

Online Helium Inventory Monitoring of JLab Cryogenic Systems

N. Hasan¹, P. Knudsen² and M. Wright²

¹Thomas Jefferson National Accelerator Facility, Newport News, VA 23606 USA

²Facility for Rare Isotope Beams (FRIB), Michigan State University (MSU), East Lansing, MI 48824 USA

Outline

- **Background**
- **Motivation**
- **Program Development**
- **Verification**
- **Sample of Achieved Results**
- **Summary**

Background



Five Cryogenic Plants:

CHL1 & CHL2

4.6 kW @ 2.0 K

ESR

1.5 kW @ 4.5 K

HDR

0.2 kW @ 4.5 K

CTF

0.65 kW @ 4.5 K

- 3 LINACs (NL, SL and LERF)
- 4 Experimental Halls
- Cryo-module Testing Facility for SRF Cavity Development
- Continuous 24/7 Operation (4.5 K / 2.0 K)

Background (contd.)

Helium Inventory:

Total Capacity: 162,800 liq. liters (approx.)

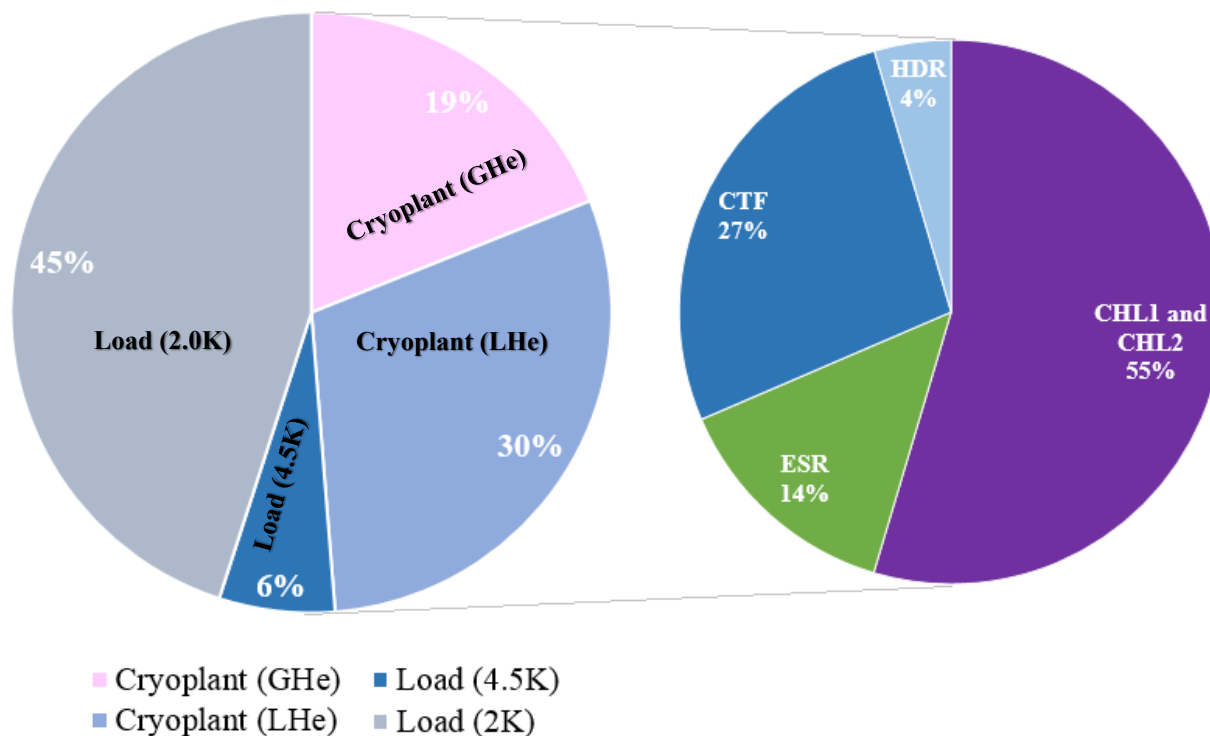
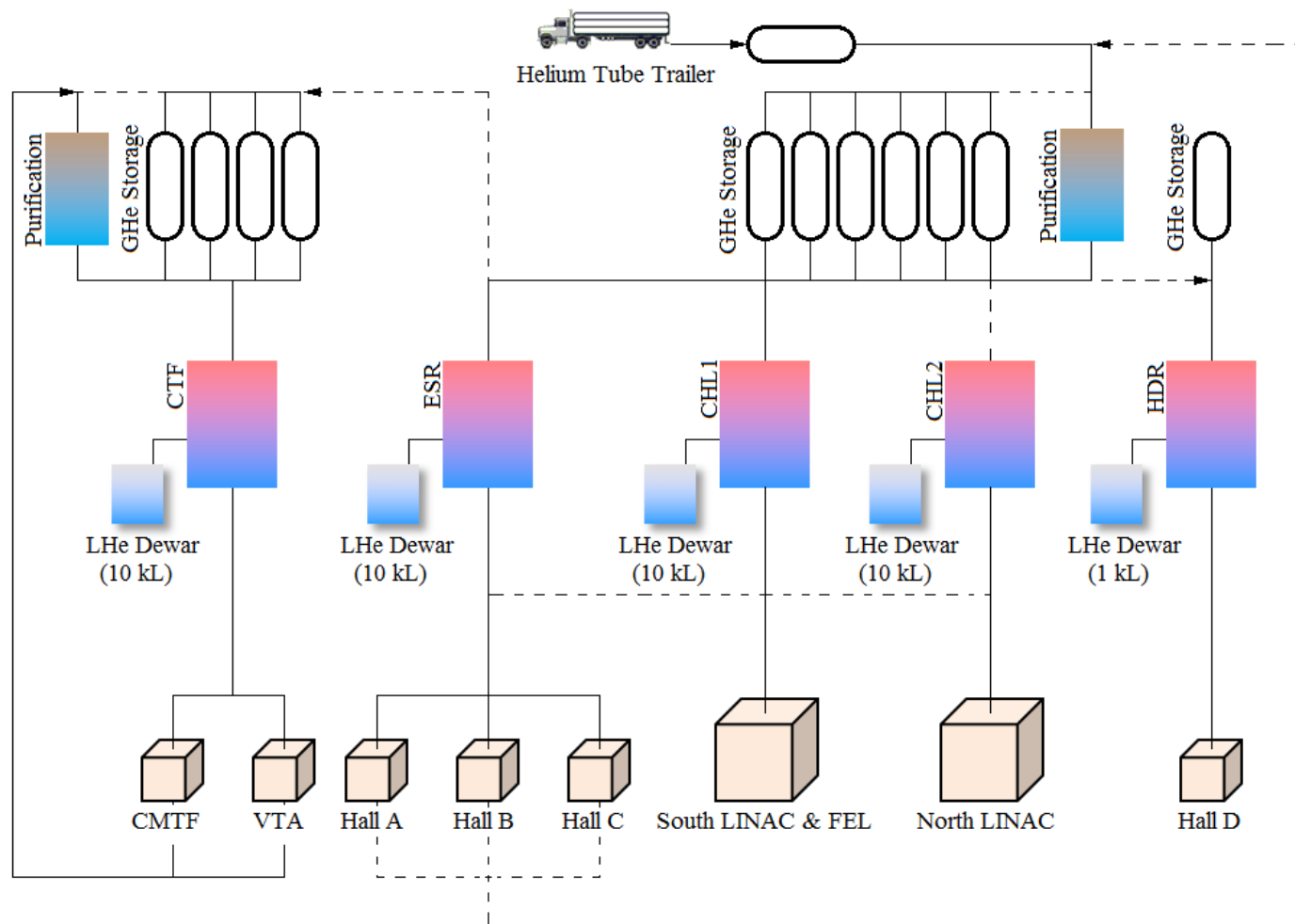


Figure. JLab Helium Storage capacity

(left – overall; right – distribution among cryo-plants).

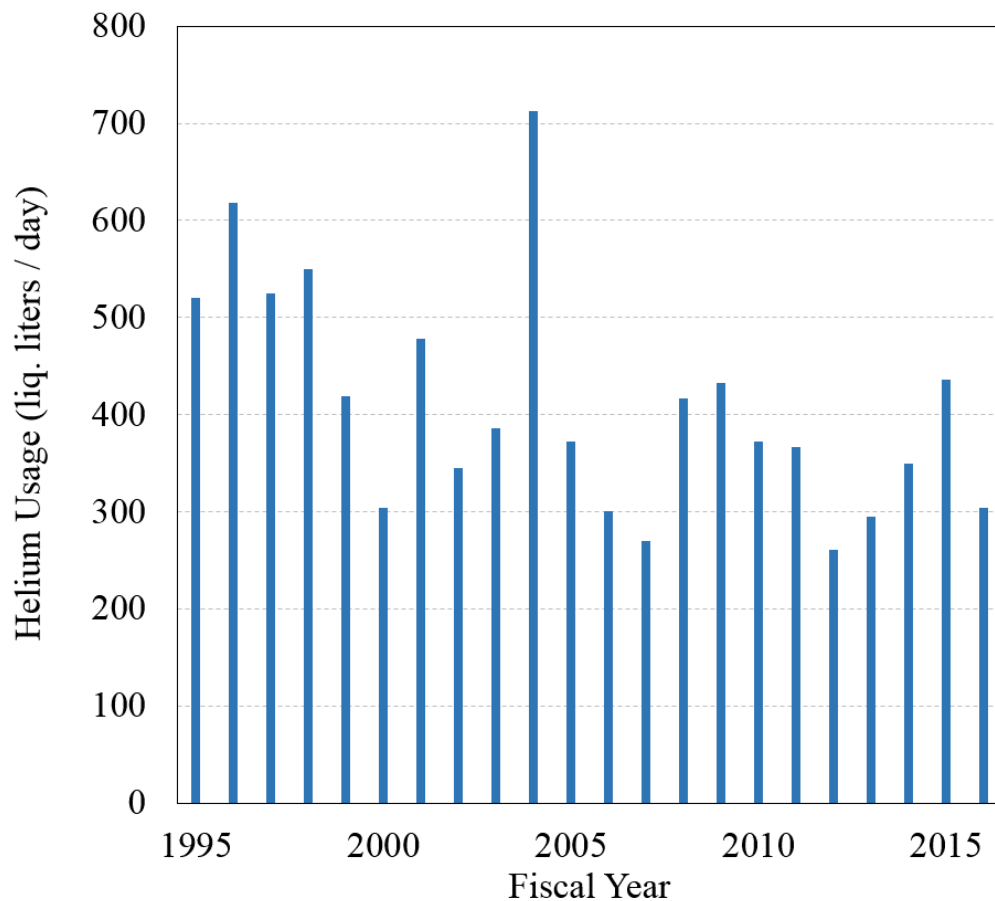
Background (contd.)

Helium Inventory Management:



Motivation

Helium Usage / Losses:



- Average loss rate 350-400 liq. liters / day for the last decade.
- 2004 – On-site LHe inventory vented during Hurricane Isabel.
- Steady rise in loss rate from 2011-15 (during 12 GeV cryogenic system and load commissioning)
- Equivalent to ~ \$1500/day

Figure. Overall helium usage at JLab over the last 21 years.

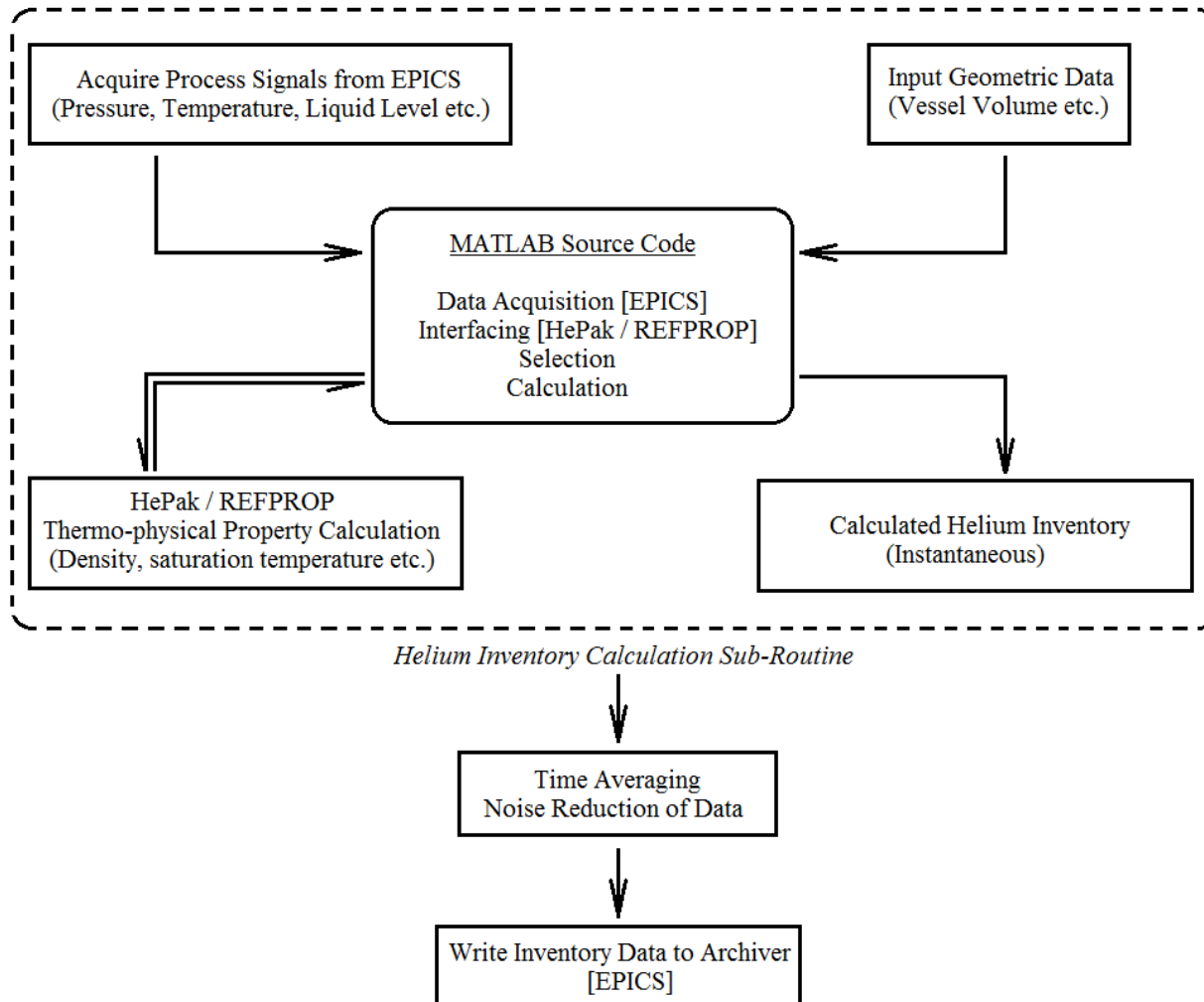
Program Development

Objectives:

- Develop a program for real-time monitoring of helium inventory.
- Identify and verify overall helium usage / loss rates.
- Analyze collected data and establish 'baseline' average daily loss rates for each of the 5 different cryo-plants.
- Monitor loss rates and check for deviation from the 'baseline' (short-term)
- Identify component(s) responsible for major share of the loss (cryo-plant level) and mitigate.

Program Development (contd.)

Helium Inventory Monitoring – Block Diagram:



Program Development (contd.)

Features:

- Interfacing between three different software applications
 - MATLAB© - used to calculate the inventory
 - REFPROP© - used to obtain thermo-physical properties of helium
 - EPICS - used to acquire process signals for the calculation
- Calculation is carried out every 30 seconds and provides an instantaneous snapshot of the helium inventory present in each of the components.
- Collected data is time averaged over a period of 15 minutes and is stored in JLab's central archiving system through EPICS.
- Can be re-called (plotted) via. EPICS by the End Users.

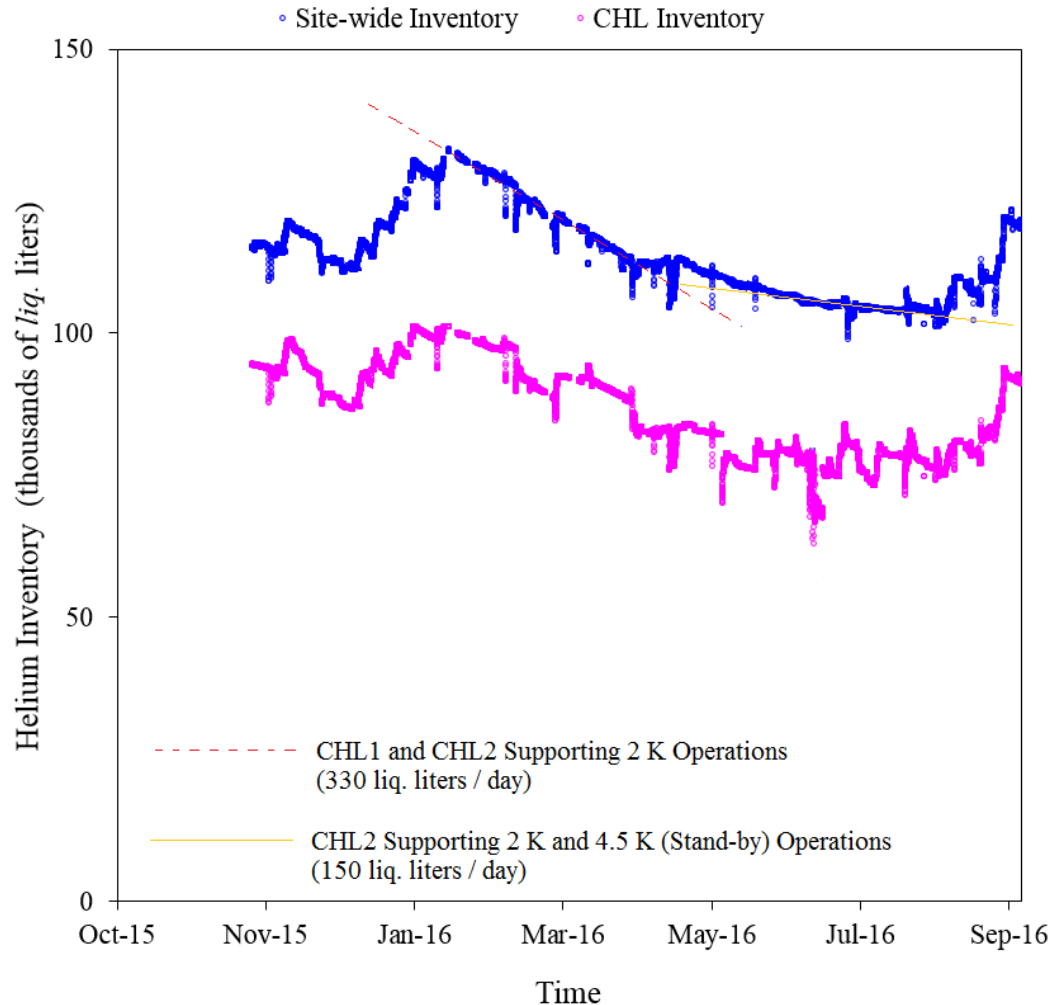
Verification

Verification Scheme:

- Real-time helium inventory monitoring program was deployed in EPICS in mid-October 2015.
- Overall (site-wide) loss rate was calculated from a temporal plot for the helium inventory.
 - Analyzed in multiple 10 day time periods with a stable helium inventory.
 - Site-wide loss rates for each of these periods were calculated.
 - All the loss rates were time averaged to obtain an ‘average daily loss rate’.
- Validated against the amount offloaded to the system during the fiscal year.

Achieved Results

Temporal Plot of JLab Helium Inventory (FY 2016):



- Two different loss rates observed.
- Spikes/Dips in inventory is attributed to transitions / 2.0 K System Shutdown (Trips).
- Gradual increase is attributed to offloading helium tube trailers.
- Several periods of short-term inventory loss can be identified.

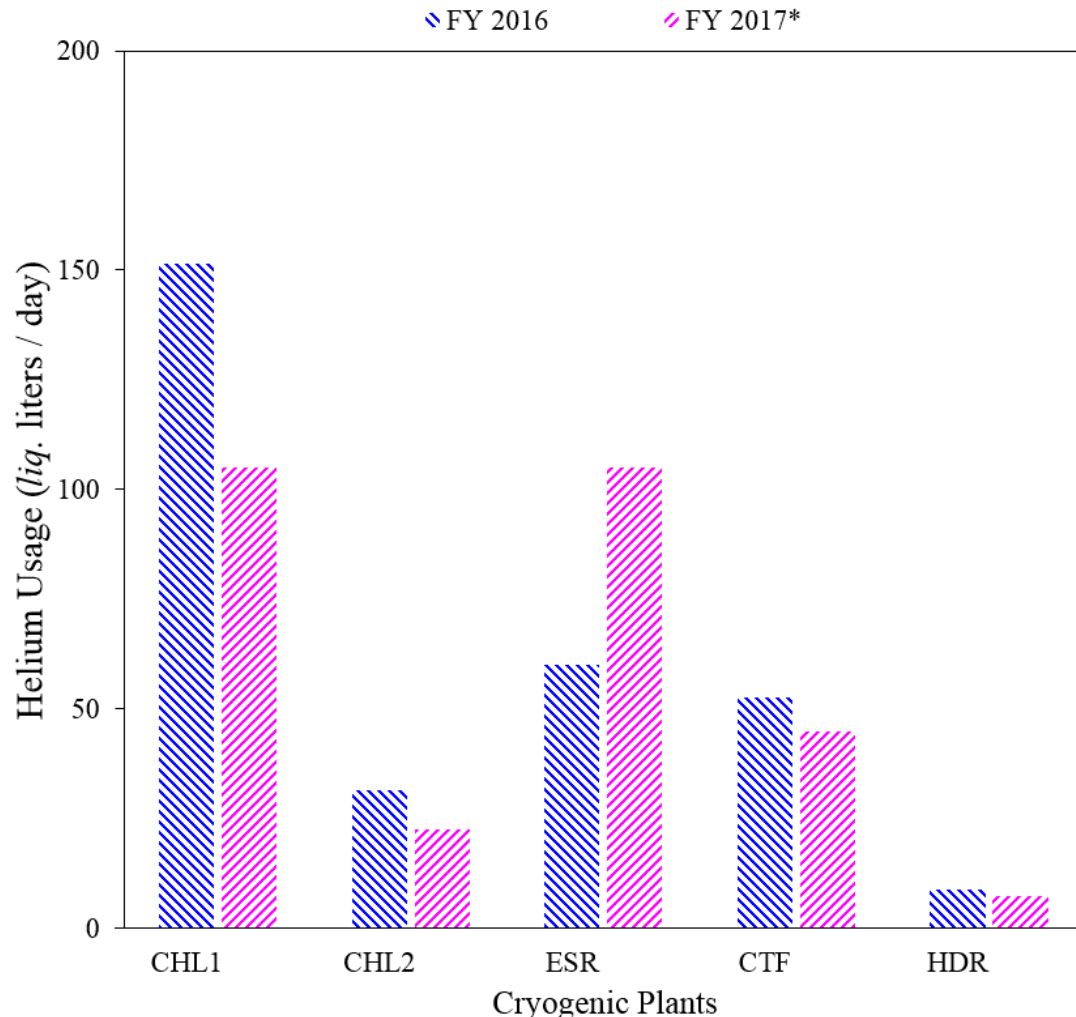
Achieved Results (contd.)

Establishing Individual (Cryo-Plant) Loss Rates:

- Depends on whether the cryo-plant is operated as a fixed inventory system (ideal), or variable inventory system (due to loads, component issues etc.)
- Individual loss rates for CHL2 and HDR were obtained from the LHe dewar liquid level depletion rate.
- Loss rate for CTF was obtained from the depletion rate of the overall inventory (GHe tanks and LHe dewar) during stable operation (i.e., when there are no loads on the plant except for the LHe dewar) and validated against the amount supplied to CTF from the CHL inventory.
- ESR loss rate was established by setting-up the plant for a fixed inventory operation for a short term and then monitoring the LHe dewar liquid level depletion rate.
- CHL1 loss rate was obtained by subtracting ESR loss rate from the inventory depletion rate of the CHL gas tanks.

Achieved Results (contd.)

Establishing Individual (Cryo-Plant) Loss Rates:



- New systems have low loss rates.
- CHL1 is the major contributor of the high average daily loss rate.
- ESR losses are mostly ‘short-term’ larger losses (due to commissioning of loads).
- CTF losses are variable depending on load.

Achieved Results (contd.)

Observations:

- Increase in the leak rate was observed when two of the three CHL1 2nd stage warm compressors were restarted after the end of SAD 2016 period. The compressors were checked and leaks were detected in the shaft seals. Resolving this issue resulted in a reduction of about 40 liq. liters per day in helium losses from CHL1.
- Increase in the leak rate was observed in CHL2 during winter 2016-17. This leak was correlated with the decrease in ambient temperature (below 280 K). After thorough examination, leaks were found in several valve packings in oil coalescing vessels (due to different coefficient of thermal expansion between the materials). Detection and resolution of this leak resulted in a reduction of about 10 liq. liters per day in helium losses from CHL2.
- A reduction of about 10 liq. liters per day in helium losses from CTF was observed after the commissioning of a new 4.5 K cold box (and de-commissioning of the existing cold box). Significant changes in daily loss rate were also observed during operation of the vacuum skid for pumping 2.0 K process flow. Refurbishment of this skid is being planned.

Achieved Results (contd.)

Observations:

- Calculating the helium inventory at CTF was found to be difficult due to the absence of accurate process signals (liquid levels, temperature etc.) at the load.
- The baseline loss rate at ESR was about 70 liq. liters per day during FY 2016. During several un-planned shutdowns and planned events (magnet testing, quenches etc.), a significant amount of helium inventory (approximately 5000 liq. liters) was lost from ESR in FY 2017. This caused a significant increase in the calculated average of the daily losses at ESR.
- Several maintenance actions on HDR warm compressors and utility valves resulted in a minor reduction in daily helium loss rate.

Summary

- Real-time Helium Inventory Monitoring Program was Developed, Deployed in EPICS and Verified.
- Program is able to provide accurate, real-time information about helium inventory present in each system (cryo-plant and load).
- The concept can be adapted to any system with proper instrumentation.
- Established 'baseline' average daily loss rates (Overall and Individual).
- Both short-term and long-term plans to reduce helium losses were established.
- The program helped in detection of some major loss events (both at load and cryo-plant level).
- Continuous process of understanding the collected data and improving detection.



Thank You