

ILC-NML Cryo September Test run results:

The south refrigerator was commissioned and performance tested along with the north compressor. The commissioning and tests were done without shift work or evening hours. In summary the refrigerator ran well with a refrigeration load but fell short with a liquefaction load.

Safety

There were no safety incidents during the test run.

Equipment

Compressor

- Ran at 60 g/s
- Compressor body is an old model retrieved from storage
- It tripped once on shaft sensor while the loading valves were being adjusted, but then ran for two weeks without further incident.
- Cooling water valve ran at 100% most of the time, which was not expected.

Engines

- Wet engine leaked past the piston seals and had to be warmed up and repaired.
- Dry engine minimum speed should be 250 rpm or higher.
- Both engines have 7.5:1 pulleys

Adsorbers

- Both north and south adsorber ran successfully, but there is no built-in method for regenerating them. The contamination gauges were railed before cooldown began.

Refrigerator

- This is not a STAR refrigerator.
- Some oil was found in the heat exchanger during installation. Based on performance the oil is completely removed.

Instruments

- Orifice flow meters appear to be working correctly. The compressor fully loaded produced 60 g/s. During various refrigerator conditions meters FX1, FX2 and FTBYPASS added up to 60g/s.
- At full power the dewar heater voltage and current were measured separately from the power transmitter with good agreement.
- The volume of storage tank four was checked and confirmed to be 14,500 gallons.

Controls

The Automation Direct PLC's required some minor programming changes but otherwise ran without incident. The AD-APACS communication with MODBUS ran without interruption. APACS programming required some minor programming changes including tuning, and a few more changes are required. As the system was started in stages, it routinely ran overnight without operator attention.

EPICS pictures and database variables were debugged, communications between the displayed variables and APACS were checked. Commissioning would have been easier with a modern interface. While EPICS performs common HMI functions, details make it

more difficult to use than common commercial software. Some specific deficiencies include:

- Database variables must be entered by hand, data base effort alone took 10man-weeks. There is no way to import OPC server variables to the database.
- There is no database viewer
- Occasionally some variables stop reading without indication.
- If a variable is forced or out-of-range in APACS the number displayed in EPICS is not updated and may have an arbitrary value.
- The inability to set/read a single variable has meant they have to be displayed twice, cluttering the displays.
- AD administration pushes patches without notice, usually crashing PC's during the night, causing loss of historical data.
- Printing pictures frequently fails when sent from NML to BEG.
- Only one plot of historical data can be displayed at time.
- Real-time variables can not be added to a historical plot
- Historical plots can not be printed, except through 'MS Paint', a cumbersome procedure. Programmers have suggested saving files to a LINUX server and printing later, but windows users don't have access to the files.
- Historical data can not be exported to excel.
- There is no way to simply select and zoom on a chart.
- Closing the historical plot with the X in the upper right prevents opening new plots without restarting EPICS.
- Displaying actual values at a given time is difficult. Either the value flashes on the screen briefly, barely time to read the numbers, nothing happens without replotting, or multiple fast flashes occur with no data. There is no ability to read all variables at a specific time easily.
- Using historical plots in my office causes some windows to blink rapidly except when they are on top. The only way to stop this is to close all X functions. This problem did not occur at NML.
- Historical pull-down menu's all show the pointer two lines above where it actually is, making selection of sub-menu's difficult. This problem is in my office but not at NML.
- Pull-down menu's to set time scale do not work with mouse alone, but must be set with arrow keys. Otherwise hour or minute settings are set to zero.
- The web-based historical plots are undeveloped, with no save function, poor auto-scaling, and are not written to work with Internet Explorer. These plots don't work at all at NML, where some other java toolkit might be needed.
- Network function is required for local operator display, so a network outage prevents an operator from monitoring the system.
- EPICS alarms are cryptic. When opened, this application it alarms constantly from MDB, so they were not used at NML. Using this application would require all alarms to come through EPICS, degrading their reliability.
- After some upgrades, smartcon1 failed under my account, but smartcon2 continued to work. It took a month for the helpdesk to resolve this problem.

- The login procedure is very cumbersome, requiring two passwords and seven lines of typed commands.

Refrigeration Performance

- Performance in refrigerator mode was tested by running the dewar heater in automatic and varying the wet engine speed. The dry engine was in automatic at the time, running about 750 RPM.
- Testing was between 8 and 10 AM on September 25, 2007.
- Heater power ran about 650 watts with heat exchanger flow between 43 and 50 g/s
- Presumably the wet engine could have run faster to increase the flow.
- Heat exchanger pressure drop is good.
- Conclude that the heat exchanger is not fouled with oil.
- Did not wait for slow oscillations to damp out to establish precise heater performance

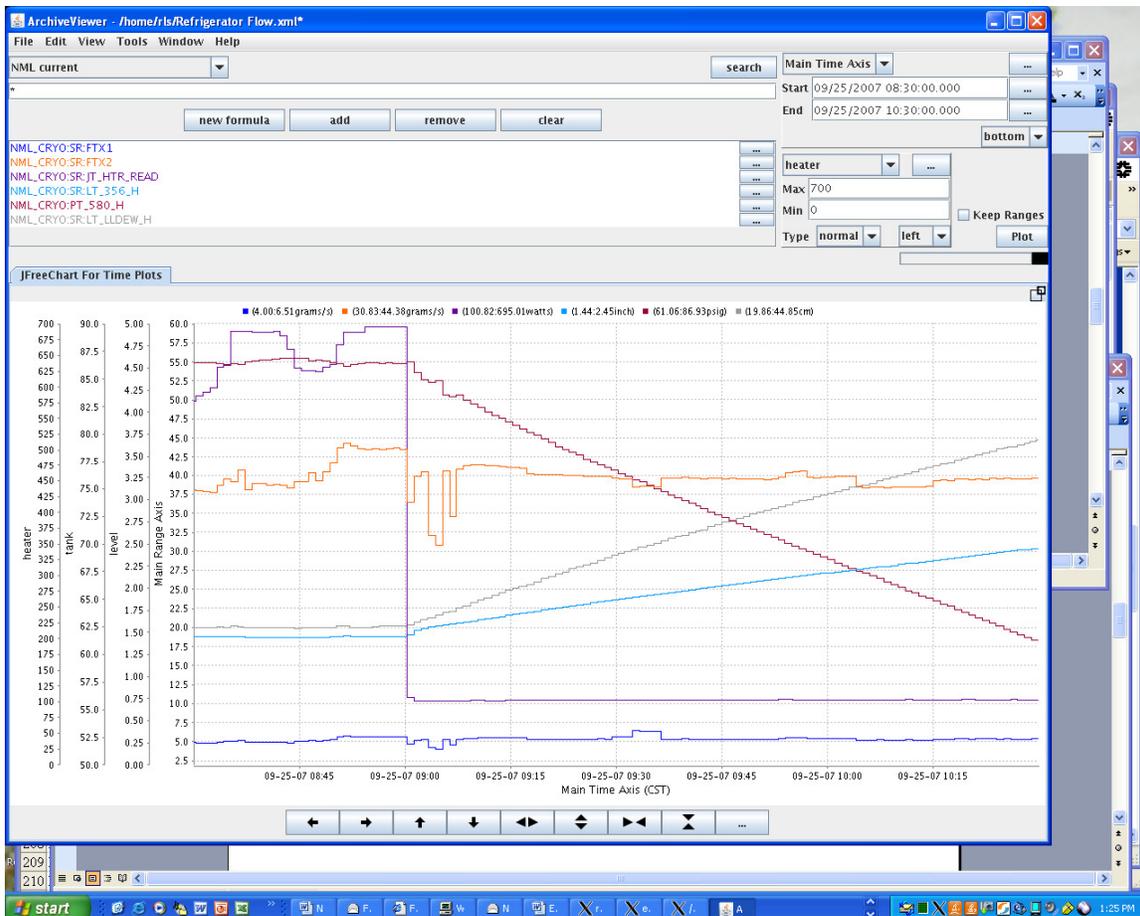
Liquefaction Performance

- Liquefaction was tested with the heater fixed at 103.6 watts, which is estimated to the refrigeration load at NML. The primary load on this system will be liquefaction for the 2K cavities. Storage dewar pressure was 8 psig.
- Liquefaction rate was to be based gas storage pressure change.

Time	PT580H	LT_DEWH	LT_356H
9/25/07	Psig	cm	inches of water
9:08	83.5	22.4	1.62
10:21	63.32	42.8	2.38

 - Storage tank 4 contains 14,500 gallons volume. The inventory to pressure ratio is 632 grams/psi.
 - The liquefaction rate of change is 2.91 grams/second.
- Liquefaction rate based on dewar level change
 - Dewar ID is 38 inches in cylindrical section.
 - Liquid density $111.8 \times 10^{-3} \text{ grams/cm}^3 = 6.969 \text{ lb/ft}^3$
 - Saturated vapor density $28.71 \times 10^{-3} \text{ grams/cm}^3 = 1.79 \text{ lb/ft}^3$
 - ΔL_{water} , assuming all saturated vapor equals 23.3 cm of level change. Would be lower if vapor is slightly warmer.
 - Liquefaction rate based on LT_DEWH in cylindrical portion of the tank, displacing saturated vapor, is 2.83 grams/second
 - Total gas flow was about 45 grams/second during the test.
- Expected performance for a STAR heat exchanger is 3.5 grams/second with 100 watts of heat load and 58 grams/second refrigerator flow.
 - Expected performance with 50 gram/second flow and the 'Old Configuration, H Barton 8/31/81' with 100 watts heat load is 2.5 grams/second liquefaction.
- Expected performance with 50 grams/second flow and the 'STAR Configuration, H Barton 8/31/81' with 100 watts heat load is 3.5 grams/second liquefaction.
- Published performance by Vanderarend, 'Advances in Cryogenic Engineering, Vol 23, p423', refrigeration 445W, 90 l/h at 4.4K, with 41.1 grams/second flow.

- The flow was too imbalanced during the liquefaction test, both engines and TVX1 all ran warmer than they should. Total flow was 45 g/s and it should have been 60 g/s. Three problem areas are identified:
 - PVXBY is too small. While it did affect the wet engine inlet temperature, when fully open it could not pull the temperature below 8.2K.
 - PVX2 was stuck open during part of the test and the trim was too big. At the end of the test it was repaired and a smaller trim installed. The control loop for this valve needs adjustment. During the testing TVX1 was about 118K.
 - The dry engine temperatures are suspicious. Indication of a dry inlet of 44K and 79% efficiency don't fit with the inability to pull down the temperature.
- Performance testing data, heat load on left, liquefaction on the right.



System Improvement List