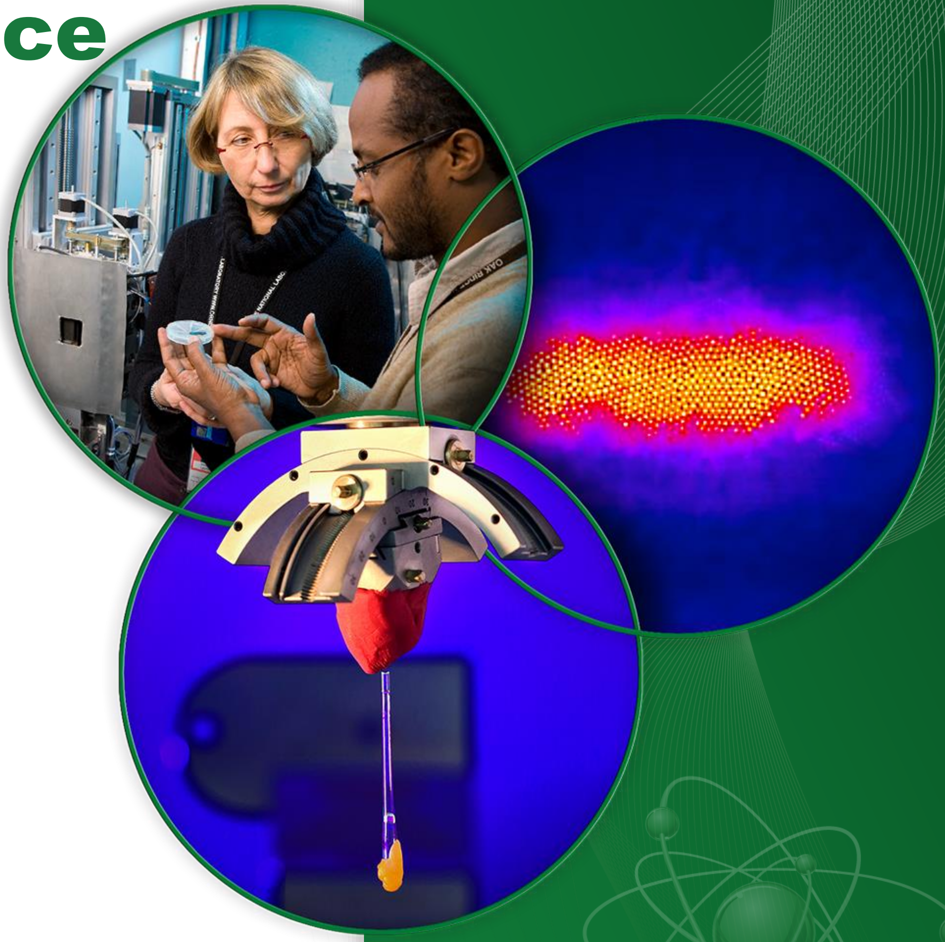
# Cryogenic System Operating Experience at SNS



Presented at the
**CEC/ICMC 2015 – C3OrA**

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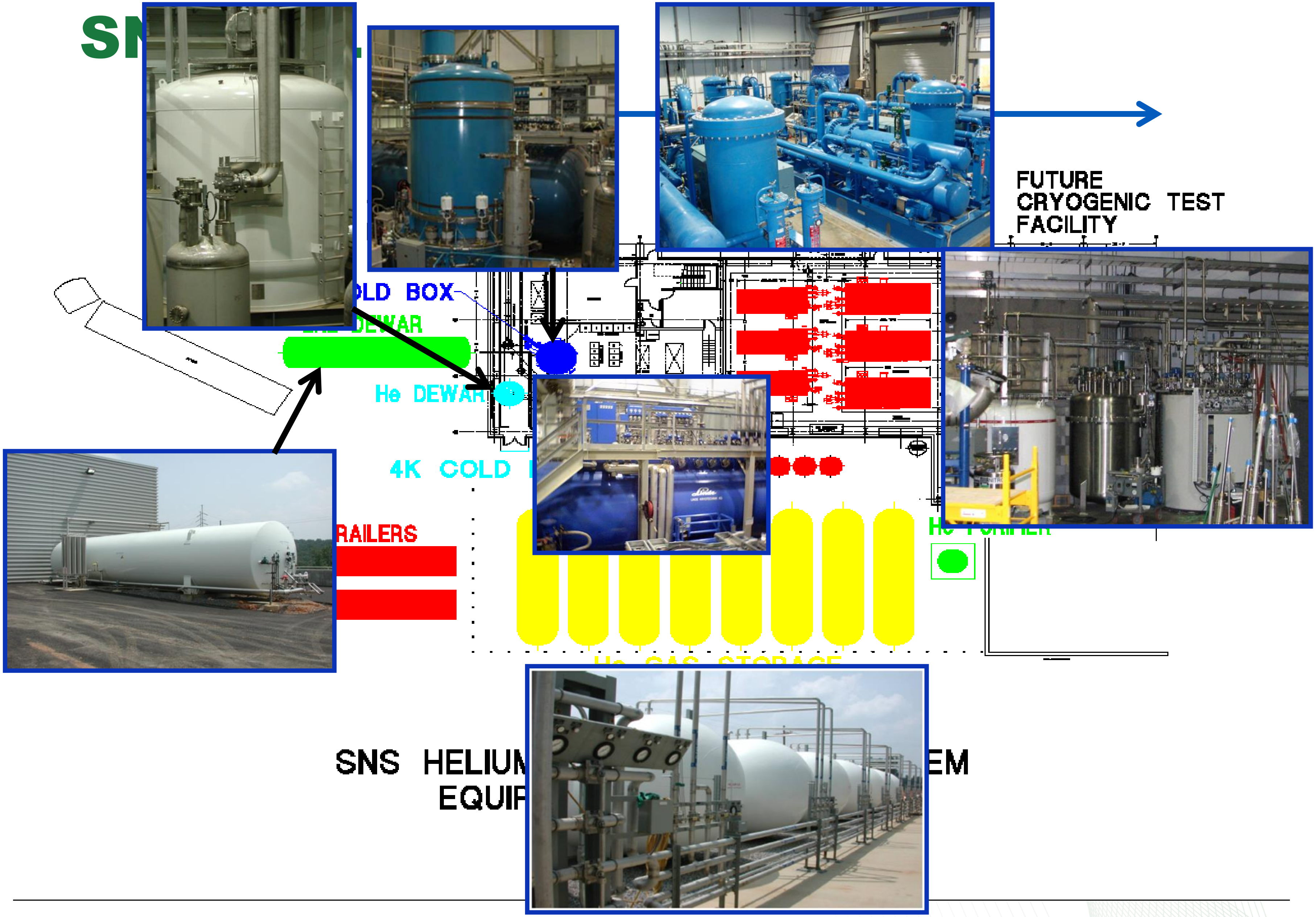
**July 01, 2015**

# Outline

- SNS cryogenic system overview
- System reliability and down time statistics
- Approach to prioritizing efforts
- Tools for maintaining reliability
- Operating experience and lessons learned with components of the cryogenic system
- Summary

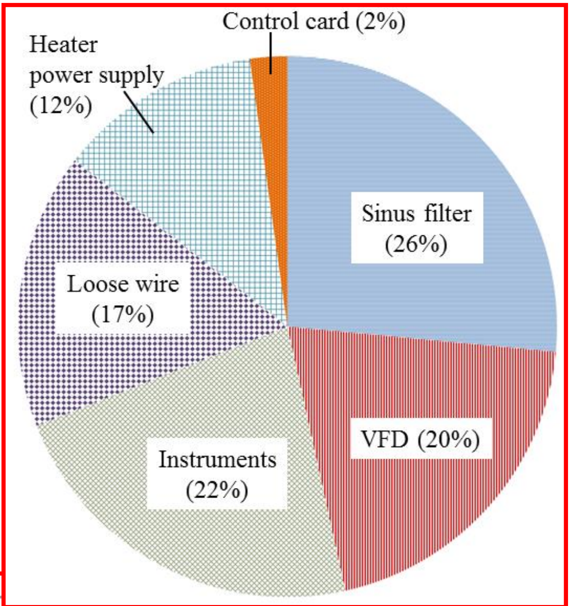

FUTURE CRYOGENIC TEST FACILITY
He DEWAR
4K COLD
SNS

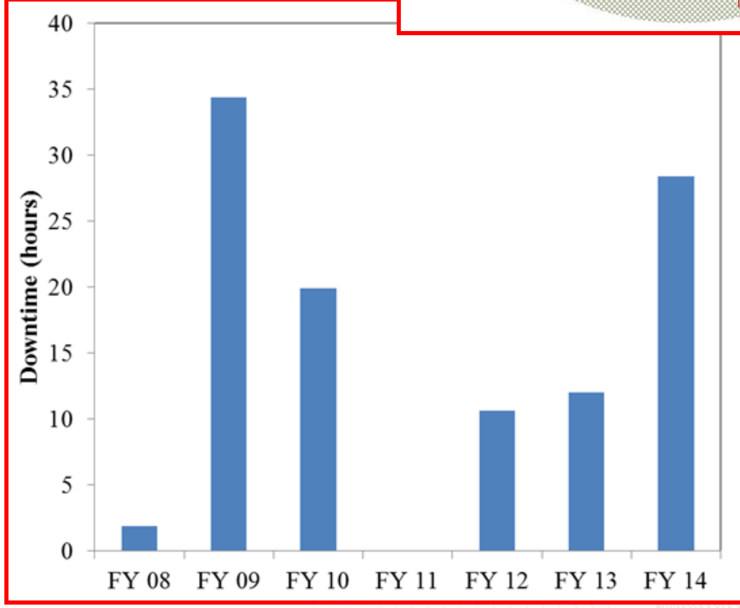
# The SNS CHL Design Specifications

| | Primary | Secondary | Shield |
|---|---|---|---|
| Supply Temperature | 4.5K | 4.5K | 38K |
| Return Temperature | 2.1K | 300K | 55K |
| Supply Pressure | 3bar | 3 bar | 4 bar |
| Return Pressure | 0.041bar | 1.05 bar | 3 bar |
| Static Load | 850 W | 5.0 g/s | 6070 W |
| Dynamic Load | 600 W | 2.5 g/s | 0 |
| Capacity | 125 g/s | 15g/s | 8300W |

# System reliability and down time statistics for CHL

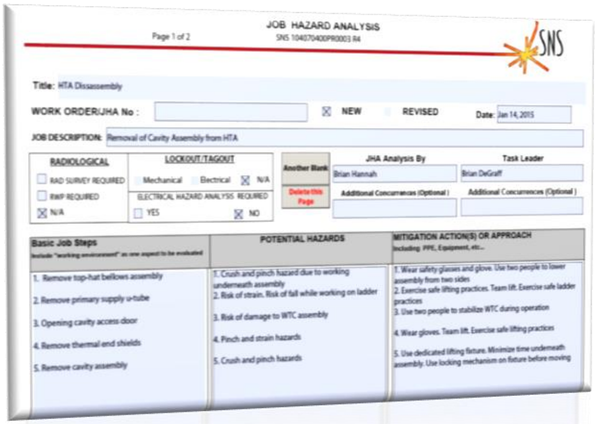
- Much experience gained in last ten years of operation
- High reliability of cryogenic system
  - ~99.7% availability during production run
- Proactive maintenance program developed to correct problems/annoyances prior to becoming issues
- FMEA conducted to prioritize efforts on high risk items
- Continuously improve system



# Preventative Maintenance Activity

- Primary goal is to correct issues before affecting neutron production
- Continuously improved and modified for emerging issues
  - Routine tightening of wire terminals added to plan
  - Compressor maintenance techniques evaluated and updated
  - Procedure and Job Hazard Analyses (JHA) red lined and updated
- DataStream software utilized
  - Creates work order based on time, operating hours, or manual entry
  - Routes work order for approval

JOB HAZARD ANALYSIS
Page 1 of 2
SNS 104070400PR0003 R4
SNS

Title: HTA Disassembly
WORK ORDER/JHA No :  ☒ NEW  REVISED  Date: Jan 14, 2015
JOB DESCRIPTION: Removal of Cavity Assembly from HTA

RADIOLOGICAL: ☐ RAD SURVEY REQUIRED ☐ RWP REQUIRED ☒ N/A
LOCKOUT/TAGOUT: Mechanical Electrical ☒ N/A
ELECTRICAL HAZARD ANALYSIS REQUIRED: ☐ YES ☒ NO
Another Blank
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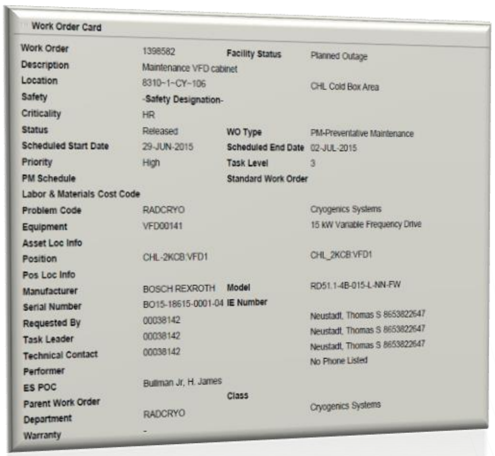
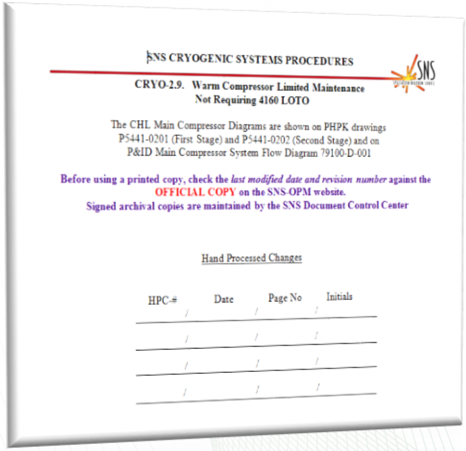
JHA Analysis By: Brian Hannah
Task Leader: Brian DeGraff
Additional Concurrences (Optional)
Additional Concurrences (Optional)

| Basic Job Steps (Include "working environment" as one aspect to be evaluated) | POTENTIAL HAZARDS | MITIGATION ACTION(S) OR APPROACH Including PPE, Equipment, etc... |
|---|---|---|
| 1. Remove top-hat bellows assembly | 1. Crush and pinch hazard due to working underneath assembly | 1. Wear safety glasses and glove. Use two people to lower assembly from two sides |
| 2. Remove primary supply u-tube | 2. Risk of strain. Risk of fall while working on ladder | 2. Exercise safe lifting practices. Team lift. Exercise safe ladder practices |
| 3. Opening cavity access door | 3. Risk of damage to WTC assembly | 3. Use two people to stabilize WTC during operation |
| 4. Remove thermal end shields | 4. Pinch and strain hazards | 4. Wear gloves. Team lift. Exercise safe lifting practices |
| 5. Remove cavity assembly | 5. Crush and pinch hazards | 5. Use dedicated lifting fixture. Minimize time underneath assembly. Use locking mechanism on fixture before moving |



Work Order Card

| | | | |
|---|---|---|---|
| Work Order | 1398582 | Facility Status | Planned Outage |
| Description | Maintenance VFD cabinet | | |
| Location | 8310-1-CY-106 | | CHL Cold Box Area |
| Safety | -Safety Designation- | | |
| Criticality | HR | | |
| Status | Released | WO Type | PM-Preventative Maintenance |
| Scheduled Start Date | 29-JUN-2015 | Scheduled End Date | 02-JUL-2015 |
| Priority | High | Task Level | 3 |
| PM Schedule | | Standard Work Order | |
| Labor & Materials Cost Code | | | |
| Problem Code | RADCRYO | | Cryogenics Systems |
| Equipment | VFD00141 | | 15 kW Variable Frequency Drive |
| Asset Loc Info | | | |
| Position | CHL-2KCB:VFD1 | | CHL_2KCB:VFD1 |
| Pos Loc Info | | | |
| Manufacturer | BOSCH REXROTH | Model | RD51.1-4B-015-L-NN-FW |
| Serial Number | BO15-18615-0001-04 | IE Number | |
| Requested By | 00038142 | | Neustadt, Thomas S 8653822647 |
| Task Leader | 00038142 | | Neustadt, Thomas S 8653822647 |
| Technical Contact | 00038142 | | Neustadt, Thomas S 8653822647 |
| Performer | | | No Phone Listed |
| ES POC | Bullman Jr, H. James | | |
| Parent Work Order | | Class | Cryogenics Systems |
| Department | RADCRYO | | |
| Warranty | - | | |



SNS CRYOGENIC SYSTEMS PROCEDURES
SNS

CRYO-2.9. Warm Compressor Limited Maintenance
Not Requiring 4160 LOTO

The CHL Main Compressor Diagrams are shown on PHPK drawings P5441-0201 (First Stage) and P5441-0202 (Second Stage) and on P&ID Main Compressor System Flow Diagram 79100-D-001

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Hand Processed Changes

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# Failure Modes and Effects Analysis of the CHL

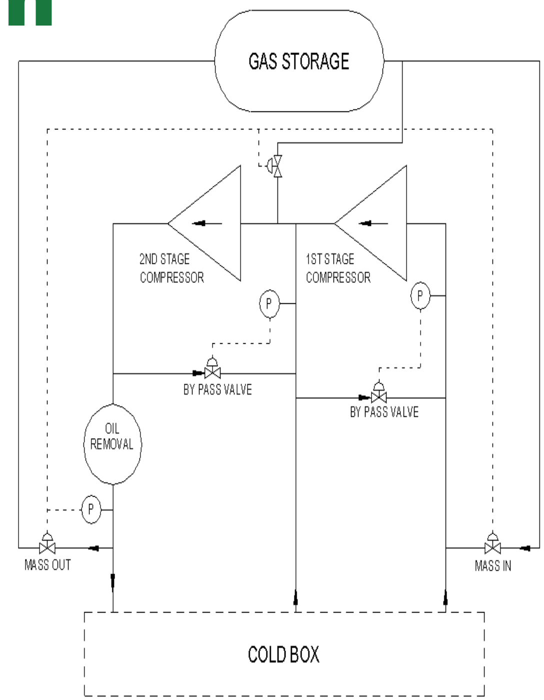
- **Breaks work down to task level for analysis**
- **Systematic approach asking two questions**
  - How could this fail during this process task?
  - If it does fail, what is the effect based on severity, probability, and detection?
- **This process delivers**
  - Weaknesses in our process
  - Ranked items in need of focus
  - An opportunity for a group to focus on a process
  - A driving force to produce action

- **Results of the FMEA**
  - Probability X Severity X Detection = Risk Priority Number (RPN)
  - 60% decrease in RPN
  - Reduction of high risk items from 76 to less than 20

# SNS Warm Compressor System

Three first stage and three second stage compressors

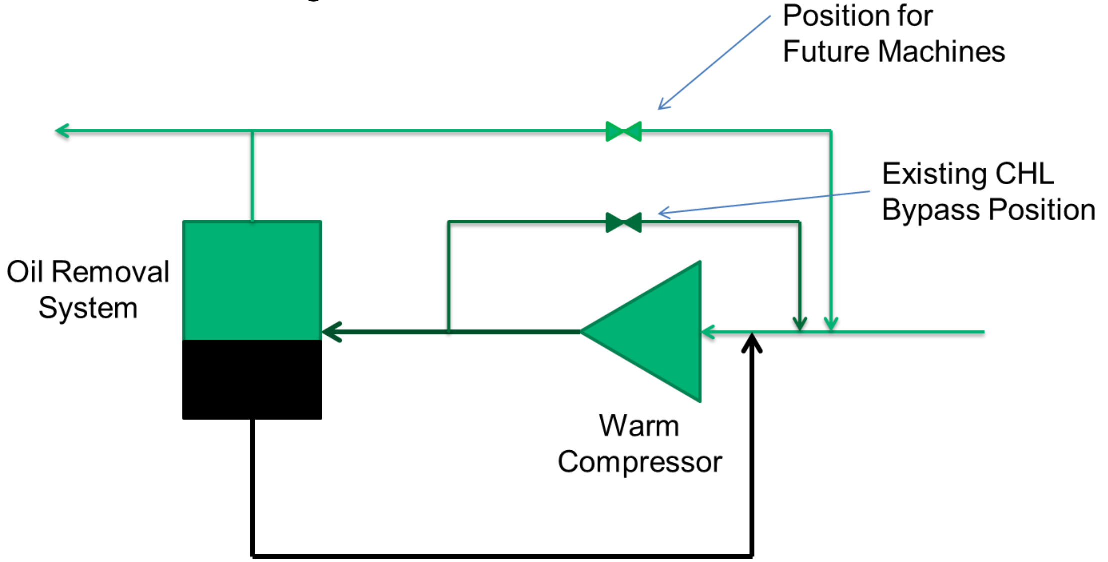
- Two of each run during 2-K operation with an in-line spare
- Howden compressors with Teco Westinghouse motors
- Equipped with oil removal stage at each skid
- Additional oil removal system on high header upstream of 4-K cold box
- Adjustable built in volume ratio




| | $1^{st}$ Stage | $2^{nd}$ Stage |
|---|---|---|
| Model # | MK6S/ WLVI321165 | MKS/ WLVIH321165 |
| Motor Size (hp) | 600 | 2500 |
| Rotor Diameter (mm) | 321 | 321 |
| Length to Dia. Ratio | 1.65 | 1.65 |
| Discharge Temp (K) | 364 | 375 |
| BVR | 2.2-5.0 | 2.2-5.0 |
| Displacement @ 3550 RPM (CFM) | 3341 | 3341 |
| Flow Rate (g/sec) | 220 | 690 |
| Required Oil Flow (GPM) | 42.7 | 180 |

# Warm Compressors– Lesson Learned

- **In-line spare compressors are beneficial**
  - Allows maintenance of compressor while operating another
- **Shaft seal upgrades**
  - Old seal
    - Experienced blistering resulting in oil leaks
  - New design
    - Utilizes dual seal
    - Improved flex by changing from a spring system to a SS bellows
- **Oil removal strategy**
  - Consider separation on bypass lines
  - Eliminates oil migration




Original design

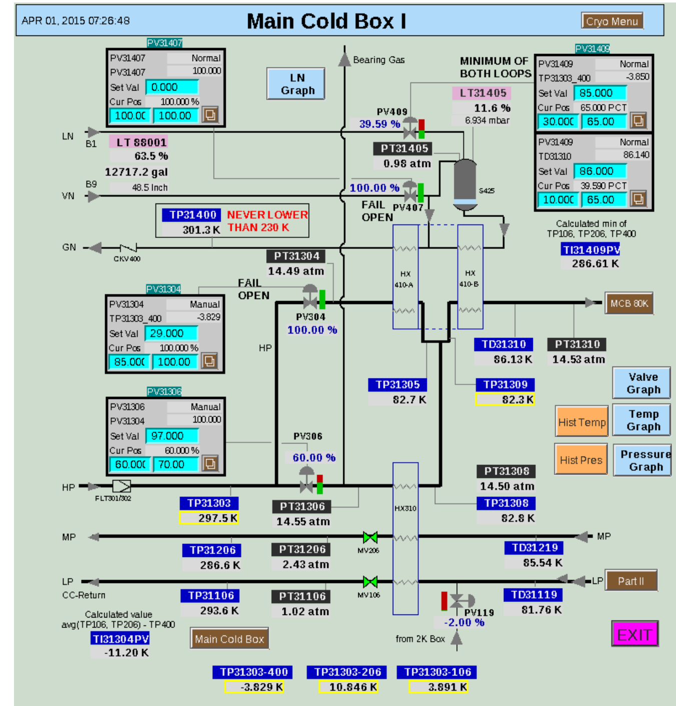
New design

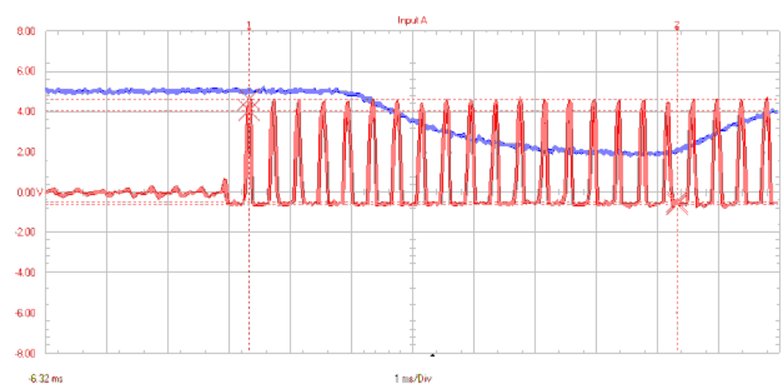
# 4-K Cold Box

- Provides primary cooling
- Provides shield cooling 38/50K (8300 watts)
- Liquefies helium in sub-cooler and dewar
- Provides two purification steps
  - Two 80-K carbon beds in parallel
  - One 20-K carbon bed with bypass
- Helium storage contained in 8 warm gas tanks and a dewar
- Ten years of operation with no prolonged shutdowns


# 4K Cold Box – Lessons Learned

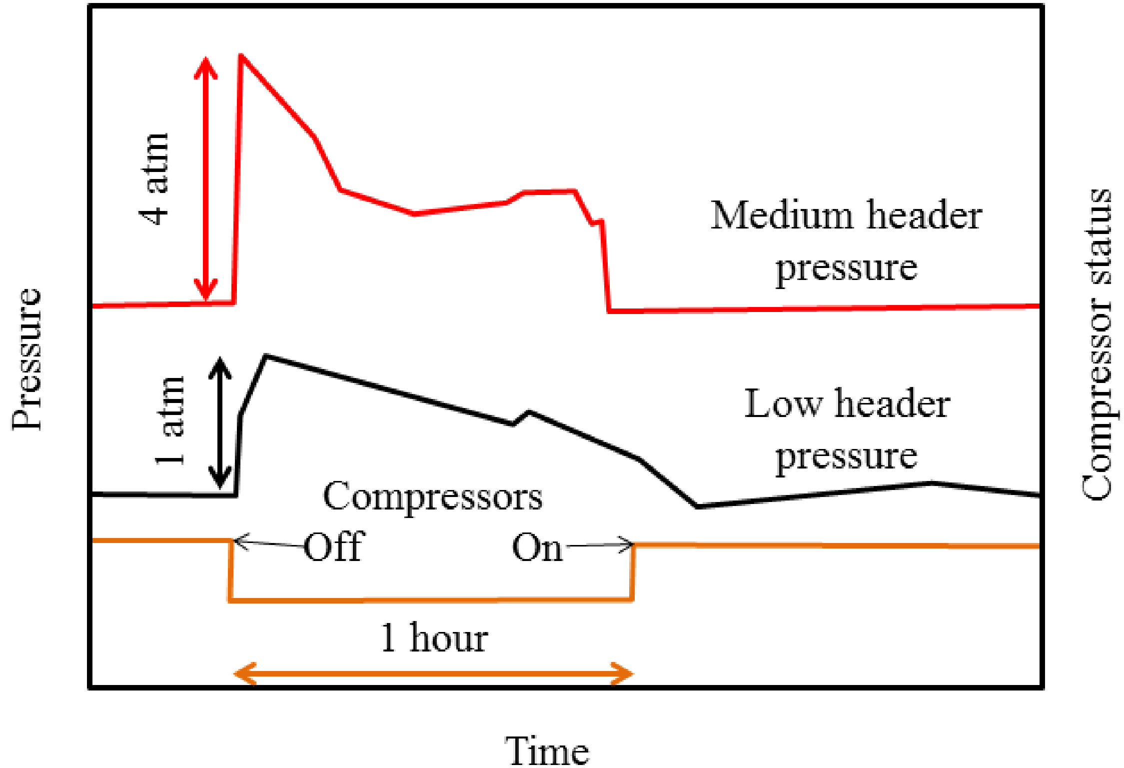
- **LN2 loop uses excess liquid nitrogen**
  - See B. DeGraff's paper "Liquid nitrogen historical and current usage of the central helium liquefier at SNS" at this conference
- **Speed sensors in turbines have been problematic when outputting low voltage signal**
  - Moved speed sensors closer to target to increase voltage of signal
  - Consider dual speed sensors in future installations
  - Dual channel oscilloscope measure output of speed sensor and output of tachometer
- **Carbon bed regeneration has been problematic**
  - Isolating bed while in operation has been difficult
- **Coriolis flow meters may be a nice upgrade as budget allows**



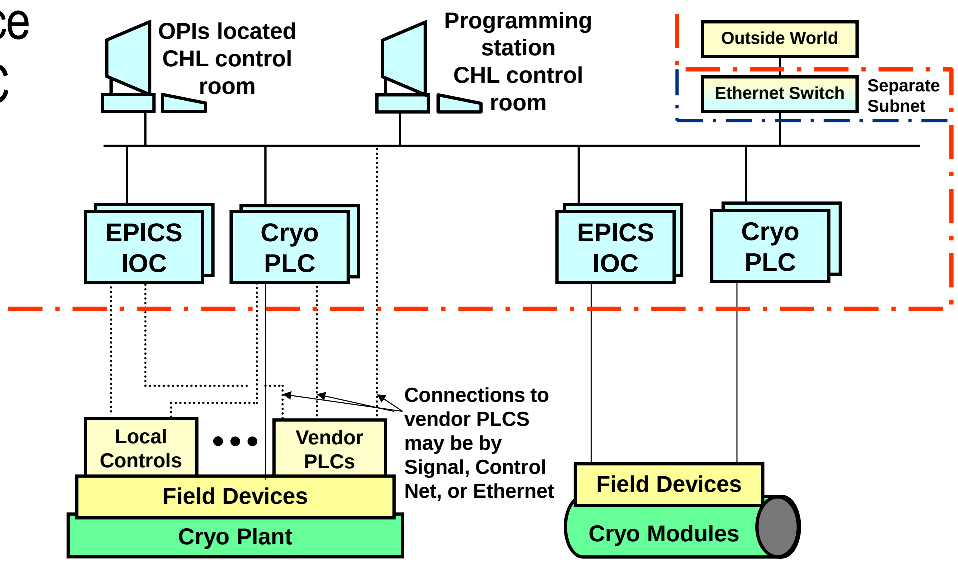
# Power Failure

- Power reliability has been incredible
- Initial pressure increase in cryomodule pressure while at 4-K operation
  - Pressure transients have resulted in component failures and cavity detuning
  - Cryomodule design for pressure fluctuations should account for safety and performance
- RS compressors allow for managing pressure until power is restored



# Electrical and Controls – Lessons Learned

- **IOC Communication – 2007 event**
  - Process variable and control device are contained within the same IOC whenever possible
- **Suggested improvements to consider**
  - Move more control into PLC
  - Decreases dependency on IOC
  - Utilize IOC as communication interface
  - Run "hot spare" PLC



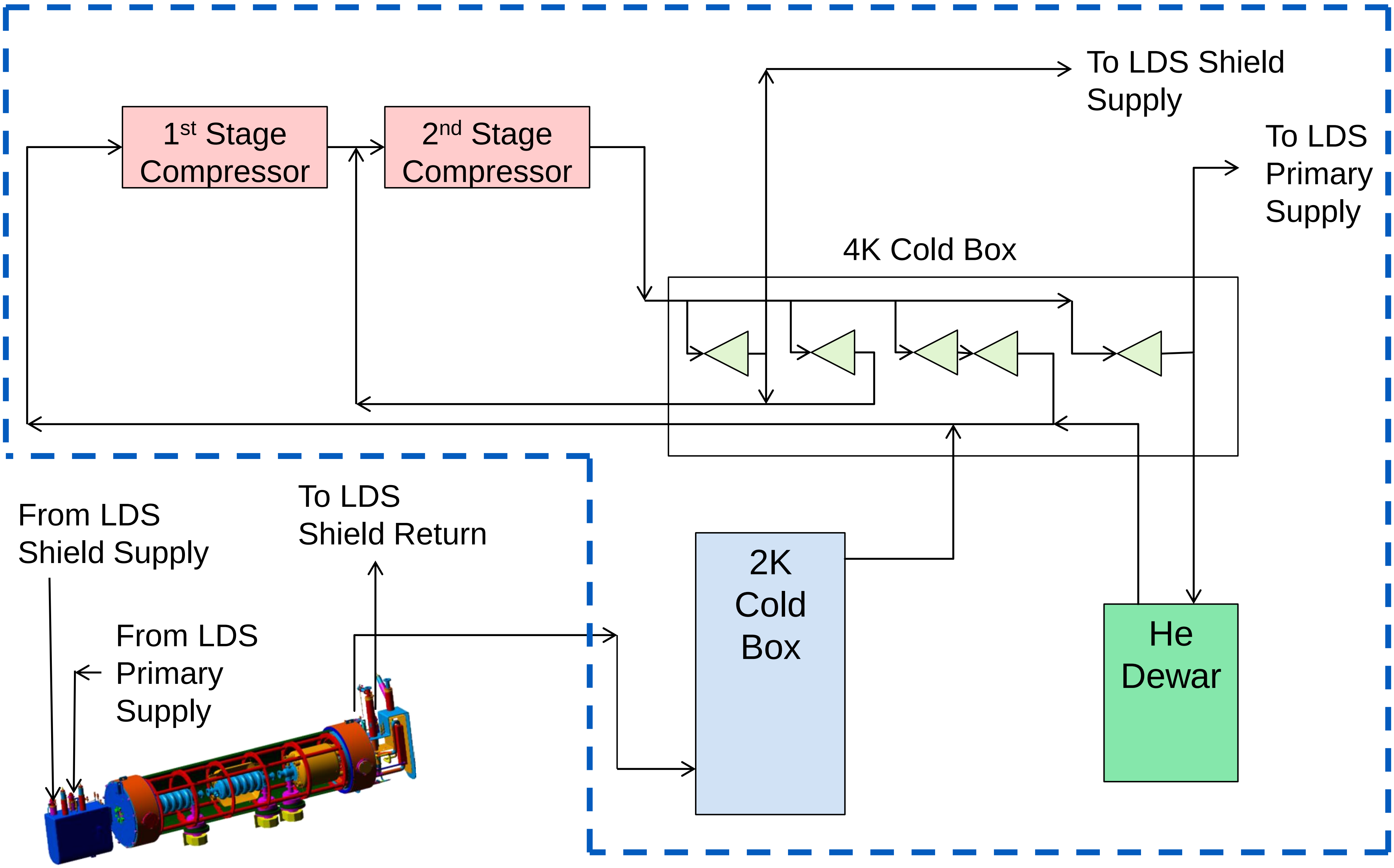

- **Component failures – Calibration program**
- **FMEA drove upgrade to PLCs, IOCs, Software to avoid obsolescence**
- **Alarm auto-dialer for call-ins during alarm events**
- **Switchgear maintenance**
  - Often delayed
  - Evidence of arcing found during maintenance

# Summary

- **The SNS CHL has operated for approximately ten years**
- **It is a highly reliable system making use of several tools**
  - 99.7% available over ten years during neutron production
  - Preventative maintenance program
  - Process FMEA
  - Incorporating lessons learned
- **Consideration to the lessons learned at SNS may benefit future installations**

# Back up slides

# CHL Block Flow Diagram



# Assigning Values and Calculate RPN

| Potential Failure Mode | Potential Effect(s) of Failure | Severity | Classification | Potential Cause(s) of Failure | Current Process | | | | RPN |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | Control Prevention | Occurance | Controls Detection | Detection | |
| Trip a second stage compressor | Unable to maintain required flow to refrigerator, delayed trip of 4KCB | 7 | | Oil Pump Trip | Preventative Maintenance | 1 | na** | 7 | 49 |
| | | 7 | | | Monitor Temperature, Pressure, Oil Level, Visual Inspection | 1 | na** | 7 | 49 |
| | | 7 | | Skid PLC Failure | na** | 10 | na** | 7 | 490 |
| | | 7 | | High discharge pressure | System Controls | 1 | System alarm | 1 | 7 |
| | | 7 | | High discharge temperature | na** | 1 | na** | 10 | 70 |
| | | 7 | | High oil temperature | na** | 1 | na** | 10 | 70 |
| | | 7 | | Low oil inventory in skid separator | Procedural & Operator Training | 1 | Daily checksheet & Log | 7 | 49 |