypass valve inlet from downstream of the ORS to upstream of the ORS

Changes made to the ORS (cont.)

- Added new oil return path to the compressor from the helium after cooler heat exchanger
- Cleaned all system lines of oil residue
- Changes made to the cold box
  - » Replaced and added redundant instrumentation within Cold Box
  - » Cleaned Heat Exchangers and Cold Box internal lines of oil residue
  - » Replaced internal filters and adsorbers
  - » Replaced other damaged components like heaters

Current Arrangement

Added Second Stage Bulk Oil Separator



Changed Coalescers to Monsanto top enter, side discharge

Added after-cooler oil return

Compressor recycle moved to upstream of ORS

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ORS before modification

ORS after modification

Control System Modifications

- » Original configuration was a SATCON PLC and a LINKS human machine interface (HMI)
  - Had to “catch” a curser to enter commands
  - Commands were all typed
  - Screens commonly “froze”
- » December 2006, re-wrote the PLC software to incorporate modifications to the 2003-NASA-JSC reverse engineered control system code from the SATCON PLC and reprogrammed the same controller logic to operate on an Allen Bradley PLC and also integrated the PLC with an ICONICS HMI
- » Developed new HMI screens to operate the system
  - Software based on Jefferson Labs “Floating Pressure Control”
  - HMI on ICONICs platform
- » In 2006, NASA JSC contracted the Cryogenics department at Thomas Jefferson Laboratory (DOE) for assistance with the project
- » Implemented Jlab control and operators interface techniques on the 3.5KW Systems on Allen Bradley and ICONICs platforms

Control Philosophy Changes

» Modified the process control to allow the compressor discharge pressure to vary with the load, i.e. to "Ganni Cycle floating pressure"

» Basically the "Ganni cycle floating pressure" balances the input power of the refrigeration to the refrigeration demand by the load

- Analogous to using gas pedal for primary speed control

» Most refrigerators control to a T-S design point and trim the load with makeup heat

- Analogous to driving with the gas pedal fully depressed for peak power and controlling speed with the brake

What does it mean?

- Instead of the compressor operating to a set point pressure and the system temperature controlled by a trim heater, the high pressure system set point is determined as function of the load return temperature
- No new equipment required to implement the floating pressure control

Other controls re-writes that proved beneficial

» Compressor startup

- Implemented changes that reduce risk to oil carry over and hardware damage

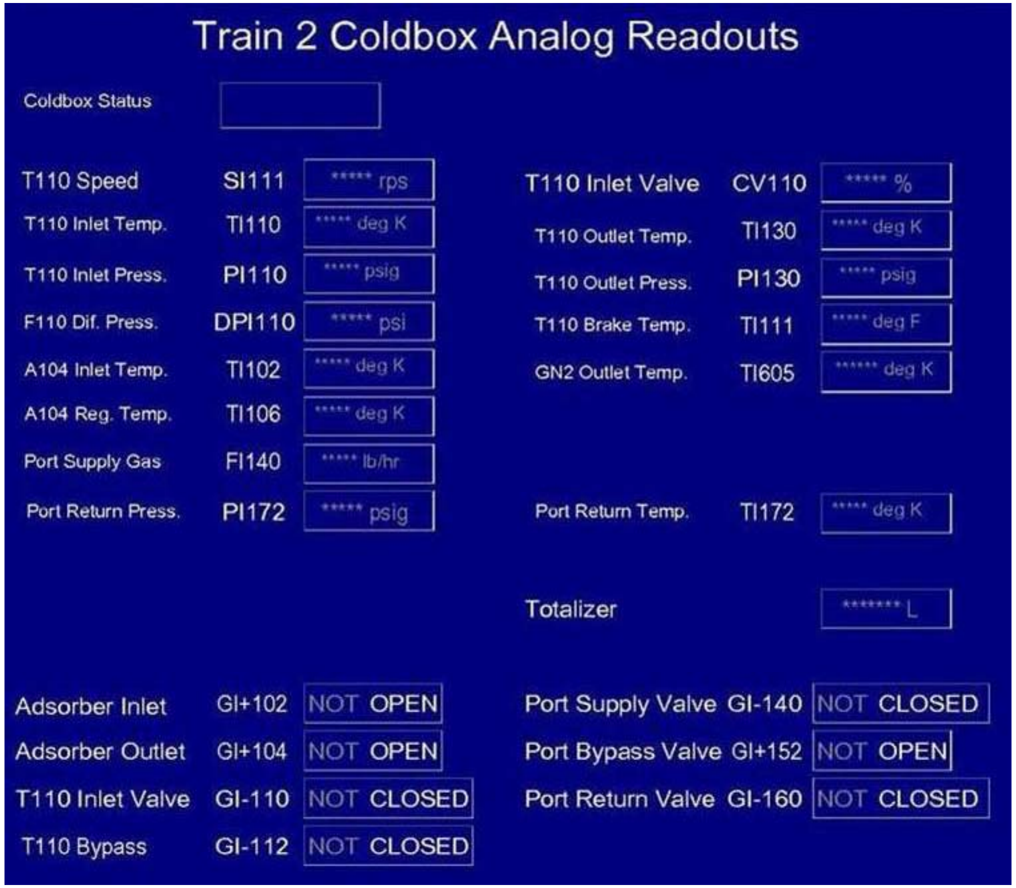
» LN2 Controls

- Changed LN2 control valve from nitrogen vent temperature control to control of temperature difference between the helium high and low pressures
- This gave much better temperature stability and reduced LN2 consumption

Operator Interface:

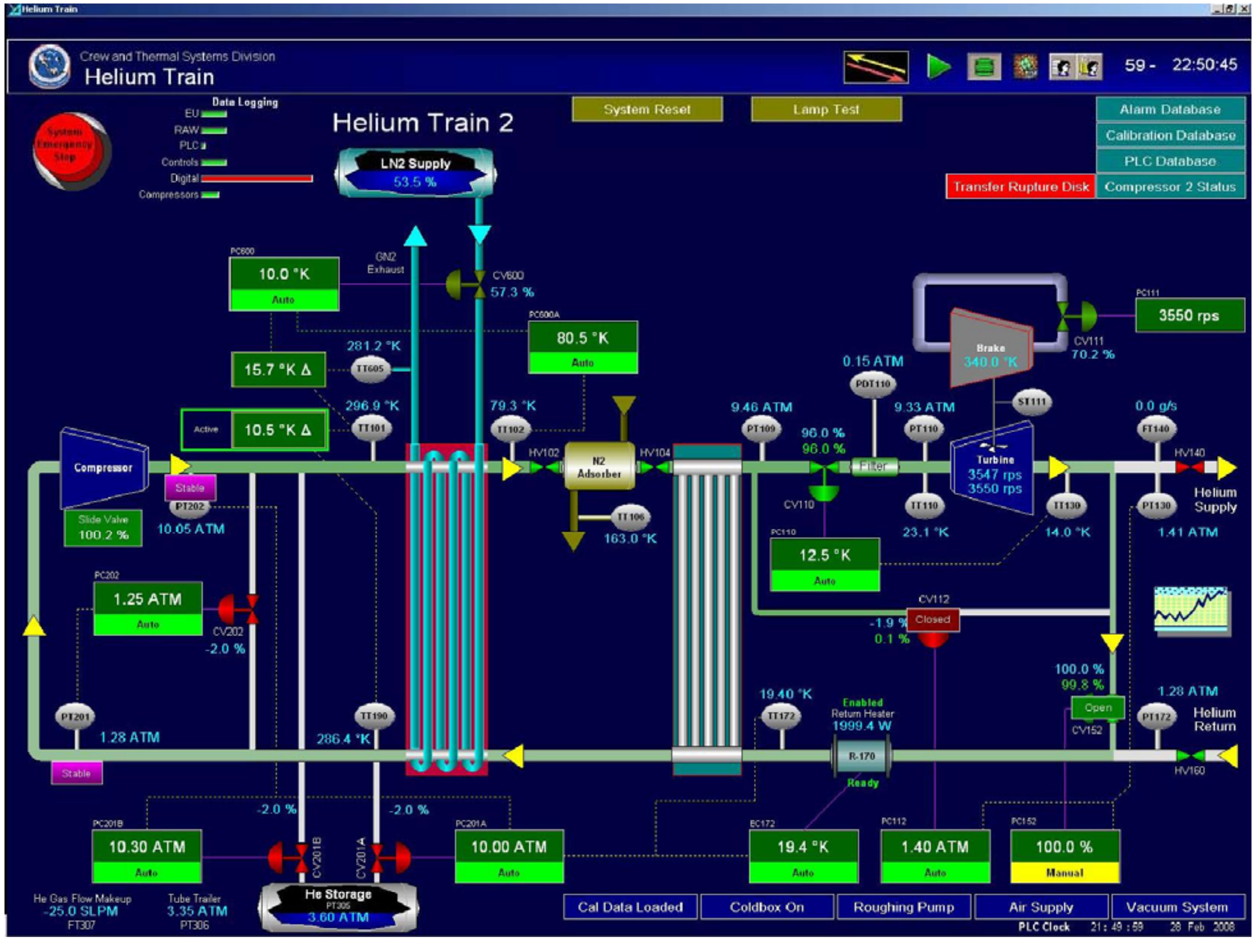
- The original HMI was a LINKS HMI
  - » The controls were archaic even in the 1990's and the HMI would often lock up not allowing the operator to see the system performance or health
- The first phase of the HMI portion of the project copied the screen appearance of the LINKS and put that format on ICONICs platform on a PC
- During the second phase the JLab "Floating Pressure Control" theory is implemented and changed the screens to show the process and the operating conditions of the key components.

Example of old control screen philosophy



Typical Pop Up for New HMI

Example of new system screen



New Turbine Information Pop-Up

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Conclusion

- The system performance is greatly improved with the controls change-over to the Ganni Cycle floating pressure control
- Improved system operational stability
- Operator intervention requirement is substantially reduced
- Power savings and reduced LN2 consumption
- Improved load temperature stability (2.5K to 0.25K)
- Maintenance requirements on the system are expected to be reduced, especially on the compressor
- Improved system reliability

3.5 KW Refrigerator System