CeC PoP 2013
Cryogenic Systems
ASSRC REVIEW
MAR 11, 2013

Coherent electron Cooling PoP
CeC PoP 2012 – Cryogenic System

Phase 1: SRF Gun with 4.4K Cryogenic System
- 1A: Liquid Helium Supply RHIC Interface Phase Separator and supply line
- 1B: Quiet Helium Source: Condenser + Valve Box Cryostat
- 1C: 112MHz 1/4wave SRF Gun Cryostat
- 1D: Cryogenic Transfer Lines
- 1E: Small Helium Compressor
- 1F: Warm Piping System and Relief Header
- 1G: Instrumentation & Controls & Power
- 1I: Noise & Oil Containment

Phase 2: SRF 5-cell with 2K Cryogenic System
- 2A: Cryogenic Transfer Lines: Supply to 704MHz 5-cell cavity cryostat
- 2B: 704MHz 5-cell cavity cryostat with Isolation Superfluid Heat Exchanger, Recovery HX, Phase Separator & valves
- 2C: Return transfer line to heating system
- 2D: 18mbar Vapor Return Electric Heating System
- 2E: Warm Return Piping System
- 2F: Vacuum Pumping System
- 2G: Instrumentation & Controls & Power

Coherent electron *Cooling* PoP
CeC Cryogenics Model

1A: Phase Separator
1B: Quiet Helium Source
1C: 112MHz SCRF Cavity
1E: Helium Compressor
Vacuum Pump Skids
RHIC tap
704MHz SCRF Cavity - 2K

Coherent electron Cooling PoP
HAZARD ANALYSIS SUMMARY

1. Are there any chemicals, toxic materials, or hazardous material handled, generated, used, or stored in this operation, including oils and solvents? Yes: UCON-LB-170X Synthetic compressor oil. Catch pan at bottom of skid.

6. Is there any energized electrical equipment used in this operation? Yes: 480 VAC, 120 HP motor and PLC panel.

7. Are there any mechanical hazards or work hazards such as material handling, elevated work, vacuum or pressure vessels, scaffolds, stored energy or structural considerations? Yes: Pressure vessels
   7b. Does the operation include the use of a hoist, crane, forklift, or rigging? Yes, hoist & forklift
   7c. Are there any structures supporting heavy loads? Yes, a support frame for the cryostats
   7i. Does any equipment operate at pressures above 15 psig or under a vacuum? Yes, Cryostats insulating Vacuum vessels, helium compressor, cryogenic piping, warm piping, heater.
   7k. Is any part of this system/operation involve a cryogenic system or dewar installation? Yes,
   7m. Are there any sources of stored energy (hydraulic, pneumatic, thermal, mechanical)? Yes, compressed helium
   7m1. Is the source capable of being easily isolated or can it be LOTO'd? Yes

8. Does this operation require work with or generate any of the following physical hazards-- confined spaces, RF or microwave radiation, magnetic fields, hot or cold surfaces, high noise levels, or oxygen deficiency?
   8i. Does this operation generate any equipment which could operate at greater than 80 dbA? Yes, emergency pressure relief . 18 g/s helium compressor and vacuum pumping skids,
   8l. Is there any possibility of creating an Oxygen Deficient Atmosphere? Yes, catastrophic failure of pressurized equipment /piping release.
   8m. Is it required for any personnel to work in an existing Oxygen Deficiency Hazard Area? Yes, RHIC tunnel ODH-0/1 during operation. ODH-0 in 1002A

11. Will this operation require trained operators or close surveillance? Yes: Cryo system operators, OPM, and monitoring from Cryo Controls DCS


13. Are there any engineering controls or Personal Protective Equipment (PPE) required (i.e., ventilation, fume hoods, interlocks, HEPA filters/vacuum cleaners, respirators)? Yes, OHD 1 equipment when operating RHIC. Electrical PPE for breakers

14. Do you rely on any facility utilities (listed as subquestions) to provide safety controls for your operations? Yes: ODH warning system: interlock and alarm feedback to cryo controls to close valve(s).
ODH 1002A

Medium Pressure Helium Compressor
Vacuum Pumps for 2K bath pumping
Interconnecting Piping
1002A building Volume: 22,500 ft³
Free volume: 20,000 ft³
Fan capacity: 3000 CFM, Required for heat removal
Discharge rate: ~ 10 g/s (steady state cavities)
Discharge rate: 18 g/s (Cooldown = compressor capacity)

Reliefs piped to outside of 1002A, rear left corner, backside.

Coherent electron Cooling PoP
<table>
<thead>
<tr>
<th>Operating Conditions</th>
<th>Inventory Liquid Liters</th>
<th>Helium equivalent</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>K, ATM</strong></td>
<td><strong>Liters</strong></td>
<td><strong>SCF</strong></td>
</tr>
<tr>
<td>RHIC Interface Phase separator</td>
<td>4.65K, 1.45 atm</td>
<td>80</td>
</tr>
<tr>
<td>112 MHz Cavity / helium vessel</td>
<td>4.4K, 1.2 atm</td>
<td>70</td>
</tr>
<tr>
<td>QHS Condenser system</td>
<td>4.3K, 1.1 atm</td>
<td>150</td>
</tr>
<tr>
<td>704 MHz Cavity / helium vessel</td>
<td>2K, 18 Torr</td>
<td>250 (budget)</td>
</tr>
<tr>
<td>Piping, 18 Torr return</td>
<td>300K, 1.5 atm</td>
<td>40 (budget)</td>
</tr>
<tr>
<td>Piping, 1 atm Return, Vacuum pumps discharge side</td>
<td>300K, 1.5 atm</td>
<td>4 (budget)</td>
</tr>
<tr>
<td>Piping, HP return to WR header, helium compressor high side</td>
<td>300K, 16 atm</td>
<td>50 (budget)</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>600</strong></td>
</tr>
</tbody>
</table>

# DEPRESSURIZATION INVENTORY / FLOW

<table>
<thead>
<tr>
<th>Operating / Release Conditions</th>
<th>Depressurization to 1 atm Inventory Liquid Liters Helium equivalent</th>
<th>Flow due to heat leak/load Compressor / pump</th>
</tr>
</thead>
<tbody>
<tr>
<td>RHIC Interface Phase separator</td>
<td>K, ATM 4.65K, 1.45 atm 20 540</td>
<td>g/s / SCF 3 g/s / 38 SCFM</td>
</tr>
<tr>
<td>112 MHz Cavity / helium vessel</td>
<td>K, ATM 4.4K, 1.2 atm 18 486</td>
<td>Goes to QHS</td>
</tr>
<tr>
<td>QHS Condenser system</td>
<td>4.3K, 1.1 atm 38 1026</td>
<td>6 g/s / 76 SCFM</td>
</tr>
<tr>
<td>Piping, 1 atm Return, Vacuum pumps discharge side</td>
<td>300K, 1.5 atm 4 (budget) 108</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>80 2160</td>
</tr>
<tr>
<td>704 MHz Cavity / helium vessel</td>
<td>4.3K, 1.5 atm 62 (budget) 1674</td>
<td>5 g/s / 64 SCFM</td>
</tr>
<tr>
<td>Piping, 18 Torr return</td>
<td>300K, 1.5 atm 40(budget) 1080</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>102 2754</td>
</tr>
<tr>
<td>Piping, HP return to WR header, helium compressor high side</td>
<td>300K, 16 atm 50 (budget) 1350</td>
<td>18 g/s / 230 SCFM</td>
</tr>
</tbody>
</table>
ODH 1002A

1002A with FAN

FAN TRIGGERS AT 18%
RAMES TO FULL SPEED in 60 sec

OXYGEN CONCENTRATION
INTEGRATED INVENTORY OUT
FAN SCFM

Coherent electron Cooling PoP
NOISE & STARTLE HAZARD

1002A
Reliefs
18 g/s helium Compressor
Tuthill vacuum pumping skids
Double hearing protection, 85 dB

1002 Tunnel / IP AREA
Reliefs

Coherent electron *Cooling PoP*
Liquid Helium is supplied to the CeC system from a local tap off the RHIC cryogenic distribution system

- Any oscillations from the RHIC distribution system will be buffered by the phase separator’s vapor volume

- **Helium vessel**
  - Stainless Steel 304L
  - MAWP: 290 psia @ 120°F
  - MAEWP: 15 psi (full vacuum) @ 120°F
  - MDMT: 4K @ 290 psia
  - ASME BPVC VIII DIV 1. U-STAMPED
  - Reliefs: Loss of insulating vacuum / cooldown

- **Cryostat Vacuum vessel**
  - Stainless Steel 304
  - MAWP: 15 psig @ 120°F
  - MAEWP: 15 psi (full vacuum) @ 120°F
  - MDMT: 4K @ 290 psia
  - Engineered and built to ASME BPVC VIII DIV 1. Not U-stamped

- **Internal Piping**: ASME B31.3.
1A: P&ID RHIC interface phase separator

Phase Separator

Coherent electron Cooling PoP
1B: Quiet Helium Source P&ID

Condenser

Boiler Vessel

Coherent electron Cooling PoP
A closed loop condenser heat exchanger system isolates the liquid around the cavity from distribution system and return helium compressor.

- Condenser mounted in a liquid helium bath = boiler side
- Condenser = cavity side
  - Helium vapor from the 112 MHz cavity enters the condenser and is liquefied and gravity drained back to cavity cryostat bath
  - Condenser has a 200 Watt heat load capacity
- Helium vessel (boiler) and condenser are ASME U-stamped
- Boiler /Condenser, Valves, and internal piping inside insulating vacuum vessel

Coherent electron Cooling PoP
1B: Quiet Helium Source

• Helium Boiler vessel
  • Stainless Steel 304L
  • MAWP: 45 psia @ 120°F MAEWP: 15 psi (full vacuum) @ 120°F
  • MDMT: 4K @ 45 psia
  • ASME BPVC VIII DIV 1. U-STAMPED
  • Reliefs: Loss of insulating vacuum / cooldown

• CONDENSER Brazed Aluminum Plate-fin Heat exchanger
  • SUMITOMO Precision Products Aluminum 5058 / 6061-T6
  • ASME BPVC VIII DIV 1. U-STAMPED
  • MAWP: 45 psia @ 120°F MAEWP: 15 psi (full vacuum) @ 120°F
  • MDMT: 4K @ 45 psia

• Cryostat Vacuum vessel
  • Stainless Steel 304
  • MAWP: 15 psig @ 120°F
  • MAEWP: 15 psi (full vacuum) @ 120°F
  • MDMT: 4K @ 290 psia
  • Engineered and built to ASME BPVC VIII DIV 1. Not U-stamped
  • Relief: Burstdisk, 4 inch ASME UD Stamped, 8 psi FIKE, o-ring sealed, vacuum service

• Internal Piping: ASME B31.3.
• Cryogenic valves
• Heater on helium vessel

Coherent electron Cooling PoP
1B: Quiet Helium Source Condenser Layout

Brazed Aluminum Heat Exchanger

Vapor inlet

Condenser fully submerged in Liquid Helium

Liquid outlet

Piping transitions from Aluminum to Stainless Steel

Height=19.7”

Coherent electron Cooling PoP
1B: Quiet Helium Source: Platform

Platform and Fixed ladder needed to access QHS components

• OSHA Specification Requirements
  • Ladder must meet requirements of (1910.27)
  • Ladder shall have extension rails at top (1910.27)
  • Ladder top rung to be even with platform (1910.27)
  • Platform must not have gap between wall greater than 1 inch (1910.23) or rails will be required
  • Opening at top of ladder to be guarded by standard railing, i.e. gate or chain, (1910.23a(2))
  • Toe boards required on platform (1910.23b(5))
  • All Railing OSHA Standard Railings
  • Standard railings and toeboard specification (1910.23(e))
  • Label platform floor loading
  • Consider where relief valves and burst disks are located, may cause acute cryo or ODH, or startle hazard

Coherent electron Cooling PoP
1B: Quiet Helium Source Condenser Layout

- **Railing**: 42” high and able to withstand 200# load
- **Platform Grating**: 122” above floor
- **Ladder**: 16” wide with box section vertical hand rails
- **Gate**
1B: Quiet Helium Source

QHS back view

QHS in full assembly

Coherent electron *Cooling* PoP
112MHz Cavity Cryostat
Collider-Accelerator Hazard Identification Tool Overview

Please refer to cavity physics slides for relevant SRF cavity hazards.

‘ 7. Are there any mechanical hazards or work hazards such as material handling, elevated work, vacuum or pressure vessels, scaffolds, stored energy or structural considerations? Yes
  7b. Does the operation include the use of a hoist, crane, forklift, or rigging? Yes, hoist & forklift
  7c. Are there any structures supporting heavy loads? Yes, a support frame for the cryostat
  7i. Does any equipment operate at pressures above 15 psig or under a vacuum? Yes, Vacuum vessel ASME BPVC VIII Div 1, U-stamped
  7k. Is any part of this system/operation involve a cryogenic system or dewar installation? Yes,
  7m. Are there any sources of stored energy (hydraulic, pneumatic, thermal, mechanical)? Yes, compressed helium
  7m1. Is the source capable of being easily isolated or can it be LOTO'd? Yes

‘ 8. Does this operation require work with or generate any of the following physical hazards-- confined spaces, RF or microwave radiation, magnetic fields, hot or cold surfaces, high noise levels, or oxygen deficiency?
  8i. Does this operation generate any equipment which could operate at greater than 80 dbA? Yes, emergency pressure relief
  8l. Is there any possibility of creating an Oxygen Deficient Atmosphere? Yes, catastrophic failure pressure relief
  8m. Is it required for any personnel to work in an existing Oxygen Deficiency Hazard Area? Yes, RHIC tunnel ODH1 during operation

‘ 11. Will this operation require trained operators or close surveillance? Yes: Cryo system operators, OPM, and monitoring from Cryo Controls DCS
‘ 13. Are there any engineering controls or Personal Protective Equipment (PPE) required (i.e., ventilation, fume hoods, interlocks, HEPA filters/vacuum cleaners, respirators)? Yes, OHD 1 equipment when operating RHIC
‘ 14. Do you rely on any facility utilities (listed as subquestions) to provide safety controls for your operations? Yes: ODH warning system: interlock and alarm feedback to cryo controls to close valve(s).
1C: 112MHz Cavity Cryostat System P&ID

Coherent electron *Cooling* PoP
The 112MHz cavity cryostat surrounds the SRF cavity with 4K liquid helium within a helium vessel. The cryostat provides an insulating vacuum space around the helium vessel to maintain the cryogenic temperatures. Internal piping routes cryogenic cooling from the Quiet Helium Source (QHS).

Manufacturer: Niowave
Subcontractor: Meyer Tool for ASME BPVC U-stamp vessel

Major Components:
- Niobium SRF cavity (See cavity physics slides)
- Liquid Helium Vessel
- Insulating Vacuum Vessel – U-Stamped
- Internal Piping
- Cryostat Stand (See cavity physics slides)
1C: 112MHz Cavity Cryostat System

SRF Cavity: Niobium

MAWP: 23 psig @ 70°F

Engineering Analysis: FEA by BNL

UHV Beam tube pressure relief: MDC / BS&B UHV Burst disc at 6 PSIG

Coherent electron Cooling PoP
1C: 112MHz Cavity Cryostat System

Liquid Helium Vessel: Stainless Steel 304L, 20 inch diameter x 41” long
MAWP: 23 psig @ 70°F
Engineering Analysis: FEA by BNL
Liquid volume: 70 liters including chimney
Primary pressure relief: Burst disc at 8 PSIG – ASME UD-Stamped

Secondary pressure relief: Spring relief at 5 PSIG
**1C: 112MHz Cavity Cryostat System**

**Insulating Vacuum Vessel:** Stainless Steel 304L, 36 inch diameter x 65” long
MAWP: 62 psig @ 120°F
MDMT: -452°F @ 50 psig
**ASME BPVC VIII DIV 1. U-STAMPED**

Primary pressure relief: Burst disc at 8 PISG – ASME UD-Stamped. FIKE 3 inch 160 kW, at 50 psig, 6.8K flow = 6.9 kg/s, 1 sec time constant
wetted area of liquid helium onto vacuum vessel wall

Secondary pressure relief: Spring relief at 2 PSIG

---

Coherent electron *Cooling PoP*
1C: 112MHz Cavity Cryostat System

Internal Piping:
Helium transfer lines
• Stainless Steel 304L
• Certified construction to ASME B31.3 piping code from vendor
• BNL to finalize piping code analysis

Heat Shield
• Copper Tubing
• Certified construction to ASME B31.3 piping code from vendor
• BNL to finalize piping code analysis

Vacuum Break
• Stainless Steel 304L
• Certified construction to ASME B31.3 piping code from vendor
• BNL stress analysis report complete
1C: 112MHz Cavity Cryostat System
Beam tube / FPC Heat Intercept

• FPC Intercept
  • Helical Channel passages:
    • Stainless steel 304L passages / pressure boundary
  • MAWP: 45 psia @ 120°F
  • MAEWP: 14.7 psi (full vacuum) @ 120°F
  • MDMT: 4K @ 45 psia
  • Engineering Analysis by BNL, B31.3

Coherent electron Cooling PoP
1C: 112MHz Cavity Cryostat System
Beam tube / FPC Heat Intercept

Coherent electron Cooling PoP
Coherent electron *Cooling* PoP
1C: 112MHz Cavity Cryostat System
Beam tube / FPC Heat Intercept

Coherent electron Cooling PoP
Safety Controls

Alarms & Shutdown Interlocks:

1. High pressure alarm & interlock: 2 psig (TBD)

2. Pressure rate increase interlock (quench detection):
   ~200mbar/s
   ~3mbar/s for normal operation (100 W of net heat input) as a comparison

3. Low liquid helium level
1D: Cryogenic Transfer Lines
Collider-Accelerator Hazard Identification Tool Overview

‘7. Are there any mechanical hazards or work hazards such as material handling, elevated work, vacuum or pressure vessels, scaffolds, stored energy or structural considerations?
Yes: Pressurized piping: Piping per ASME B31.3

‘8. Does this operation require work with or generate any of the following physical hazards--confined spaces, RF or microwave radiation, magnetic fields, hot or cold surfaces, high noise levels, or oxygen deficiency?
Release of cold gas, C-AD access training includes: Recognition of Release of Cryogens
Startle Hazard during reliefs valves lifting

‘11. Will this operation require trained operators or close surveillance?
Yes: Cryo system operators, OPM, and monitoring from Cryo Controls DCS

‘12. Are there any fire protection or life safety concerns in this operation?
Yes: Construction: Welding for piping: Fire protection, weld permit, work planning.
ODH: ODH 0, ODH sensor with 2 sample location, alarm, lights, exhaust fan and inlet damper

‘13. Are there any engineering controls or Personal Protective Equipment (PPE) required (i.e., ventilation, fume hoods, interlocks, HEPA filters/vacuum cleaners, respirators)? Yes:
Typical PPE required for standard operations in C-AD will be used as required: hard hats and gloves for rigging, proper PPE for electrical safety when throwing breakers or energizing electrical systems, hearing protection, visual shields for welding, etc. PPE for cryogenic operations

‘14. Do you rely on any facility utilities (listed as subquestions) to provide safety controls for your operations?
Yes: ODH warning system: interlock and alarm feedback to cryo controls to close valve(s).

Coherent electron Cooling PoP
# 1D: Cryogenic Transfer Lines

<table>
<thead>
<tr>
<th>Description</th>
<th>Size</th>
<th>Design Pressure</th>
<th>Design Temperature</th>
<th>Manufacturing</th>
</tr>
</thead>
<tbody>
<tr>
<td>From RHIC Interface separator to 4.5K QHS Cryostat</td>
<td>½ x 2 VJ SS304/304L</td>
<td>Full vacuum to 290 psia</td>
<td>4K -120°F</td>
<td>Vendor</td>
</tr>
<tr>
<td>Interconnect multi lines between 4.5K QHS Cryostat and 112MHz Cavity Cryostat. Two VJ bundles</td>
<td>½” Supply ½” Fill 2” Return ½” Shields SS304/304L</td>
<td>Full vacuum to 45 psia</td>
<td>4K -120°F</td>
<td>Vendor</td>
</tr>
</tbody>
</table>
1E: Small Helium Compressor Collider-Accelerator Hazard Identification Tool Overview

' 1. Are there any chemicals, toxic materials, or hazardous material handled, generated, used, or stored in this operation, including oils and solvents?
Yes: UCON-LB-170X Synthetic compressor oil. Catch pan at bottom of skid.

' 6. Is there any energized electrical equipment used in this operation?
Yes: 480 VAC, 120 HP motor and PLC panel.
High current interrupt capability: SCCR: 65 kA. UL 508A CERTIFIED and LABELED by Horlick Co. Inc

' 7. Are there any mechanical hazards or work hazards such as material handling, elevated work, vacuum or pressure vessels, scaffolds, stored energy or structural considerations?
Yes: Pressure & stored energy: Skid components ASME BPVC VIII Div 1, U-stamped,

' 8. Does this operation require work with or generate any of the following physical hazards--confined spaces, RF or microwave radiation, magnetic fields, hot or cold surfaces, high noise levels, or oxygen deficiency?
Hot surfaces: Will be labeled. High noise level: Will be posted noise protection required single or double depending on dB level.

' 11. Will this operation require trained operators or close surveillance?
Yes: Cryo system operators, OPM, and monitoring from Cryo Controls DCS

' 12. Are there any fire protection or life safety concerns in this operation?
Yes: Construction: Welding for piping: Fire protection, weld permit, work planning.
ODH: ODH 0, ODH sensor with 2 sample location, alarm, lights, exhaust fan and inlet damper

' 13. Are there any engineering controls or Personal Protective Equipment (PPE) required (i.e., ventilation, fume hoods, interlocks, HEPA filters/vacuum cleaners, respirators)?
Yes:
Typical PPE required for standard operations in C-AD will be used as required: hard hats and gloves for rigging, proper PPE for electrical safety when throwing breakers or energizing electrical systems, hearing protection, visual shields for welding, etc.

' 14. Do you rely on any facility utilities (listed as subquestions) to provide safety controls for your operations?
Yes: ODH warning system: interlock and alarm feedback to cryo controls to close valve(s).
1E: Small Helium Compressor

This compressor brings low pressure helium gas back to RHIC’s Warm Return (WR) line from the 4K and sub atmospheric pumping systems.
Normal Operation: Suction: 15.5 psia, 293K, Discharge: 265 psig, 350K, 308K skid exit

MANUFACTURER: AG EQUIPMENT CO.
Compressor packager for large system. ASME VIII Div 1 shop.

SKID Major Components:
• Oil flooded Screw Compressor. Water cooled heat exchanger.
• Coalescing filters, 4 stages. Charcoal adsorber bed. Outlet Particulate Filter
• Inlet check valve. Discharge back pressure regulator. Skid piping.
• MCC & PLC Panel. Oil Drip Pan

**Oil flooded Screw Compressor:** Standard Dunham-Bush compressor commonly used in small helium plants
Vertical screw compressor with integral oil sump and motor inside housing: Semi-Hermetic.
• MAWP: 410 PSIG @200° F
• MDMT: 20F @ 410 psig
• Capacity: 18 g/sec
• Power: 120 HP, 480VAC, 3 Phase, 60 Hz, max. 50 Amp
Coherent electron Cooling PoP

1E: Small Helium Compressor

Charcoal Adsorber Bed: Carbon Steel 8 inch diameter x 51” H
MAWP: 300 psig @ 200°F
MDMT: -20°F @ 300 psig
ASME BPVC VIII DIV 1. U-STAMPED

Water cooled heat exchanger: 3 stream: Oil, Helium, Water
ITT Stainless Steel 304L Brazed Plate Frame Exchanger
MAWP: 435 psig @ 450°F
MDMT: -310°F @ 435 psig
ASME BPVC VIII DIV 1. U-STAMPED

Coalescing Filters: 4 stages, Parker Finite filters
Width – 4.55", Length – 10.83", 1" NPT Connections
Material: Head – Machined aluminum, internals – stainless steel / plastic, bowl - Aluminum
MAWP: 800 psig @ 175°F
MDMT: 175°F @ 800 psig

Outlet Particulate Filter: Parker Finite filters
Width – 4.55", Length – 14.36", 1" NPT Connections
Material: Head – Machined aluminum, internals – stainless steel / plastic, bowl - Aluminum
MAWP: 800 psig @ 175°F
MDMT: 175°F @ 800 psig
1E: Small Helium Compressor

Relief: Capacity for full compressor flow 18 g/s at 285 psig (230 SCFM)

Piping:

- ASME B31.3, Engineered & manufactured
- Stainless 304/304L
- Pipe stress analysis & Fatigue cycle analysis
- Weld Procedures WPS
- NDE
- CMTR’s
- Pressure Test

Oil: UCON LB-170X Synthetic Oil PEG (Same as RHIC Compressors), 5?? gallon

Oil Drip Pan: Welded at bottom of frame, 2” wall

Vibration isolators legs:
- To isolate compressor from Foundation

Braided Flex lines:
- To isolate compressor from piping
SAFETIES:
E-STOP
Alarms & Shutdown Interlocks:
High discharge temperature alarm & switch: 160°F, 180°F
High discharge pressure alarm & interlock: 265 psig, 275 psig
Low Suction pressure alarm & interlock: 0.5 psig, 0 psig
High Suction pressure alarm & interlock: 4 psig, 5 psig
Low oil level switch.
High cooling return water temperature alarm: 120°F
High Suction temperature alarm: 100°F
Low Suction temperature alarm: 40°F
1E: Small Helium Compressor

MCC PANEL:
120 HP, 480VAC, 3 Phase, 60 Hz, max. 150 Amp
Softstart MCC
High current interrupt capability: SCCR: 65 kA
UL 508A CERTIFIED and LABELED by Horlick Co. Inc

PLC PANEL SECTION:
PLC Chassis with I/O

NOISE:
>85 dB at 3 ft
1002A will be most likely Double hearing protection

Coherent electron Cooling PoP
Coherent electron Cooling PoP
# 1F: WARM Lines & RELIEF Line

## WARM LINES

<table>
<thead>
<tr>
<th>Description</th>
<th>Size</th>
<th>Design Pressure</th>
<th>Design Temperature</th>
<th>Manufacturing</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 atm Return line from 4.5K QHS</td>
<td>½ x 2 VJ</td>
<td>Full vacuum to 50 psig</td>
<td>-20°F -120°F</td>
<td>Vendor</td>
</tr>
<tr>
<td>1 atm manifold Vacuum pump discharge to 18 g/s He compressor</td>
<td>4” SS304/304L</td>
<td>Full vacuum to 50 psig</td>
<td>-20°F -120°F</td>
<td>BNL / Central shop or Vendor</td>
</tr>
<tr>
<td>16 atm supply to WR (RHIC Return) header</td>
<td>1½” SS304/304L</td>
<td>Full vacuum to 300 psig</td>
<td>-20°F -120°F</td>
<td>BNL / Central shop or Vendor</td>
</tr>
</tbody>
</table>

## RELIEF LINES

<table>
<thead>
<tr>
<th>Description</th>
<th>Design Pressure</th>
<th>Design Temperature</th>
<th>Manufacturing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Relief header for 18 g/s compressor</td>
<td>2” NPS</td>
<td>150 psig</td>
<td>-20°F -120°F</td>
</tr>
<tr>
<td>Relief header for 1 atm manifold Vacuum pumps discharges to 18 g/s He compressor</td>
<td>4” NPS Copper</td>
<td>15 psig</td>
<td>-20°F -120°F</td>
</tr>
</tbody>
</table>
# 1G: Controls & Power

<table>
<thead>
<tr>
<th>EQUIPMENT</th>
<th>LOCATION</th>
<th>POWER</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quantum PLC Chassis &amp; Rack</td>
<td>1002B building</td>
<td>120 VAC, 1-phase, 150W</td>
</tr>
<tr>
<td>28 Volt power supplies: 4-20mA</td>
<td>1002B building</td>
<td>120 VAC, 1-phase, 1 kW</td>
</tr>
<tr>
<td>Lakeshore 218S</td>
<td>1002B building</td>
<td>120 VAC, 1-phase, 100W</td>
</tr>
<tr>
<td>AMI or Cryomagnetics Controller</td>
<td>1002B building</td>
<td>120 VAC, 1-phase, 200W</td>
</tr>
<tr>
<td>Load heaters for 112MHz and QHS</td>
<td>112 MHz and QHS cryostats</td>
<td>120 VAC, 1-phase, 100W</td>
</tr>
</tbody>
</table>

## POWER

<table>
<thead>
<tr>
<th>EQUIPMENT</th>
<th>LOCATION</th>
<th>POWER</th>
</tr>
</thead>
<tbody>
<tr>
<td>20 KW, Electric heater</td>
<td>QHS CRYOSTAT SYSTEM</td>
<td>480 VAC, 3-phase, 20 kW</td>
</tr>
<tr>
<td>Cold Helium gas heating Heater Controller</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MCC, 18 g/s Helium compressor PLC Panel, helium compressor</td>
<td>1002A building</td>
<td>480 VAC, 3-phase, 100kW, 250 FLA</td>
</tr>
<tr>
<td></td>
<td></td>
<td>120 VAC, 1-phase, 2 kW</td>
</tr>
<tr>
<td>PLC RACKS</td>
<td>1002B building</td>
<td>120 VAC, 1-phase, 3 kW</td>
</tr>
</tbody>
</table>

Coherent electron *Cooling PoP*
Phase 2 – 2K system

Phase 2: SRF 5-cell with 2K Cryogenic System

- 2A: Cryogenic Transfer Lines: Supply to 704MHz 5-cell cavity cryostat
- 2B: 704MHz 5-cell cavity cryostat with
  - Two (2) superfluid volumes
  - Isolation Superfluid Heat Exchanger
- 2K-4K Recovery HX
- Phase Separator
- Valves
- Relief stack
- 2C: Return transfer line to heating system
- 2D: 18mbar Vapor Return Electric Heating System
- 2E: Warm Return Piping System
- 2F: Vacuum Pumping System
- 2G: Instrumentation & Controls & Power

Coherent electron Cooling PoP
## 2A: CRYOGENIC SUPPLY

<table>
<thead>
<tr>
<th>Description</th>
<th>Size</th>
<th>Design Pressure</th>
<th>Design Temperature</th>
<th>Manufacturing</th>
</tr>
</thead>
<tbody>
<tr>
<td>From RHIC Interface separator to 2K 704MHz Cavity Cryostat</td>
<td>½ x 2 VJ</td>
<td>Full vacuum to 290 psia</td>
<td>4K -120°F</td>
<td>Vendor</td>
</tr>
</tbody>
</table>
2B: 704 MHz Cryogenic System

Coherent electron Cooling PoP
2B: 704 MHz Cavity Cryostat System

Main Components

• Cryostat Vacuum vessel: ASME BPVC VIII DIV.1 U-STAMPED
• 704MHz 5-cell Niobium Cavity
• Titanium helium vessel Cavity side and Pumped bath side
• Super-fluid helium heat exchanger
• Parallel, Redundant Cold reliefs between cavity side / pumped side
• Relief and burst disk Pumped bath side
• Counter flow heat exchanger (JT or recover heat exchanger)
• Phase separator, 4.4K
• Beam tube and FPC heat intercepts
• Fundamental Power coupler, copper/stainless
• Heat shield cooling
• Magnetic shields (2 layers)
• Cryogenic valves

Coherent electron Cooling PoP
2B: 704 MHz Cavity Cryostat System

Coherent electron Cooling PoP
2B: 704 MHz Cavity Cryostat System

Coherent electron Cooling PoP
2B: 704 MHz Cavity Cryostat System

• Cryostat Vacuum vessel
  • Stainless Steel 304
  • MAWP: 50 psig @ 120°F
  • MAEWP: 15 psi (full vacuum) @ 120°F
  • MDMT: 4K @ 50 psig
  • ASME BPVC VIII DIV 1. U-stamped
  • Relief: Burstdisk, 3 or 4 inch ASME UD Stamped, 8 psi FIKE, o-ring sealed, vacuum service

• 704MHz SC Cavity
  • Niobium, High RRR
  • MAWP: 23 psia @ 120°F  MAEWP: 15 psi (full vacuum) @ 120°F
  • MDMT: 2K @ 23 psia
  • Engineering: Good engineering practice
  • Manufacturing: Good manufacturing practice and welder qualification and procedures

• Cavity side Helium vessel, surround the cavity and SuperFluid heat exchanger
  • Titanium
  • MAWP: 23 psia @ 120°F  MAEWP: 15 psi (full vacuum) @ 120°F
  • MDMT: 2K @ 23 psia
  • Engineering: Good engineering practice
  • Manufacturing: Good manufacturing practice and welder qualification and procedures
  • Reliefs: Loss of insulating vacuum or Beam vacuum / cooldown

Coherent electron Cooling PoP
2B: 704 MHz Cavity Cryostat System

• Pumped Bath Side Helium vessel, surround the cavity and SuperFluid heat exchanger
  • Titanium
  • MAWP: 23 psia @ 120°F        MAEWP: 15 psi (full vacuum) @ 120°F
  • MDMT: 2K @ 23 psia
  • Engineering: Good engineering practice
  • Manufacturing: Good manufacturing practice and welder qualification and procedures
  • Reliefs: Loss of insulating vacuum / cooldown

• Superfluid Heat exchanger
  • Copper, OFHC
  • MAWP: 23 psia @ 120°F        MAEWP: 23 psi (full vacuum) @ 120°F
  • MDMT: 4K @ 45 psia
  • Engineering: Good engineering practice
  • Manufacturing: Good manufacturing practice and welder qualification and procedures

Coherent electron Cooling PoP
2B: 704 MHz Cryogenic System
Counter-flow Heat Exchanger

• Tube side:
  • 3/8” x 0.030” Copper tube, finnned 0.12 high fins
  • MAWP: 100 psi @ 120°F
  • MAEWP: 100 psi (full vacuum) @ 120°F
  • MDMT: 2K @ 100 psi

• Shell side
  • 4” NPS sch 10 SS304L Pipe
  • ASTM-TP312
  • ASME B31.3
  • Mandrel: Teflon

Vapor Flow

Copper finned tube

Coherent electron Cooling PoP
2B: 704 MHz Cryogenic System
Counter-flow Heat Exchanger

Coherent electron *Cooling* PoP
2B: 704 MHz Cryogenic System
Beam tube and FPC heat intercept

• Two heat intercepts along both beam tubes and FPC
• Stainless beam tube section is cooled with helium vapor
• Niobium beam tube section is cooled with super-fluid helium
  • The heat intercept is using unique properties of super-fluid helium
  • Super-fluid helium consists of two fluids, one is super-fluid fraction and the other the normal fluid, when heat is applied in the helium, the super-fluid component flow towards heat source and normal fluid component flows away from the heat source, then carry the heat away with it
2B: 704 MHz Cryogenic System
Super-fluid Heat Exchanger Design

- Pumped Bath
- RF Cavity Bath
- Super-fluid heat exchanger

Coherent electron *Cooling* PoP
Super-fluid heat exchanger

- Is made of OFHC copper tubes
  - Tube side: Pumped Bath Side
  - 1” x 0.035” Copper tube
- MAWP: 23 psi @ 120°F
- MAEWP: 23 psi (full vacuum) @ 120°F
- MDMT: 2K @ 23 psi
- Engineering Analysis by BNL
- Engineering: Good engineering practice

2B: 704 MHz Cryogenic System
Super-fluid Heat Exchanger Design

Coherent electron Cooling PoP
Coherent electron Cooling PoP

2B: 704 MHz Cryogenic System
Phase separator, 4.4K

• Phase separator, 4.4K
  • Stainless 304L
  • MAWP: 29 psi @ 120°F
  • MAEWP: 14.7 psi (full vacuum) @ 120°F
  • MDMT: 4K @ 29 psi
  • Diameter: 6 inch or less
  • Engineering Analysis by BNL, B31.3

• Relief: Loss of insulating vacuum / cooldown supply

• Phase separator, 4.4K
  • Liquid supply to counter flow recovery heat exchanger
  • 4.4K Vapor to shield and FPC intercept
  • Liquid level sensor
  • Fill Valve
2B: 704 MHz Cryogenic System
Heat shield cooling & Beam tube intercept

• Heat shield
  • Tubing: Copper
  • Shield Sheet: Copper
• MAWP: 29 psi @ 120°F
• MAEWP: 14.7 psi (full vacuum) @ 120°F
• MDMT: 4K @ 29 psi
• Engineering Analysis by BNL, B31.3

• Beam tube Intercept
• Copper connections to shield cooling loop

Coherent electron Cooling PoP
2B: 704 MHz Cryogenic System

FPC Heat Intercept

• FPC Intercept
  • Helical Channel:
    • MAWP: 23 psia @ 120°F
    • MAEWP: 14.7 psi (full vacuum) @ 120°F
    • MDMT: 4K @ 23 psi
    • Engineering Analysis by BNL, B31.3

Coherent electron Cooling PoP
<table>
<thead>
<tr>
<th>Description</th>
<th>Size</th>
<th>Design Pressure</th>
<th>Design Temperature</th>
<th>Manufacturing</th>
</tr>
</thead>
<tbody>
<tr>
<td>18 mbar to 1 atm Return line from 704MHz Cryostat to heater</td>
<td>2½ x 4 VJ</td>
<td>Full vacuum to 50 psig</td>
<td>4K -120°F</td>
<td>Vendor</td>
</tr>
</tbody>
</table>
## 2E: Warm Return Piping System

<table>
<thead>
<tr>
<th>Size</th>
<th>Design Pressure</th>
<th>Design Temperature</th>
<th>Manufacturing</th>
</tr>
</thead>
<tbody>
<tr>
<td>8 NPS</td>
<td>FULL VACUUM to 50 psig</td>
<td>-20°F -120°F</td>
<td>BNL / Central shop or Vendor</td>
</tr>
</tbody>
</table>

- Return line from Return Heater to vacuum pumps

18 mbar to 1 atm
## RETURN HEATER & HOUSING

<table>
<thead>
<tr>
<th></th>
<th>Size</th>
<th>Design Pressure</th>
<th>Design Temperature</th>
<th>Manufacturing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heater. 15 kW</td>
<td>8” NPS 150# ANSI</td>
<td>Full vacuum to 50 psig</td>
<td>4K -120°F</td>
<td>Heater: Vendor</td>
</tr>
<tr>
<td>Calrod incoloy</td>
<td>Flanges</td>
<td></td>
<td></td>
<td>Housing: Cryo Vendor</td>
</tr>
<tr>
<td>rods, flanged</td>
<td>Inlet side bayonet or</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>electric heater,</td>
<td>field joint</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>480VAC 3-phase,</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Overtemp protection</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dual sheet</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>temperature</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>sensors</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Relief</td>
<td>Sized for 15 kW +</td>
<td>Set 50 psig</td>
<td>4K -120°F</td>
<td></td>
</tr>
<tr>
<td></td>
<td>TBD</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**RETURN HEATER & HOUSING**

**Heater:** 15 kW Calrod incoloy rods, flanged electric heater, 480VAC 3-phase, Overtemp protection Dual sheet temperature sensors

**Size:** 8” NPS 150# ANSI Flanges Inlet side bayonet or field joint

**Design Pressure:** Full vacuum to 50 psig

**Design Temperature:** 4K -120°F

**Manufacturing:** Heater: Vendor Housing: Cryo Vendor

---

Coherent electron *Cooling PoP*
2F: Vacuum Pumping System (2 Kelvin)
Collider-Accelerator Hazard Identification Tool Overview

1. Are there any chemicals, toxic materials, or hazardous material handled, generated, used, or stored in this operation, including oils and solvents?
   Yes: UCON-LB-170X Synthetic compressor oil. Catch pan at bottom of skid.

6. Is there any energized electrical equipment used in this operation?
   Yes: 480 VAC, 3 x (60 HP+20 HP) motor and PLC panel.
   High current interrupt capability: SCCR: 65 kA. UL 508A CERTIFIED and LABELED by Horlick Co. Inc

7. Are there any mechanical hazards or work hazards such as material handling, elevated work, vacuum or pressure vessels, scaffolds, stored energy or structural considerations?
   Yes: Pressure & stored energy: Skid components Water cooled heat exchanger: ASME BPVC VIII Div 1, U-stamped,

8. Does this operation require work with or generate any of the following physical hazards--confined spaces, RF or microwave radiation, magnetic fields, hot or cold surfaces, high noise levels, or oxygen deficiency?
   Hot surfaces: Will be labeled. High noise level: Will be posted noise protection required single or double depending on dB level.

11. Will this operation require trained operators or close surveillance?
   Yes: Cryo system operators, OPM, and monitoring from Cryo Controls DCS

12. Are there any fire protection or life safety concerns in this operation?
   Yes: Construction: Welding for piping: Fire protection, weld permit, work planning.
   ODH: ODH 0, ODH sensor with 2 sample location, alarm, lights, exhaust fan and inlet damper

13. Are there any engineering controls or Personal Protective Equipment (PPE) required (i.e., ventilation, fume hoods, interlocks, HEPA filters/vacuum cleaners, respirators)? Yes:
   Typical PPE required for standard operations in C-AD will be used as required: hard hats and gloves for rigging, proper PPE for electrical safety when throwing breakers or energizing electrical systems, hearing protection, visual shields for welding, etc.

14. Do you rely on any facility utilities (listed as subquestions) to provide safety controls for your operations?
   Yes: ODH warning system: interlock and alarm feedback to cryo controls to close valve(s).

Coherent electron Cooling PoP
2F: Vacuum Pumping System

Coherent electron Cooling PoP
Tuthill Vacuum Pumps: This vacuum pumps pumps on the cavity helium bath at 18 mbar 15 Torr and compress this to 1 psig to send the gas to the small helium recovery compressor.
Normal Operation: Suction: 10 mbar to 80 mbar, 293K, Discharge: 15.7 psia or 1 psig, 80°F.

MANUFACTURER: TUTHILL BLOWER CO.
Manufacturer of Liquid ring vacuum and blowers
SKID Major Components:
• Oil injection cooled Roots Blower
• Liquid Ring Vacuum pump, oil sealed, oil cooled
• Water cooled heat exchanger
• Centrifugal Oil pump
• Coarse Coalescing filter
• Oil collection reservoir
• Inlet Control valve.
• Outlet isolation valve
• Oil Drip Pan
• Electrical Junction Panel Box
2F: Vacuum Pumping System

Oil Demisting Filter:
Volume: 7 Gallon
Stored energy: 2000 Joules
Carbon Steel
MWP: 14.7 psig @ 200°F
MDMT: -20°F @ 14.7 psig

Oil Collection reservoir:
MWP: 14.7 psig
Volume: 11 Gallons
Stored energy: 3200 Joules
Design:
Stainless Steel 304
Rated: 50 psig @ 200°F
Test pressure 100 psig

Water cooled heat exchanger: 2 stream: Oil, Water
Shell & Tube Exchanger
MAWP: psig @ °F
MDMT: °F @ psig
ASME BPVC VIII DIV 1. U-STAMPED

Coherent electron Cooling PoP
2F: Vacuum Pumping System

Piping: Carbon steel Sch 40 CS A53
Pressure/Leak Test

**Oil:** UCON LB-170X  Synthetic Oil PEG (Same as RHIC Compressors), ~ 5 gallon

**Oil Drip Pan:**
Welded at bottom of frame, 2” wall?

**Vibration isolators legs:**
To isolate compressor from Foundation

**Braided Flex lines:**
To isolate compressor from piping

**SKID NOISE:**
>80 dB at 3 ft.
Survey when in operation
Requires double hearing protection
2F: Vacuum Pumping System P&ID

Coherent electron Cooling PoP
MCC PANEL:
80 HP, 480VAC, 3 Phase, 60 Hz, max. Amp. Softstart MCC
High current interrupt capability: SCCR: 65 kA
UL 508A CERTIFIED and LABELED by Horlick Co. Inc
UL listed: CF-192727

PLC PANEL SECTION: PLC Chassis with I/O’s
UL 508A CERTIFIED and LABELED by Horlick Co. Inc
UL listed: CF-192726

SAFETIES:
E-STOP
Alarms & Shutdown Interlocks:
High discharge temperature alarm & switch: 160°F, 180°F
High discharge pressure alarm & interlock: 265psig, 275 psig
Low Suction pressure alarm & interlock: 0.5 psig, 0 psig
High Suction pressure alarm & interlock: 4 psig, 5 psig
Low oil level switch.
High cooling return water temperature alarm: 120°F
High Suction temperature alarm: 100°F
Low Suction temperature alarm: 40°F
2F: Vacuum Pumping System

Torque Requirements
Terminals
1492-J4  4.8-8.9 lb in
1492-JD3 3.5-5.3 lb in
1492-WTF3 4.2-4.6 lb in
1492-EA35 4.4-7.1 lb in
1492-JG4 4.4-8.9 lb in
Jumpers 0.2 lb in

Motor Protectors
8.9-22 lb in

Circuit Breakers
G Frame 20 lb in
J Frame 180 lb in
1492-SP 21-27 lb in
194R 35 lb in

Soft Starters
SMC-3  power 20-35 lb in
Control 4.4-8.0 lb in

VFD
PF40 4-4.7 lb in control
PF40 26-33 lb in power

Relays
Base 7 lb in
1S Barrier 7 lb in

PLC Cards
1746 series 8 lb in

---

Coherent electron Cooling PoP
# 2G: Controls & Power

<table>
<thead>
<tr>
<th>EQUIPMENT</th>
<th>LOCATION</th>
<th>POWER</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quantum PLC Chassis &amp; Rack</td>
<td>1002B building</td>
<td></td>
</tr>
<tr>
<td>28 Volt power supplies: 4-20mA</td>
<td>1002B building</td>
<td></td>
</tr>
<tr>
<td>Lakeshore 218S</td>
<td>1002B building</td>
<td></td>
</tr>
<tr>
<td>AMI or Cryomagnetics Controller</td>
<td>1002B building</td>
<td></td>
</tr>
<tr>
<td>Load heaters for 112MHz and QHS</td>
<td>112 MHz and QHS cryostats</td>
<td></td>
</tr>
</tbody>
</table>

## POWER

<table>
<thead>
<tr>
<th>EQUIPMENT</th>
<th>LOCATION</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>MCC, Tuthill vacuum skids</td>
<td>1002A building, mezzanine</td>
<td>480 VAC, 3-phase, 100kW, 369 FLA</td>
</tr>
<tr>
<td>PLC Panel, Tuthill vacuum skids</td>
<td>1002A building, floor level</td>
<td>120 VAC, 1-phase, 2 kW</td>
</tr>
</tbody>
</table>

Coherent electron *Cooling* PoP