CeC PoP 2013
Cryogenic Systems
ASSRC REVIEW
MAR 11, 2013

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CeC PoP 2012 – Cryogenic System

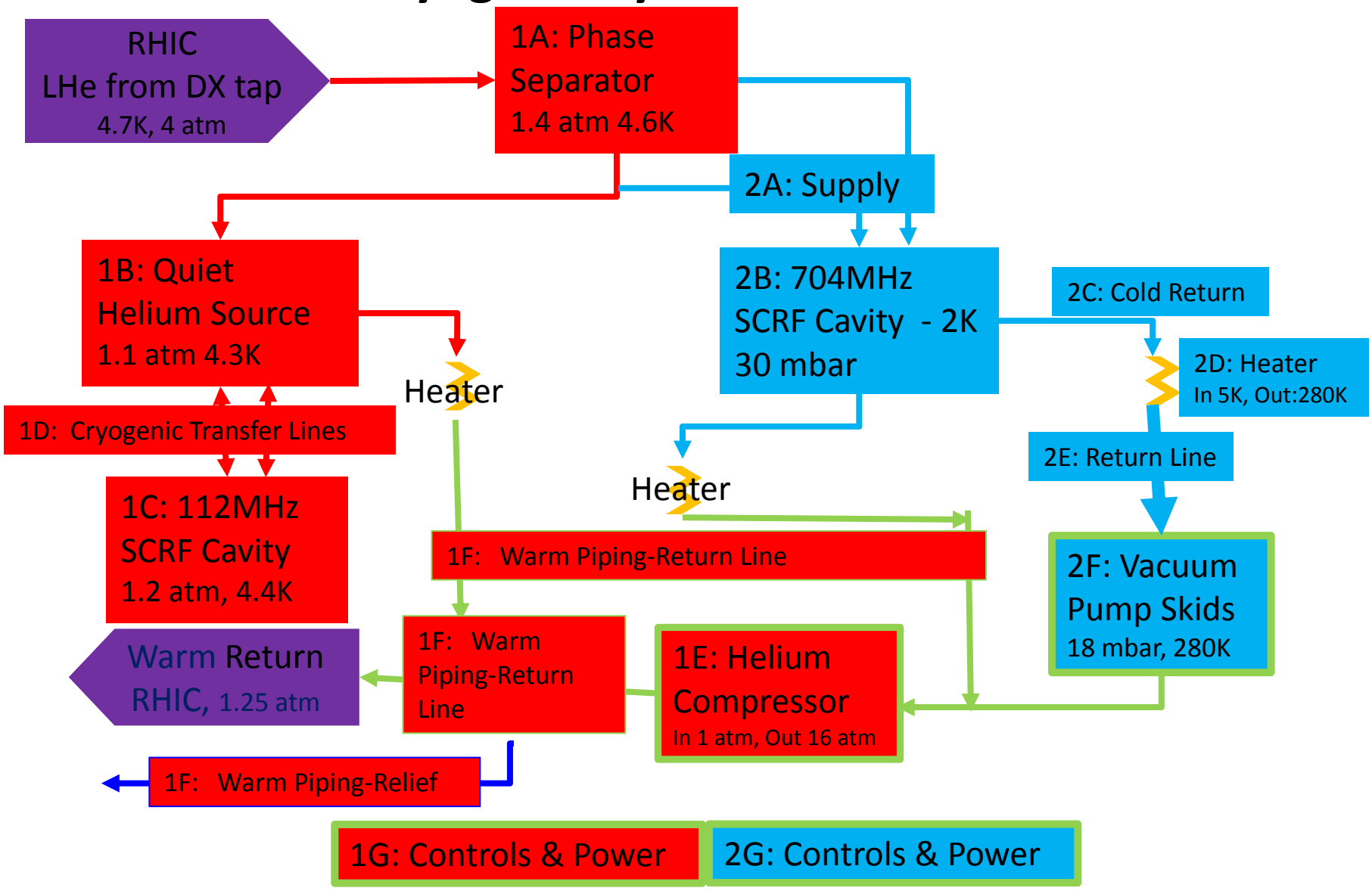
Phase 1: SRF Gun with 4.4K Cryogenic System

- 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
- 1F: ODH Requirements
- 1I : Noise & Oil Containment

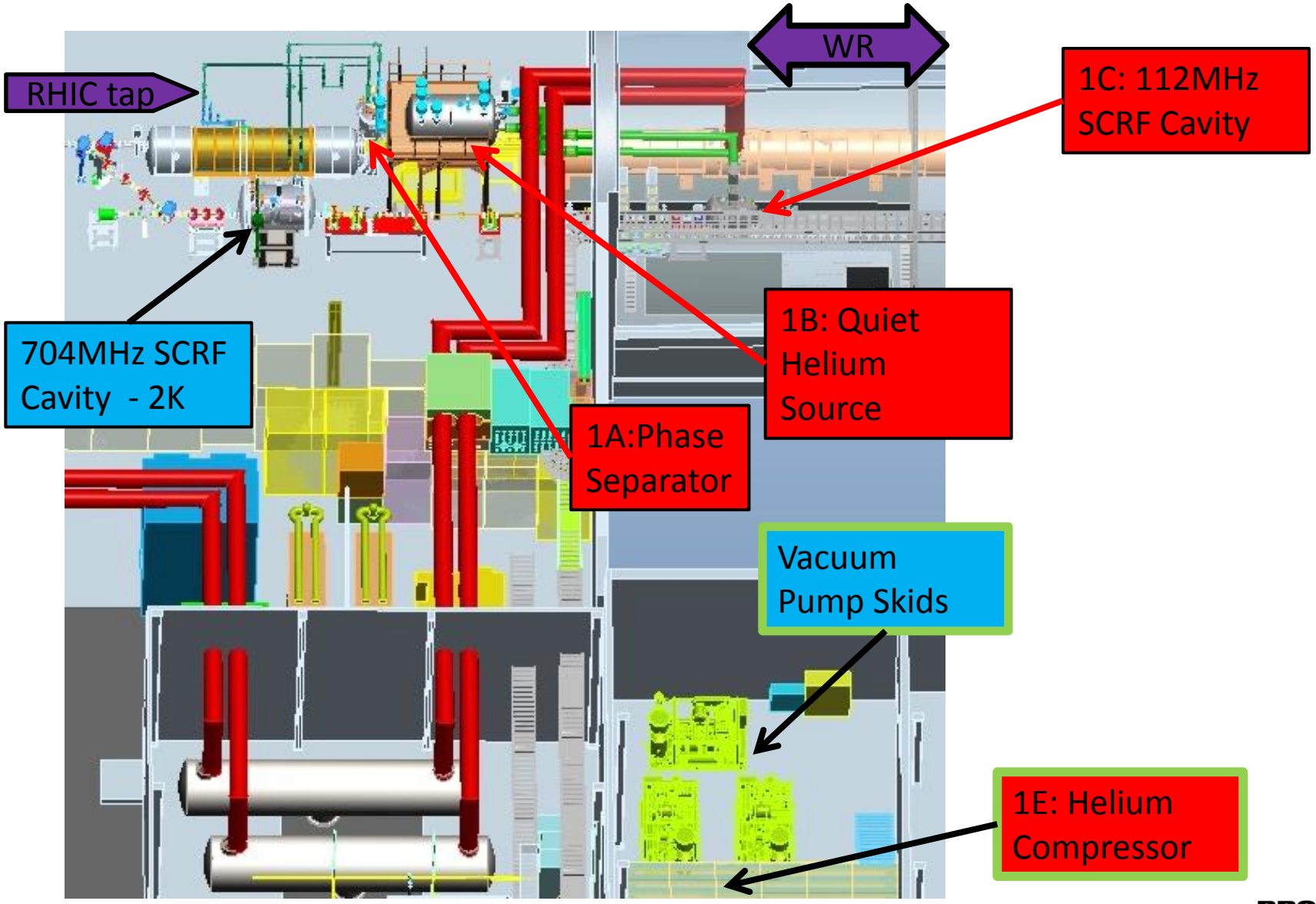
Phase 2: SRF 5-cell with 2K Cryogenic System

- 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

Cryogenic System Overview



CeC Cryogenics Model



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

‘ 12. Are there any fire protection or life safety concerns in this operation? Yes: Construction, Welding for piping: Fire protection, weld permit, work planning.

‘ 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.

ODH 1002A

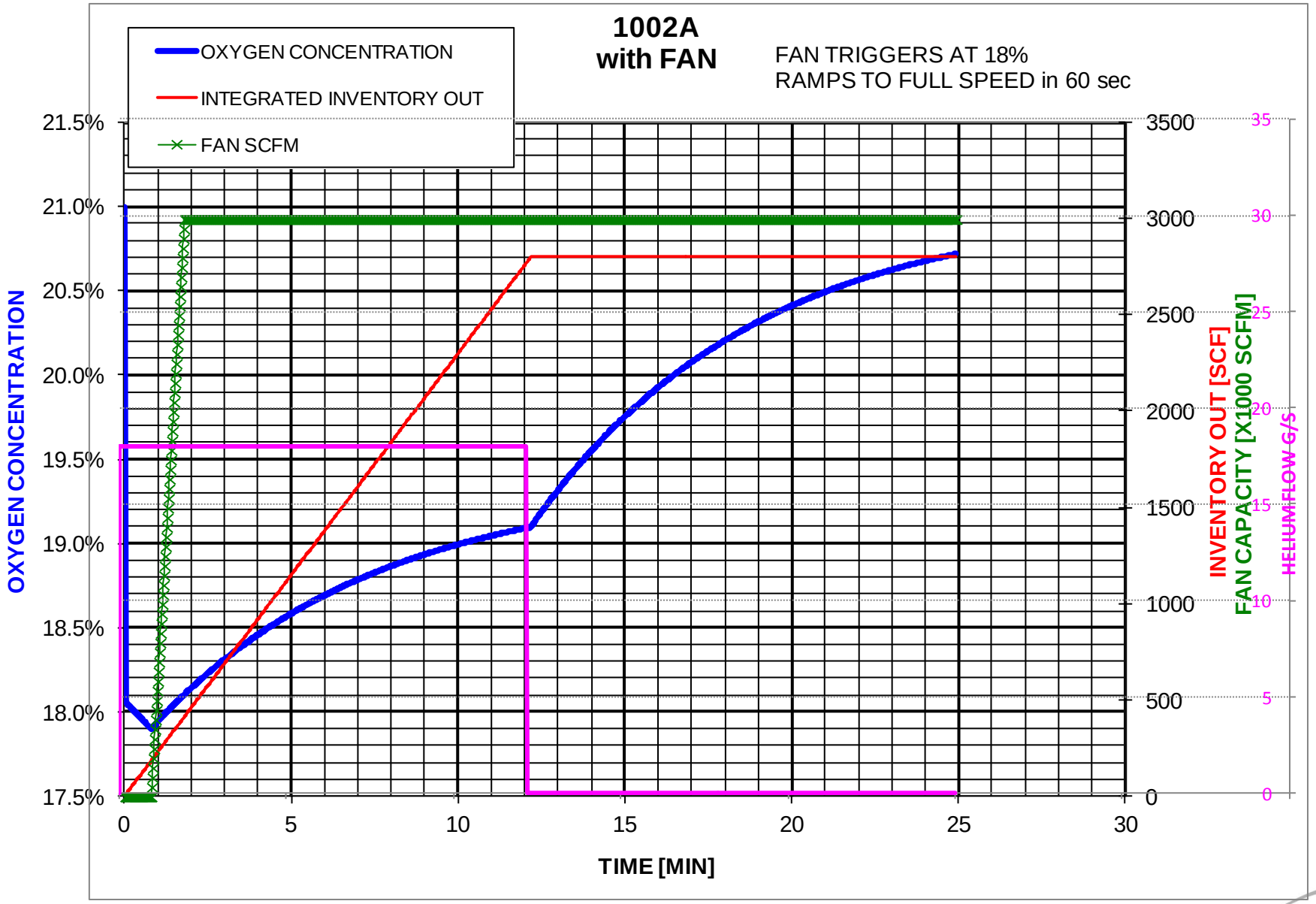
TOTAL INVENTORY			
	Operating Conditions	Inventory Liquid Liters Helium equivalent	
	K, ATM	Liters	SCF
RHIC Interface Phase separator	4.65K, 1.45 atm	80	2160
112 MHz Cavity / helium vessel	4.4K, 1.2 atm	70	1890
QHS Condenser system	4.3K, 1.1 atm	150	4050
704 MHz Cavity / helium vessel	2K, 18 Torr	250 (budget)	6750
Piping, 18 Torr return	300K, 1.5 atm	40 (budget)	1080
Piping, 1 atm Return, Vacuum pumps discharge side	300K, 1.5 atm	4 (budget)	108
Piping, HP return to WR header, helium compressor high side	300K, 16 atm	50 (budget)	1350
		600	16,200

ODH 1002A

DEPRESSURIZATION INVENTORY / FLOW

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

ODH 1002A


1002A
with FAN
FAN TRIGGERS AT 18%
RAMPS TO FULL SPEED in 60 sec
OXYGEN CONCENTRATION
INTEGRATED INVENTORY OUT
FAN SCFM
21.5%
21.0%
20.5%
20.0%
19.5%
19.0%
18.5%
18.0%
17.5%
OXYGEN CONCENTRATION
3500
3000
2500
2000
1500
1000
500
0
INVENTORY OUT [SCF]
FAN CAPACITY [X1000 SCFM]
35
30
25
20
15
10
5
0
HELIUM FLOW G/S
0
5
10
15
20
25
30
TIME [MIN]

NOISE & STARTLE HAZARD

1002A

Reliefs

18 g/s helium Compressor

Tuthill vacuum pumping skids

Double hearing protection, 85 dB

1002 Tunnel / IP AREA

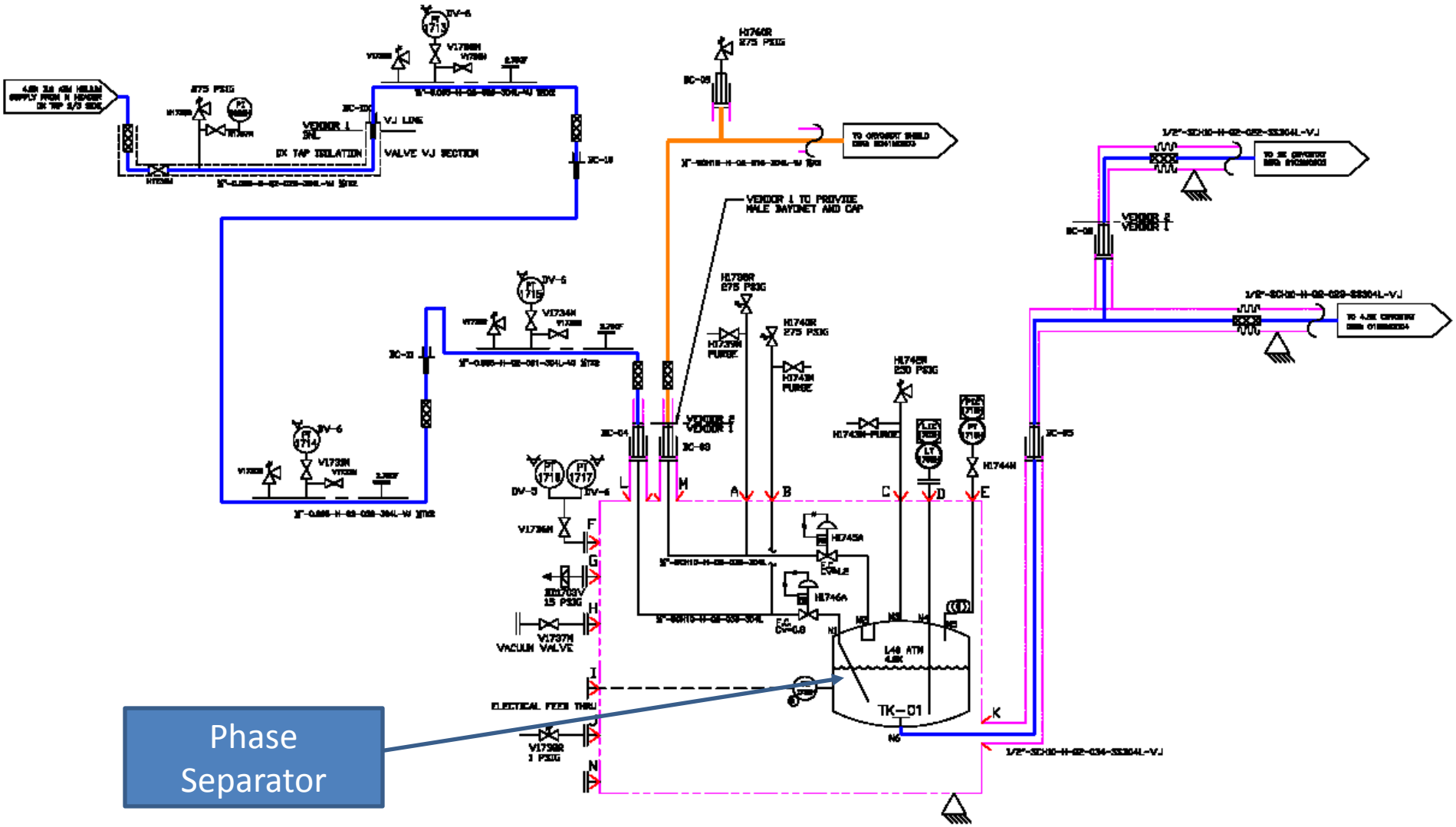
Reliefs

1A: RHIC interface phase separator

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



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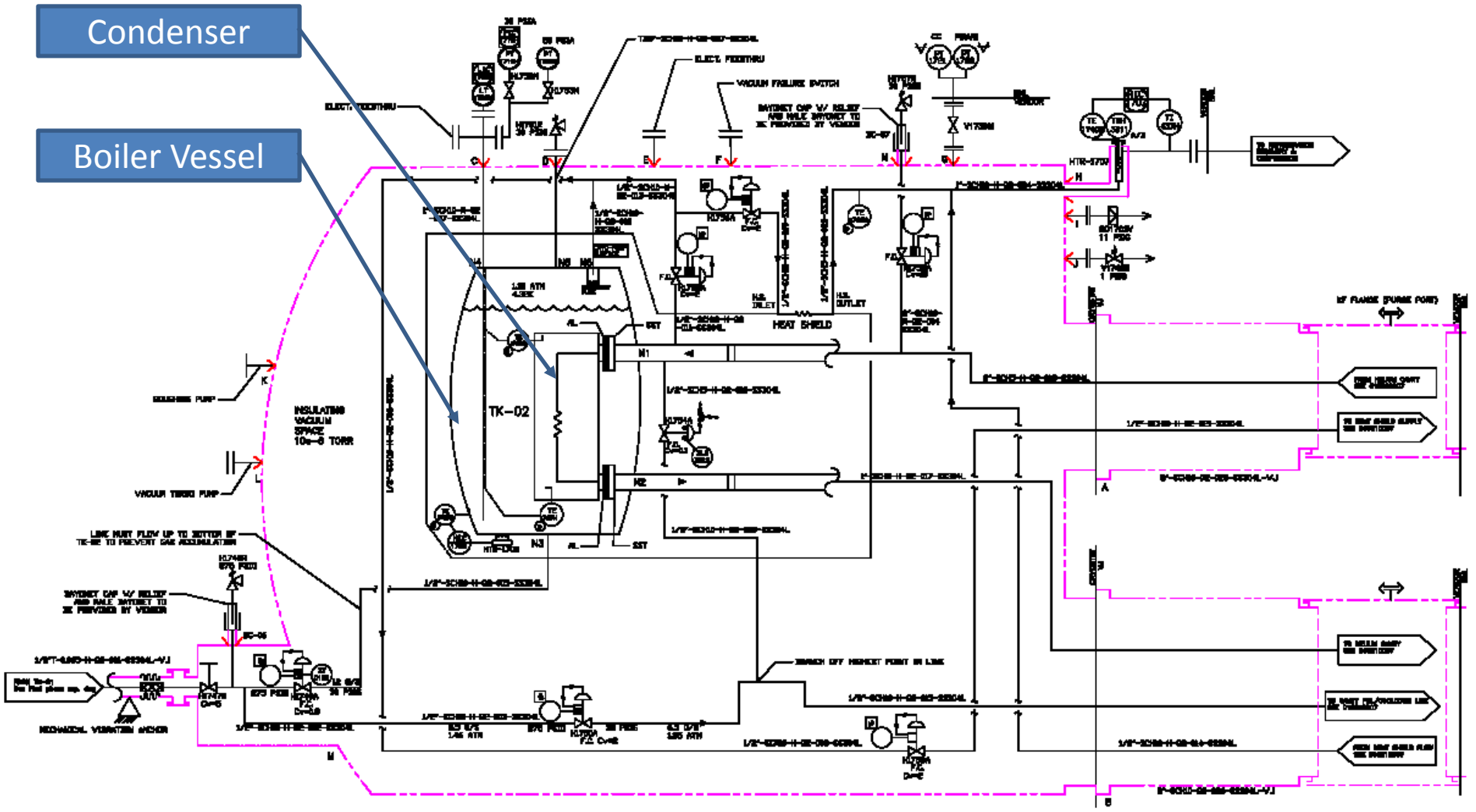
1B: Quiet Helium Source P&ID

Condenser

Boiler Vessel



1B: Quiet Helium Source

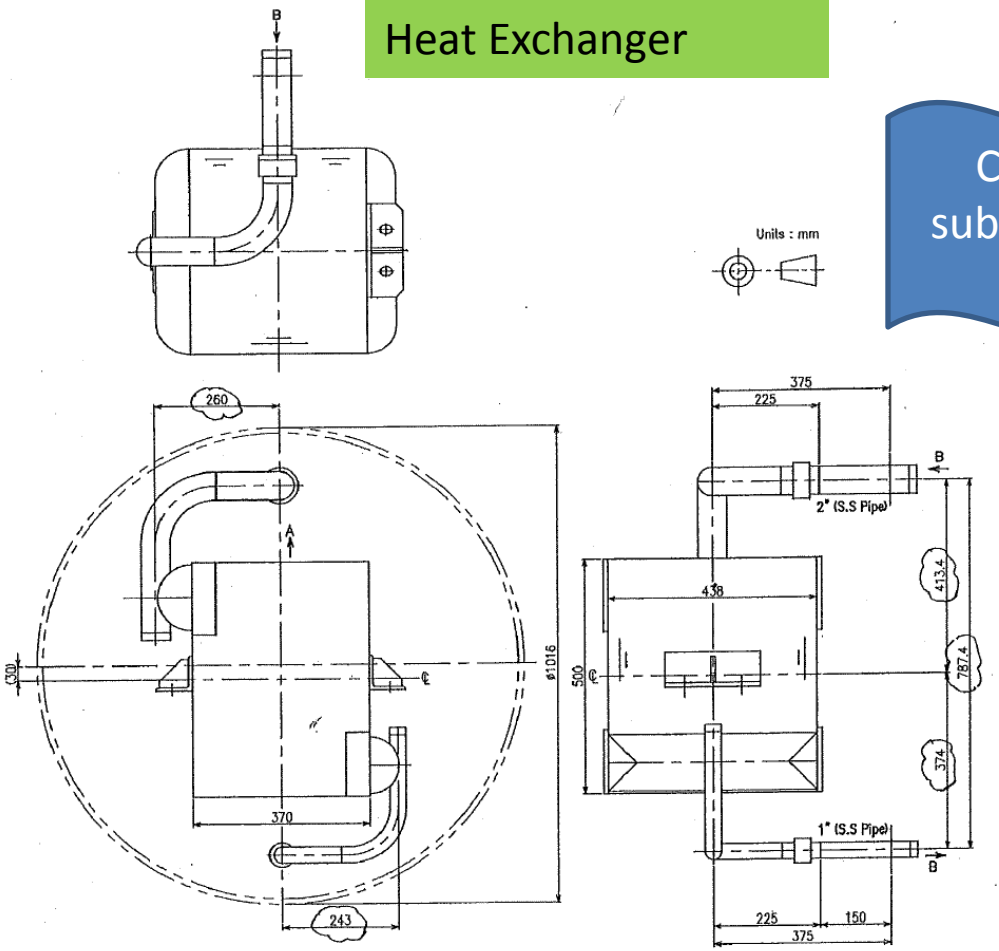
- A closed loop condenser heat exchanger system isolates the liquid around the cavity from distribution system and return helium compressor.
- Condenser mounted in a liquid helium bath = boiler side
- Condenser = cavity side
  - Helium vapor from the 112 MHz cavity enters the condenser and is liquefied 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

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**

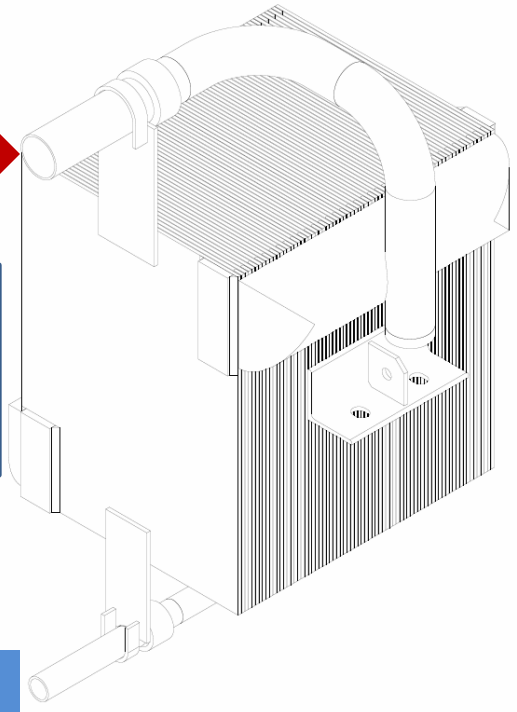
1B: Quiet Helium Source Condenser Layout

Brazed Aluminum Heat Exchanger



Vapor inlet

Condenser fully submerged in Liquid Helium



Liquid outlet

Piping transitions from Aluminum to Stainless Steel

Height=19.7”

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1B: Quiet Helium Source: Platform

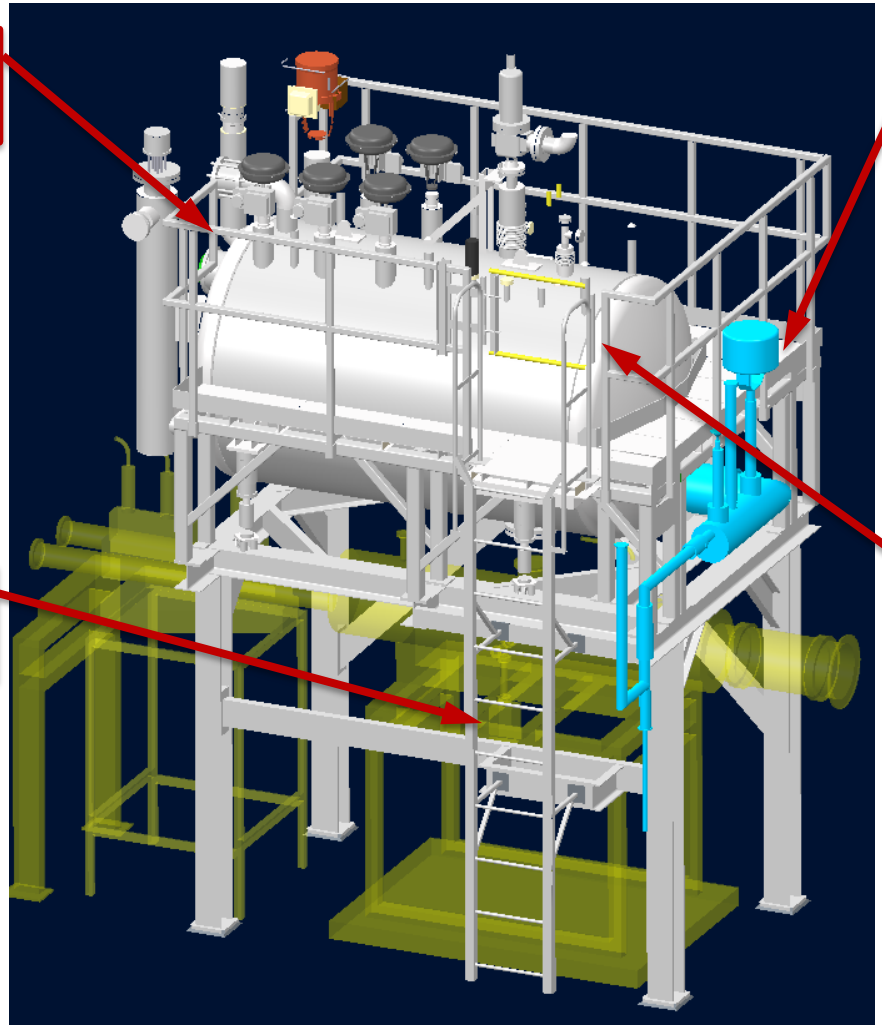
Platform and Fixed ladder needed to access QHS components

- **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 cyro or ODH, or startle hazard

1B: Quiet Helium Source Condenser Layout

Railing

42” high and able to withstand 200# load



Platform Grating

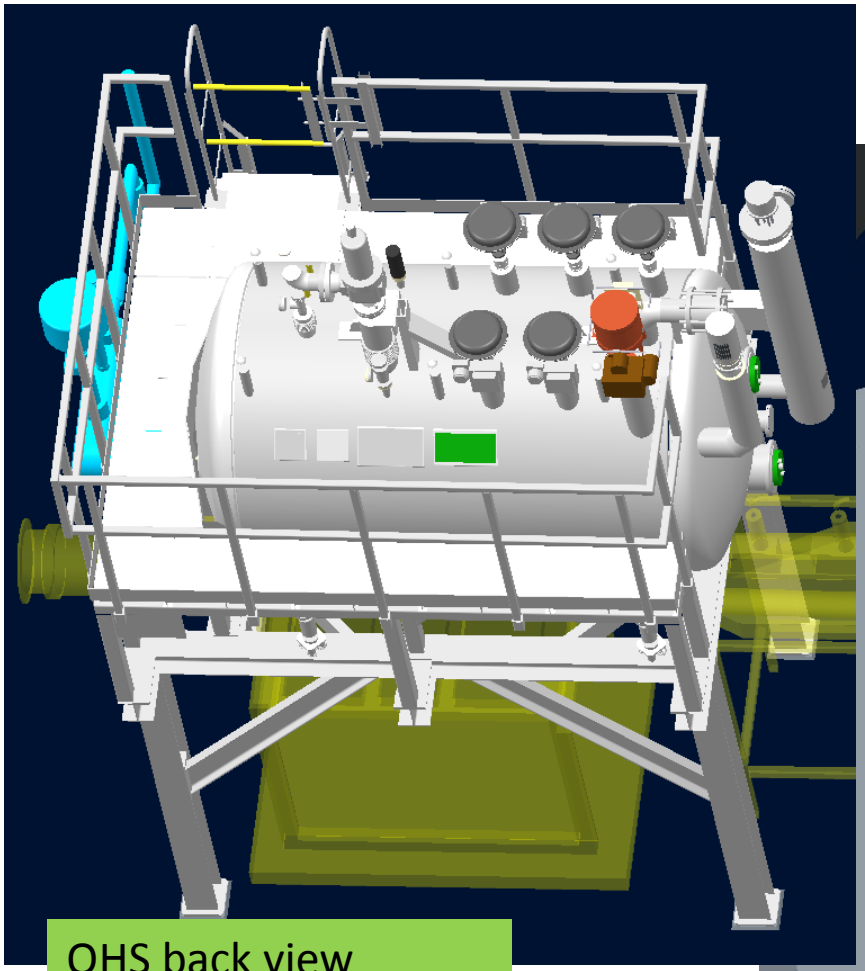
122” above floor

Gate

Ladder

16” wide with box section vertical hand rails

1B: Quiet Helium Source



QHS back view

QHS in full assembly

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

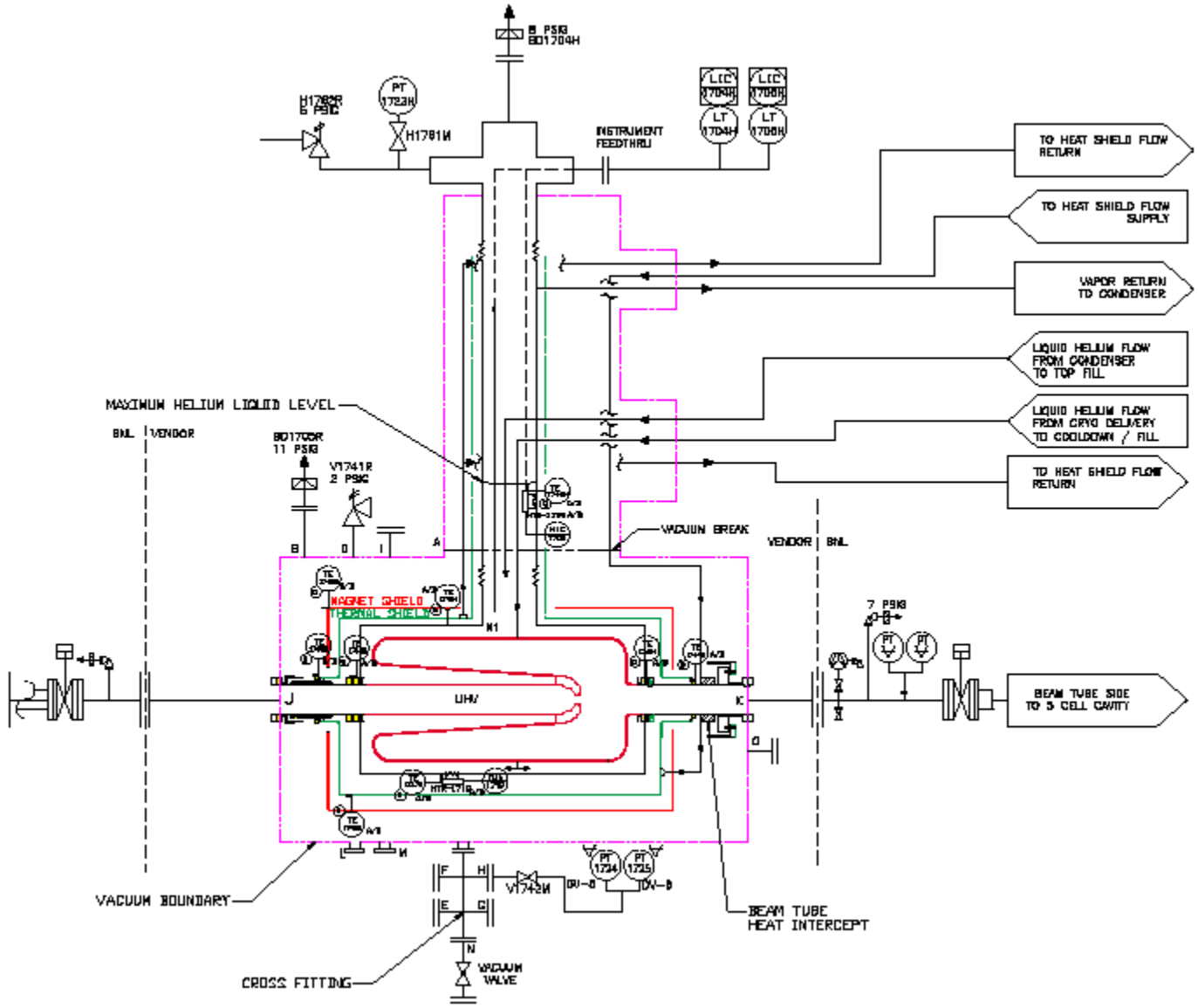
‘ 12. Are there any fire protection or life safety concerns in this operation? Yes: Construction, Welding for piping: Fire protection, weld permit, work planning.

‘ 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



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1C: 112MHz Cavity Cryostat System

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).

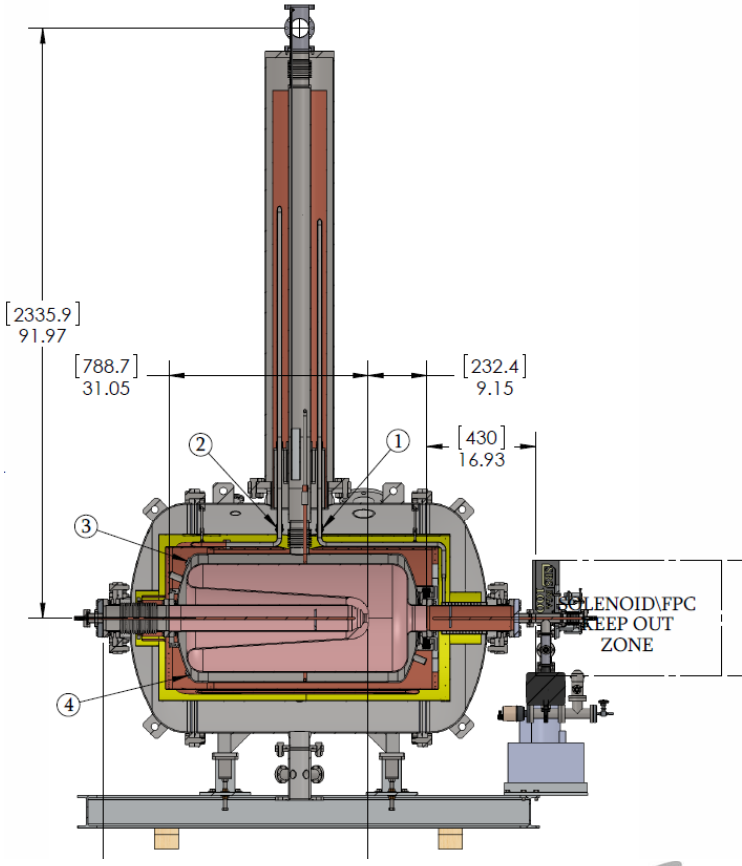
Manufacturer: Niowave

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)



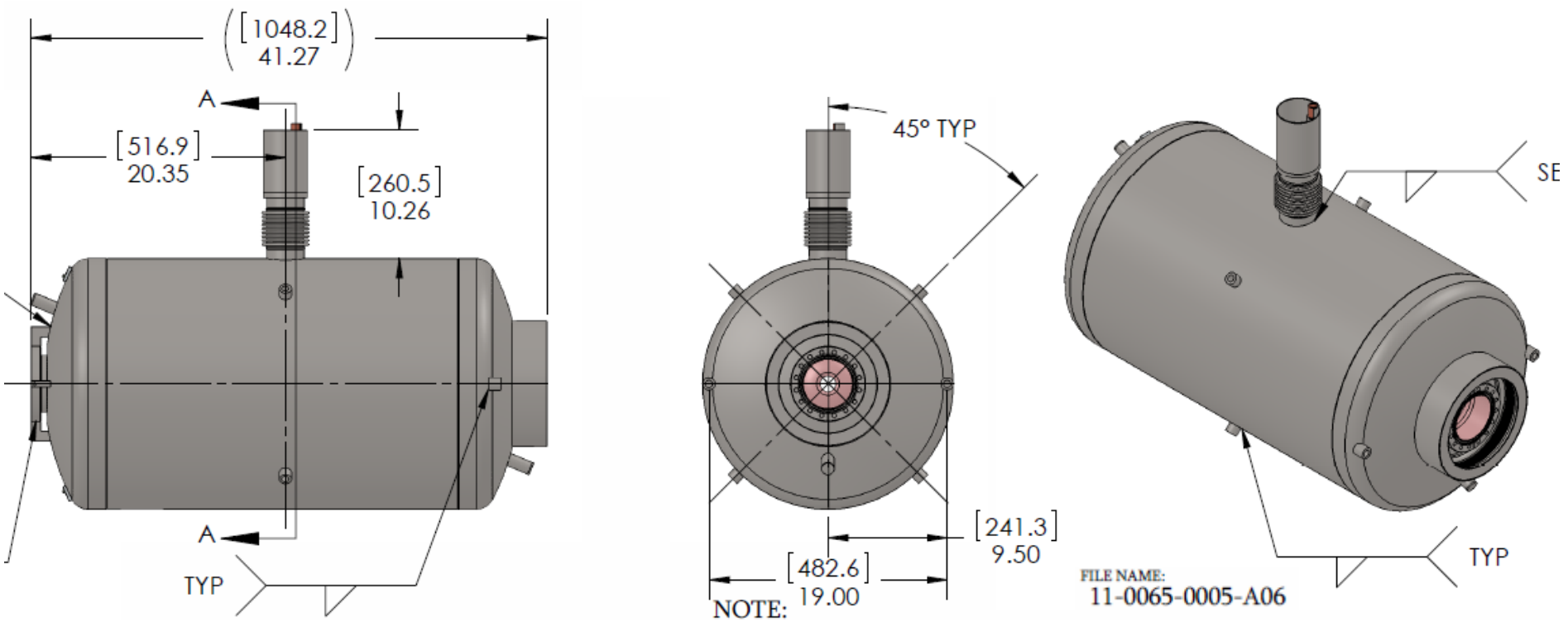
1C: 112MHz Cavity Cryostat System

SRF Cavity: Niobium

MAWP: 23 psig @ 70°F

Engineering Analysis: FEA by BNL

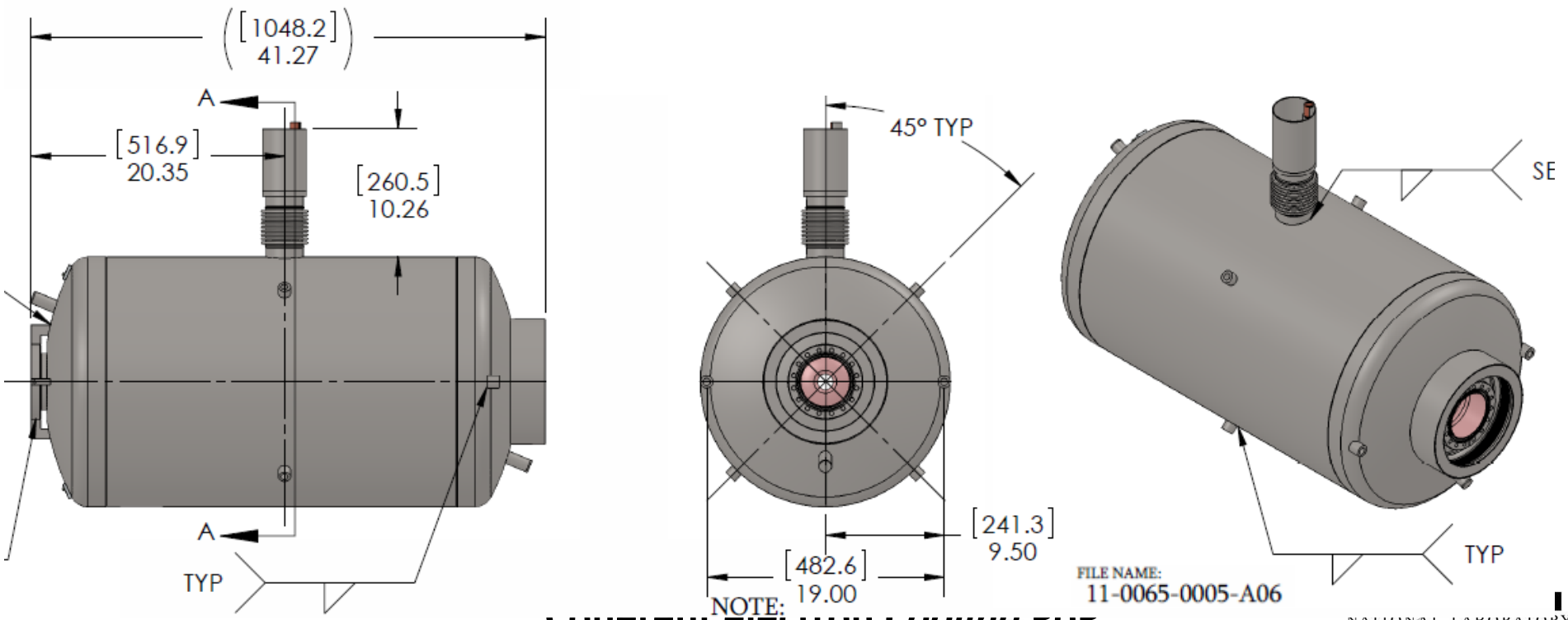
UHV Beam tube pressure relief: MDC / BS&B UHV Burst disc at 6 PSIG



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



Coherent electron cooling PoP

NATIONAL LABORATORY

1C: 112MHz Cavity Cryostat System

Insulating Vacuum Vessel: Stainless Steel 304L, 36 inch diameter x 65” long

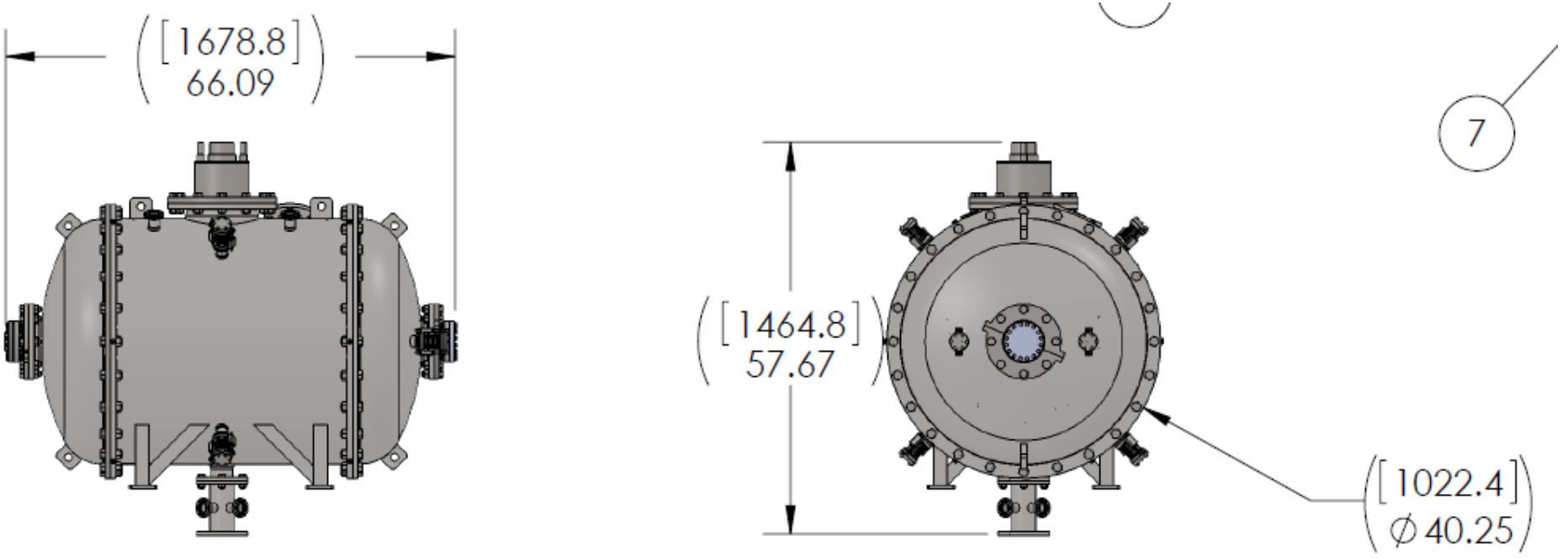
MAWP: 62 psig @ 120°F

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



1C: 112MHz Cavity Cryostat System

Internal Piping:

Helium transfer lines

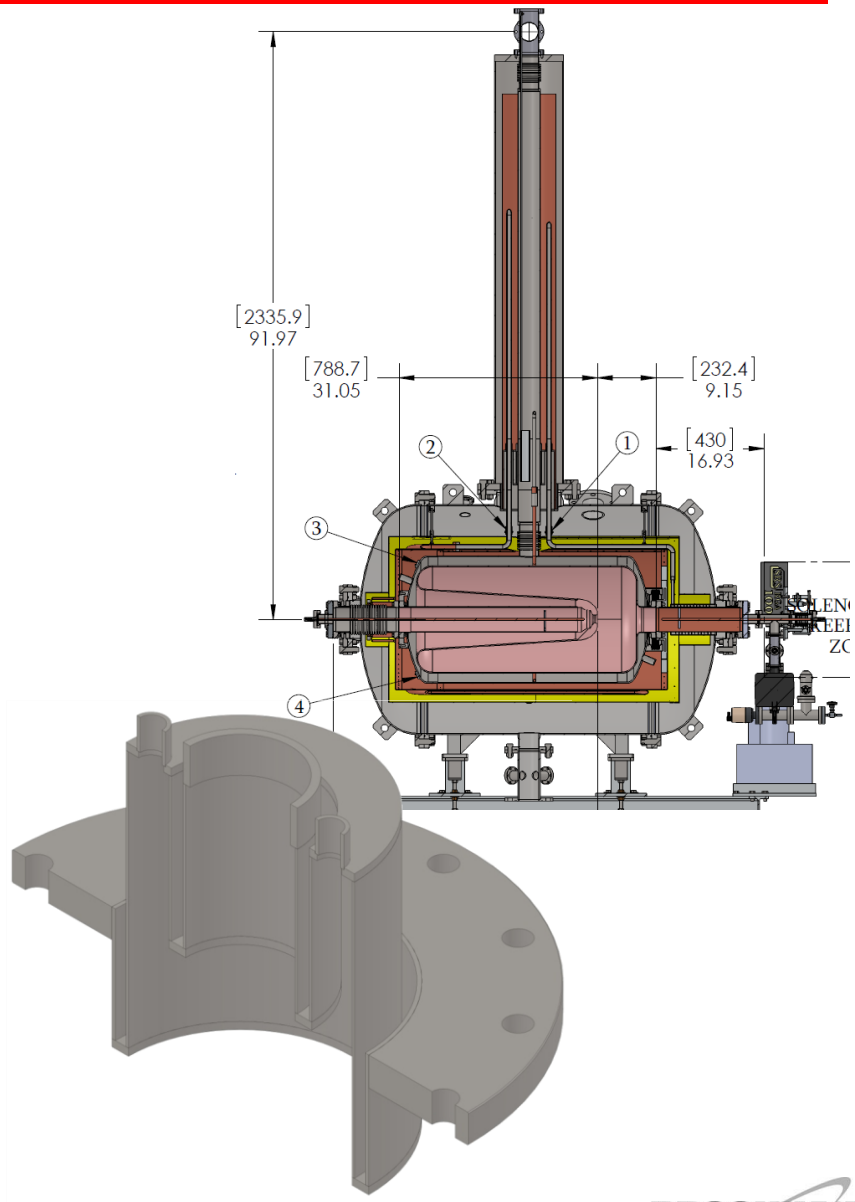
- Stainless Steel 304L
- Certified construction to ASME B31.3 piping code from vendor
- BNL to finalize piping code analysis

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

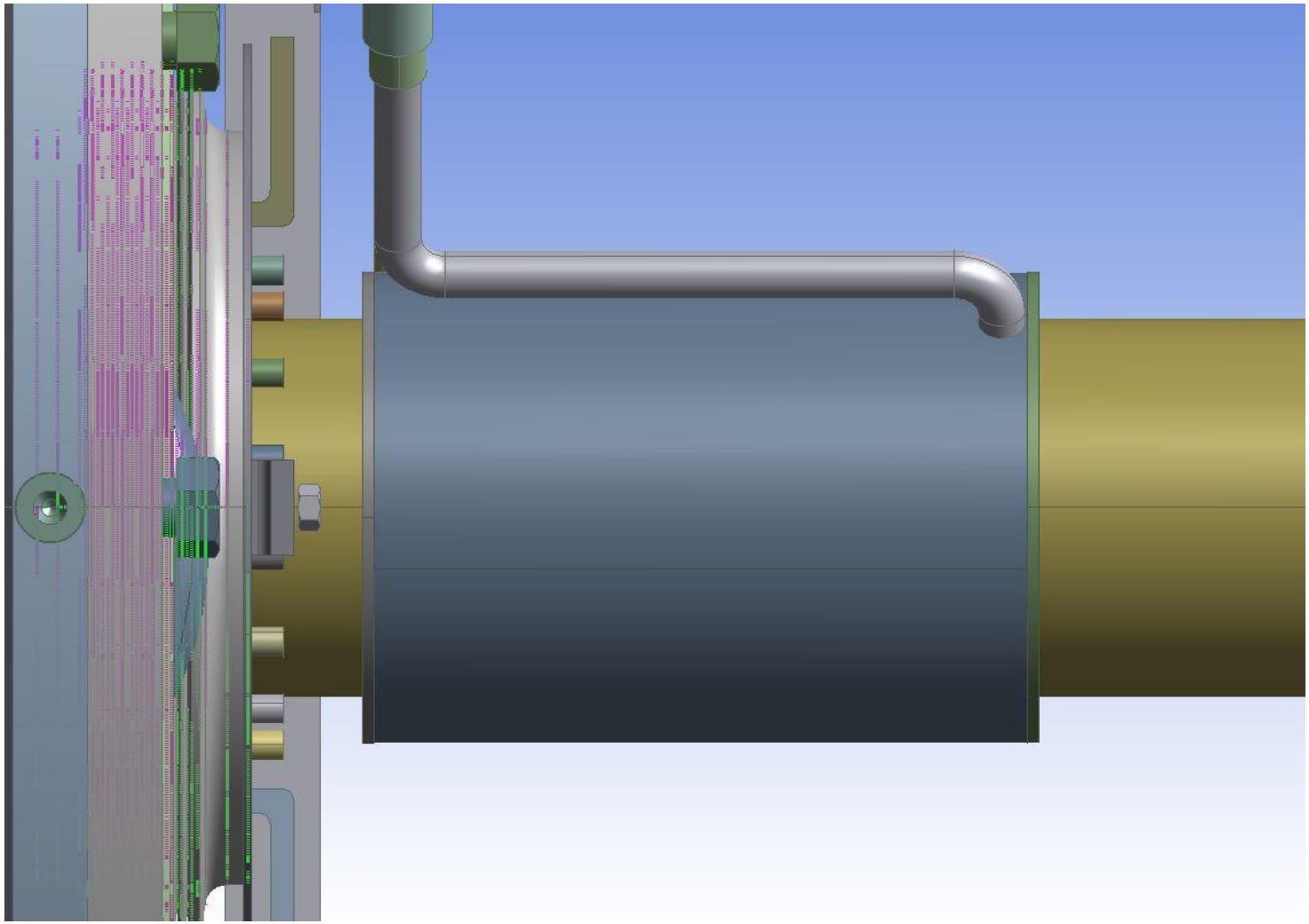


1C: 112MHz Cavity Cryostat System
Beam tube / FPC Heat Intercept

- 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

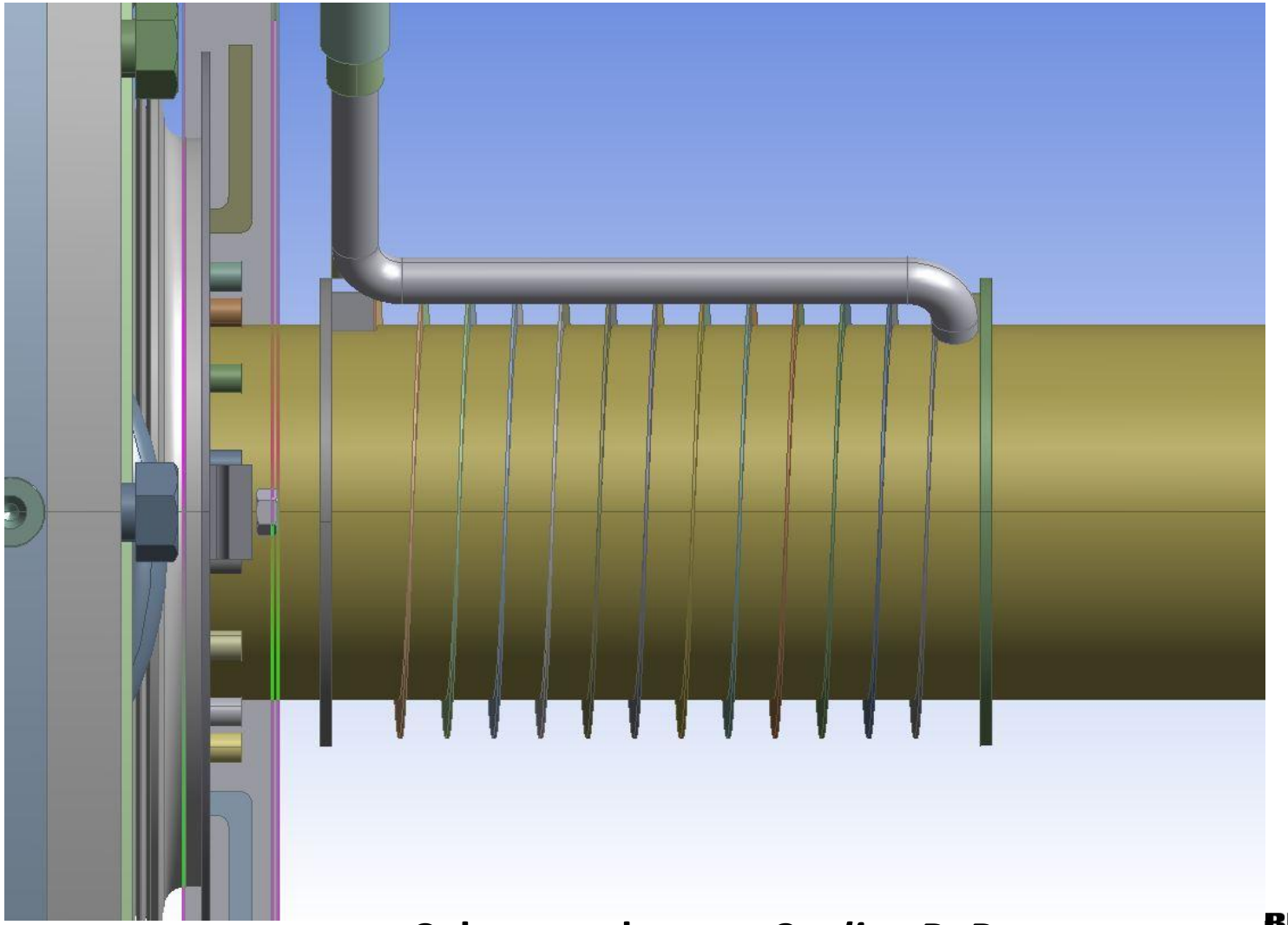
1C: 112MHz Cavity Cryostat System

Beam tube / FPC Heat Intercept



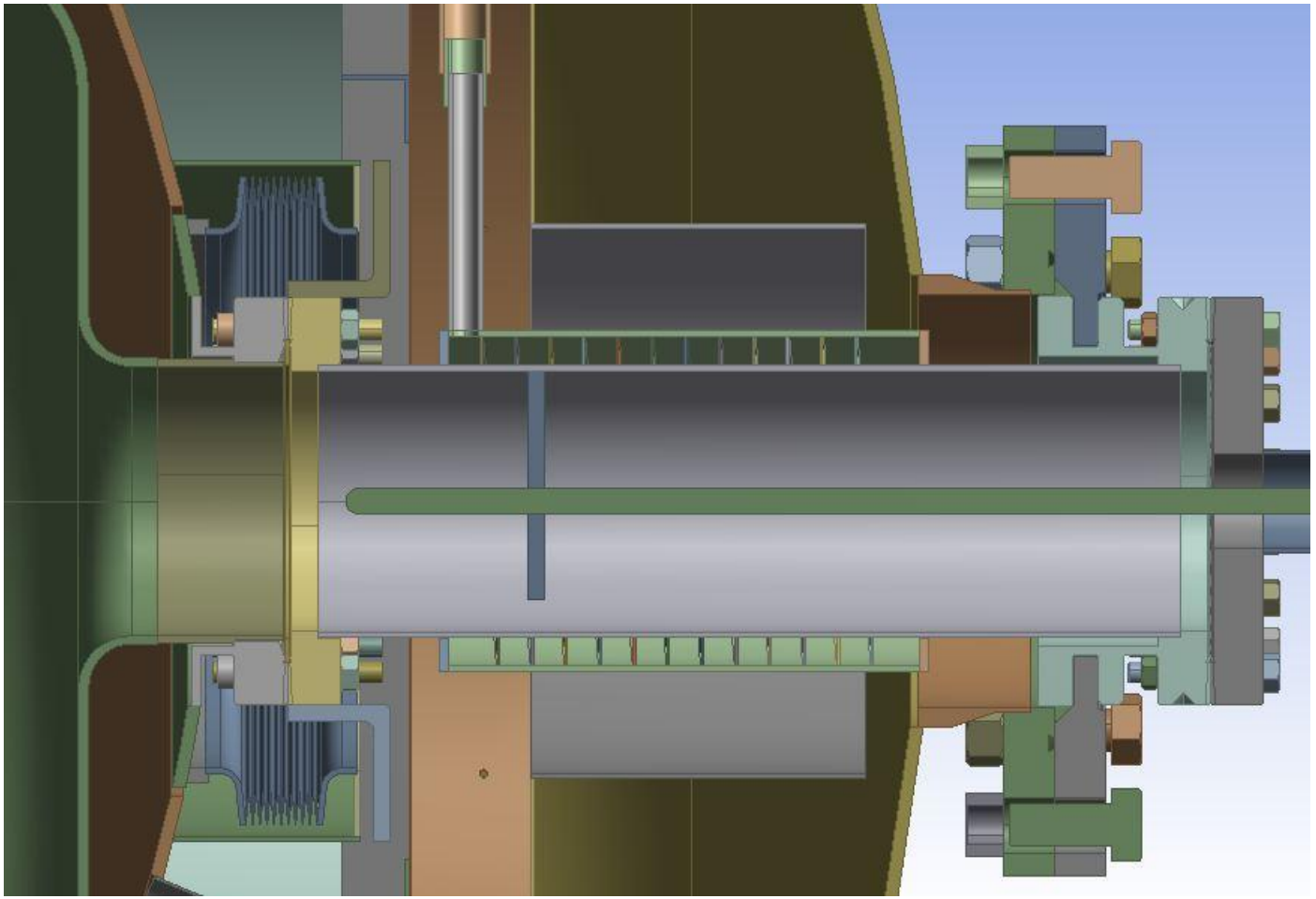
1C: 112MHz Cavity Cryostat System

Beam tube / FPC Heat Intercept



1C: 112MHz Cavity Cryostat System

Beam tube / FPC Heat Intercept



1C: 112MHz Cavity Cryostat System

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).

1D: Cryogenic Transfer Lines

Description ASME B31.3	Size	Design Pressure	Design Temperature	Manufacturing
From RHIC Interface separator to 4.5K QHS Cryostat	½ x 2 VJ SS304/304L	Full vacuum to 290 psia	4K -120°F	Vendor
Interconnect multi lines between 4.5K QHS Cryostat and 112MHz Cavity Cryostat. Two VJ bundles	½" Supply ½" Fill 2" Return ½" Shields SS304/304L	Full vacuum to 45 psia	4K -120°F	Vendor

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

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

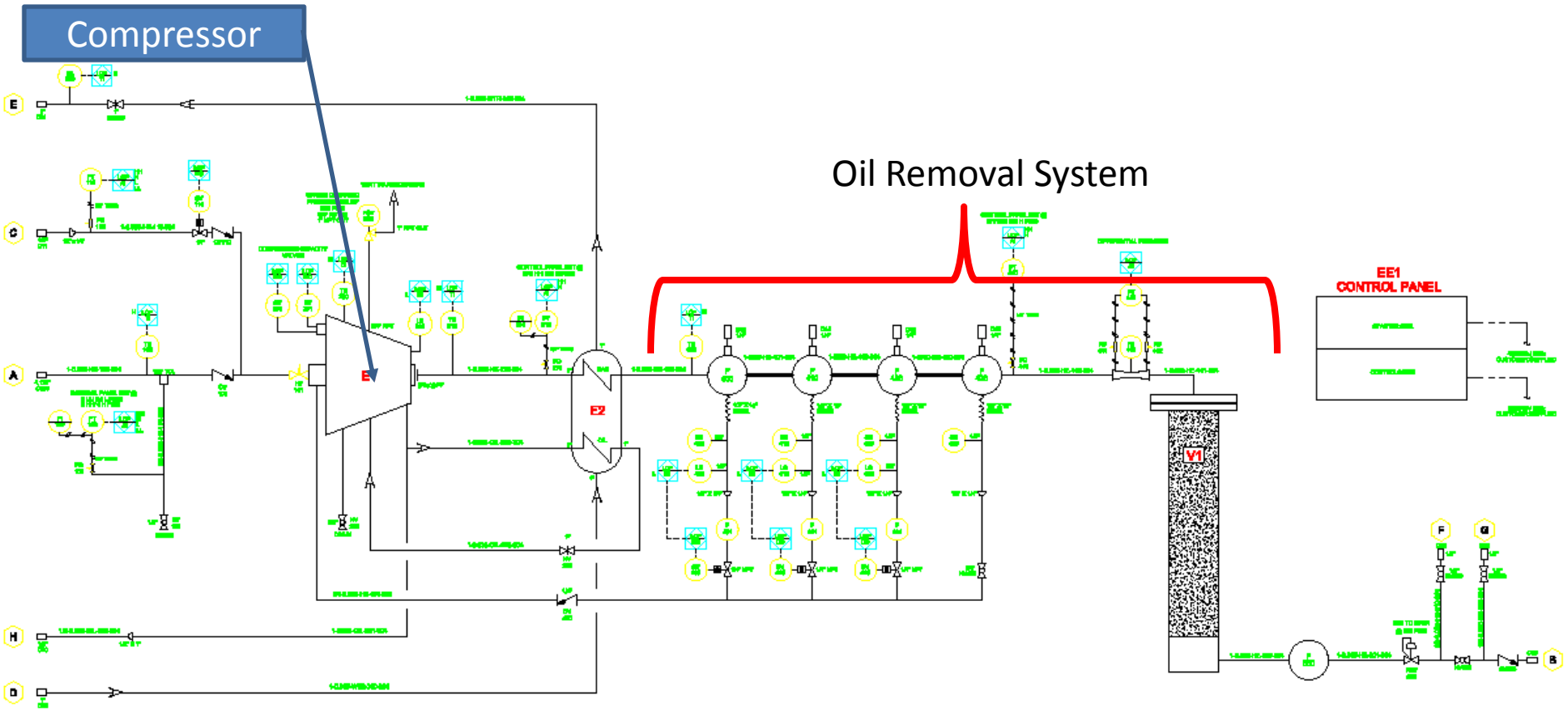
Vibration isolators legs:

To isolate compressor from Foundation

Braided Flex lines:

To isolate compressor from piping

1E: P&ID Small Helium Compressor



1E: Small Helium Compressor

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

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

1E: Small He Compressor: Panels UL 508A LISTING

Manufactured by:
Horlick Co., Inc.
91 Pacella Park Dr.
Randolph, MA 02368

TYPE 12 ENCLOSURE

Main Voltage: 480 VAC, 60HZ, 3PH
SCCR: 25KAIC
Package FLA: 250 Amps

Motor: 480VAC, 3PH, 60Hz
Horsepower: 125
Full Load Amps: 156A

Project: Brookhaven 480V Power Panel
DWG NO. 22253

Manufactured by:
Horlick Co., Inc.
91 Pacella Park Dr.
Randolph, MA 02368

TYPE 12 ENCLOSURE

Main Voltage: 480 VAC, 60HZ, 3PH
SCCR: 25KAIC
Package FLA: 250 Amps

Motor: 480VAC, 3PH, 60Hz
Horsepower: 125
Full Load Amps: 156A

Project: Brookhaven 480V Power Panel
DWG NO. 22253

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 6.2 lb in

Circuit Breakers
1492-SP 21-27 lb in

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 6.2 lb in

Circuit Breakers
1492-SP 21-27 lb in

Torque Requirements

Terminals
1492-J4 or eqv. 4.8-8.9 lb in
1492-JD3 or eqv. 3.5-5.3 lb in
1492-WTF3 or eqv. 4.2-4.6 lb in
1492-EA35 or eqv. 4.4-7.1 lb in
1492-JG4 or eqv. 4.4-8.9 lb in
Jumpers or eqv. 6.2 lb in

Circuit Breaker
G Frame
30 - 40 lb. In.

Soft Starter
30 lb. In.

c UL US LISTED
ENCLOSED INDUSTRIAL CONTROL PANEL
No. CG - 033712

Torque Requirements

Terminals
1492-J4 or eqv. 4.8-8.9 lb in
1492-JD3 or eqv. 3.5-5.3 lb in
1492-WTF3 or eqv. 4.2-4.6 lb in
1492-EA35 or eqv. 4.4-7.1 lb in
1492-JG4 or eqv. 4.4-8.9 lb in
Jumpers or eqv. 6.2 lb in

Circuit Breaker
G Frame
30 - 40 lb. In.

Soft Starter
30 lb. In.

c UL US LISTED
ENCLOSED INDUSTRIAL CONTROL PANEL
No. CG - 033713

Manufactured by:
Horlick Co., Inc.
91 Pacella Park Dr.
Randolph, MA 02368

TYPE 12 ENCLOSURE

Control Voltage: 120VAC, 60HZ, 1PH

Project: Brookhaven PLC Panel
WIRING PRINT: 22253-PLC

c UL US LISTED
ENCLOSED INDUSTRIAL CONTROL PANEL
No. CF - 192780

Manufactured by:
Horlick Co., Inc.
91 Pacella Park Dr.
Randolph, MA 02368

TYPE 12 ENCLOSURE

Control Voltage: 120VAC, 60HZ, 1PH

Project: Brookhaven PLC Panel
WIRING PRINT: 22253-PLC

c UL US LISTED
ENCLOSED INDUSTRIAL CONTROL PANEL
No. CG - 033711

1F: WARM Lines & RELIEF Line

WARM LINES

Description ASME B31.3	Size	Design Pressure	Design Temperature	Manufacturing
1 atm Return line from 4.5K QHS	½ x 2 VJ SS304/304L	Full vacuum to 50 psig	-20°F -120°F	Vendor
1 atm manifold Vacuum pump discharge to 18 g/s He compressor	4" SS304/304L	Full vacuum to 50 psig	-20°F -120°F	BNL / Central shop or Vendor
16 atm supply to WR (RHIC Return) header	1½" SS304/304L	Full vacuum to 300 psig	-20°F -120°F	BNL / Central shop or Vendor

RELIEF LINES

		Design Pressure	Design Temperature	Manufacturing
Relief header for 18 g/s compressor	2" NPS SS304/304L	150 psig	-20°F -120°F	BNL / Central shop or Vendor
Relief header for 1 atm manifold Vacuum pumps discharges to 18 g/s He compressor	4" NPS Copper SS304/304L	15 psig	-20°F -120°F	BNL / Central shop or Vendor

1G: Controls & Power

EQUIPMENT	LOCATION		
Quantum PLC Chassis & Rack	1002B building	120 VAC, 1-phase, 150W	
28 Volt power supplies: 4-20mA	1002B building	120 VAC, 1-phase, 1 kW	
Lakeshore 218S	1002B building	120 VAC, 1-phase, 100W	
AMI or Cryomagnetics Controller	1002B building	120 VAC, 1-phase, 200W	
Load heaters for 112MHz and QHS	112 MHz and QHS cryostats	120 VAC, 1-phase, 100W	

POWER

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

Phase 2 – 2K system

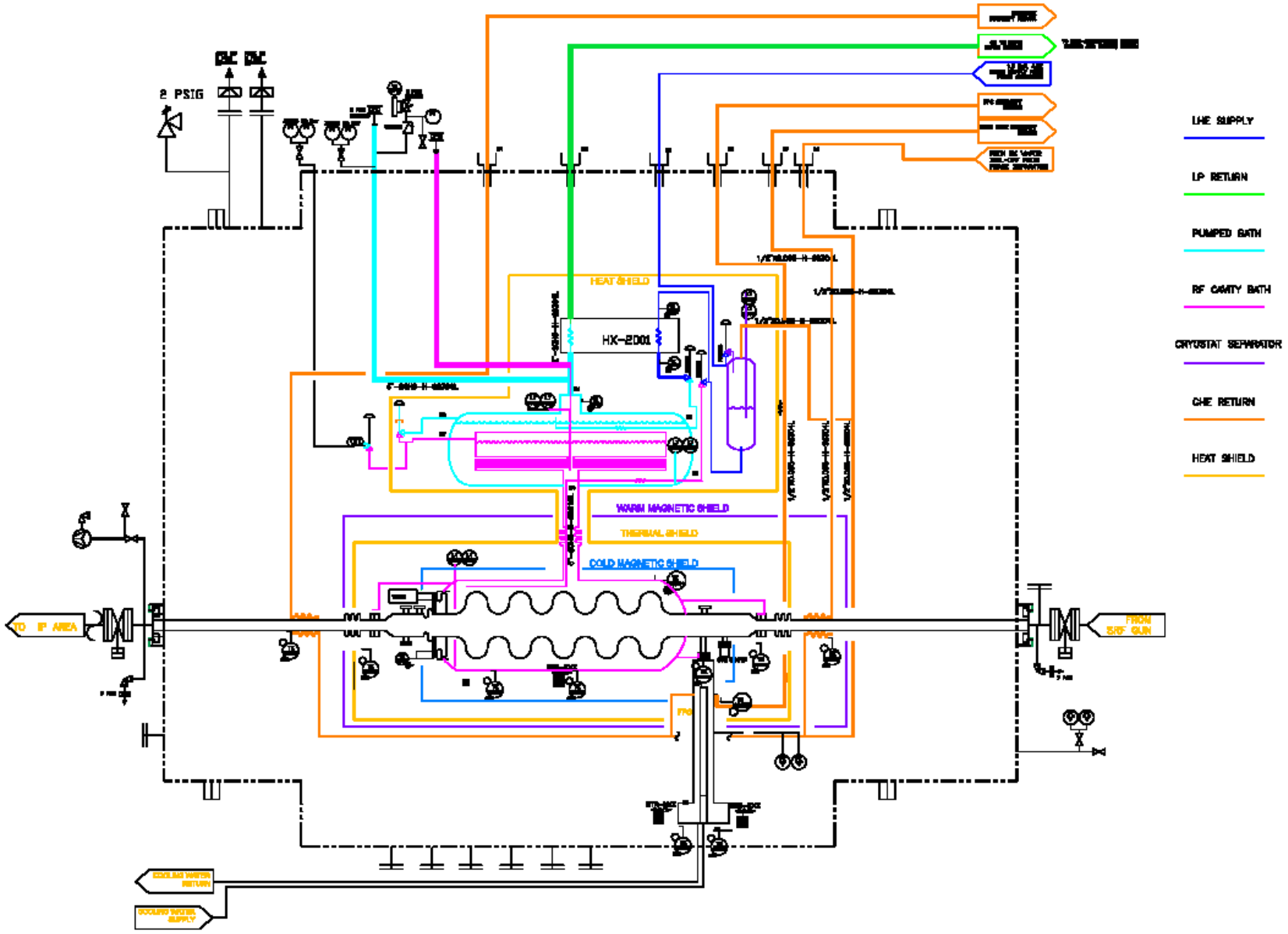
Phase 2: SRF 5-cell with 2K Cryogenic System

- 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

2A: CRYOGENIC SUPPLY

Description	Size	Design Pressure	Design Temperature	Manufacturing
From RHIC Interface separator to 2K 704MHz Cavity Cryostat	½ x 2 VJ	Full vacuum to 290 psia	4K -120°F	Vendor

2B: 704 MHz Cryogenic System



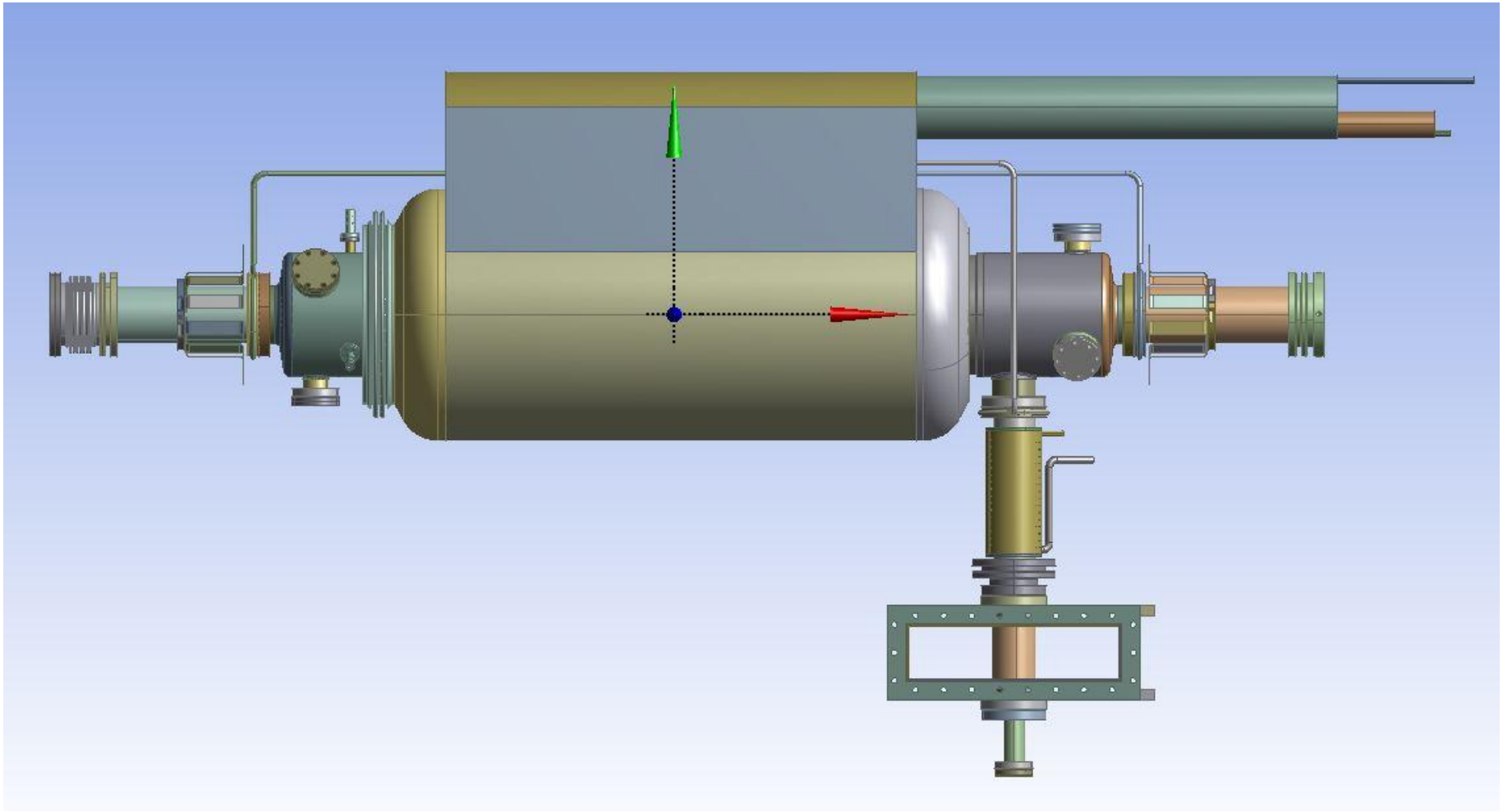
Coherent electron *Cooling* PoP

2B: 704 MHz Cavity Cryostat System

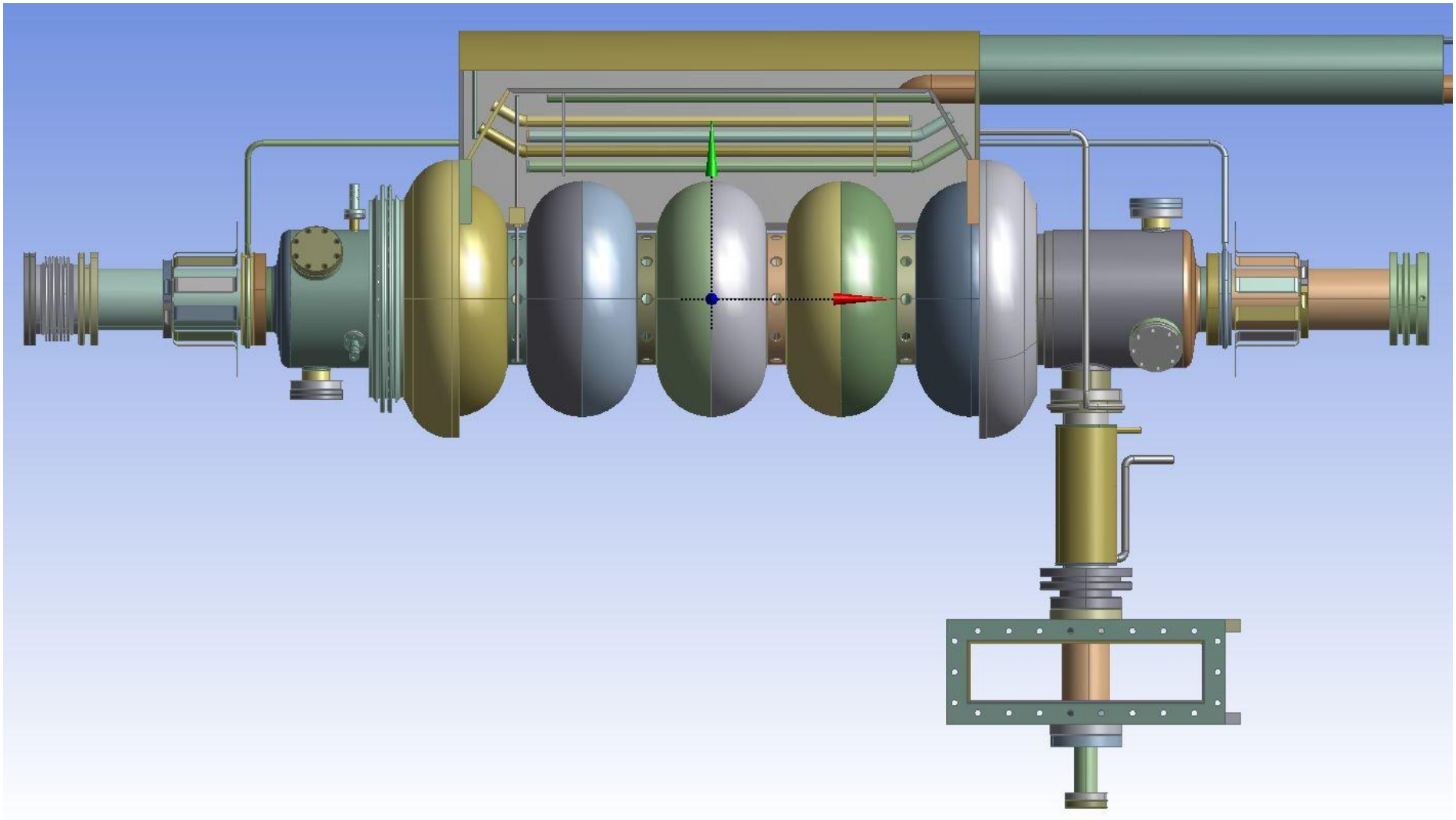
Main Components

- 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

2B: 704 MHz Cavity Cryostat System



2B: 704 MHz Cavity Cryostat System



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

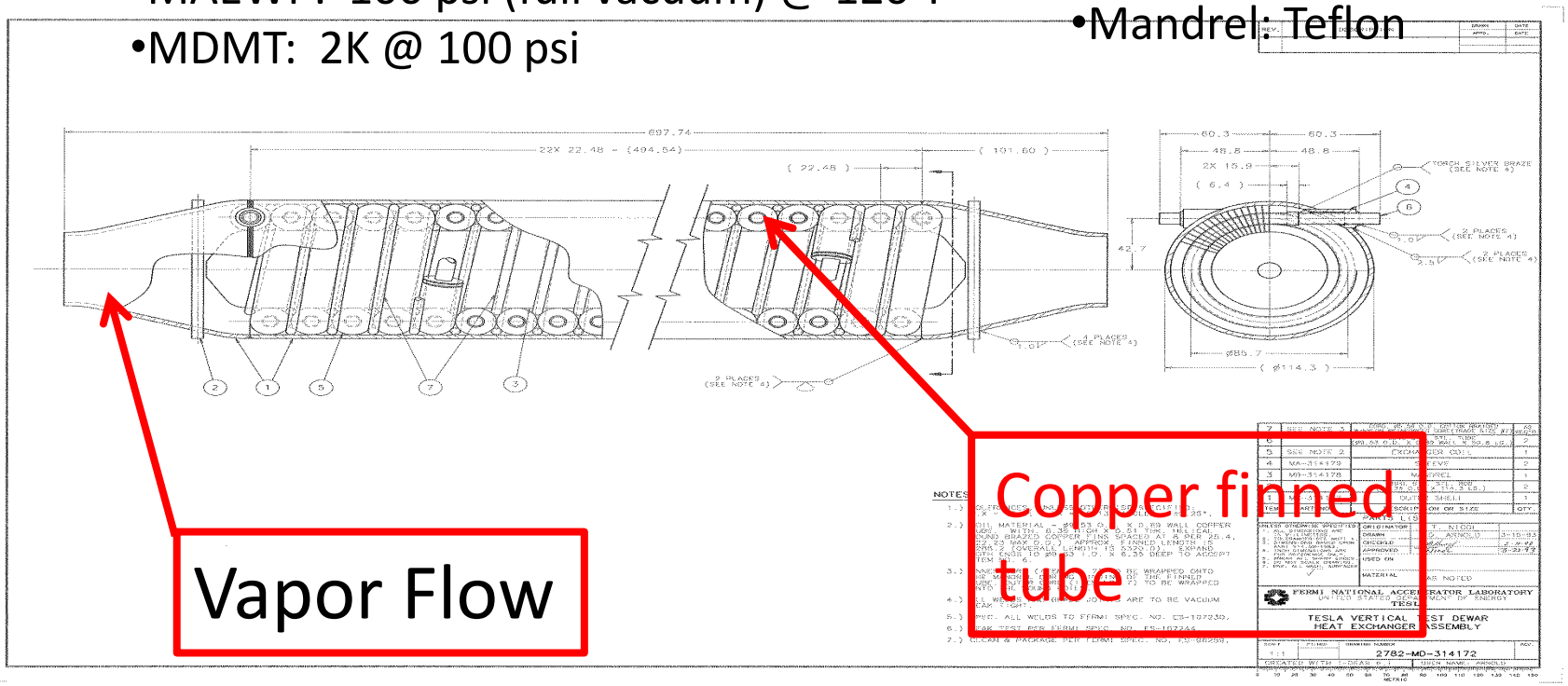
2B: 704 MHz Cavity Cryostat System

- **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

2B: 704 MHz Cryogenic System
Counter-flow Heat Exchanger

- Tube side:
  - 3/8” x0.030” 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

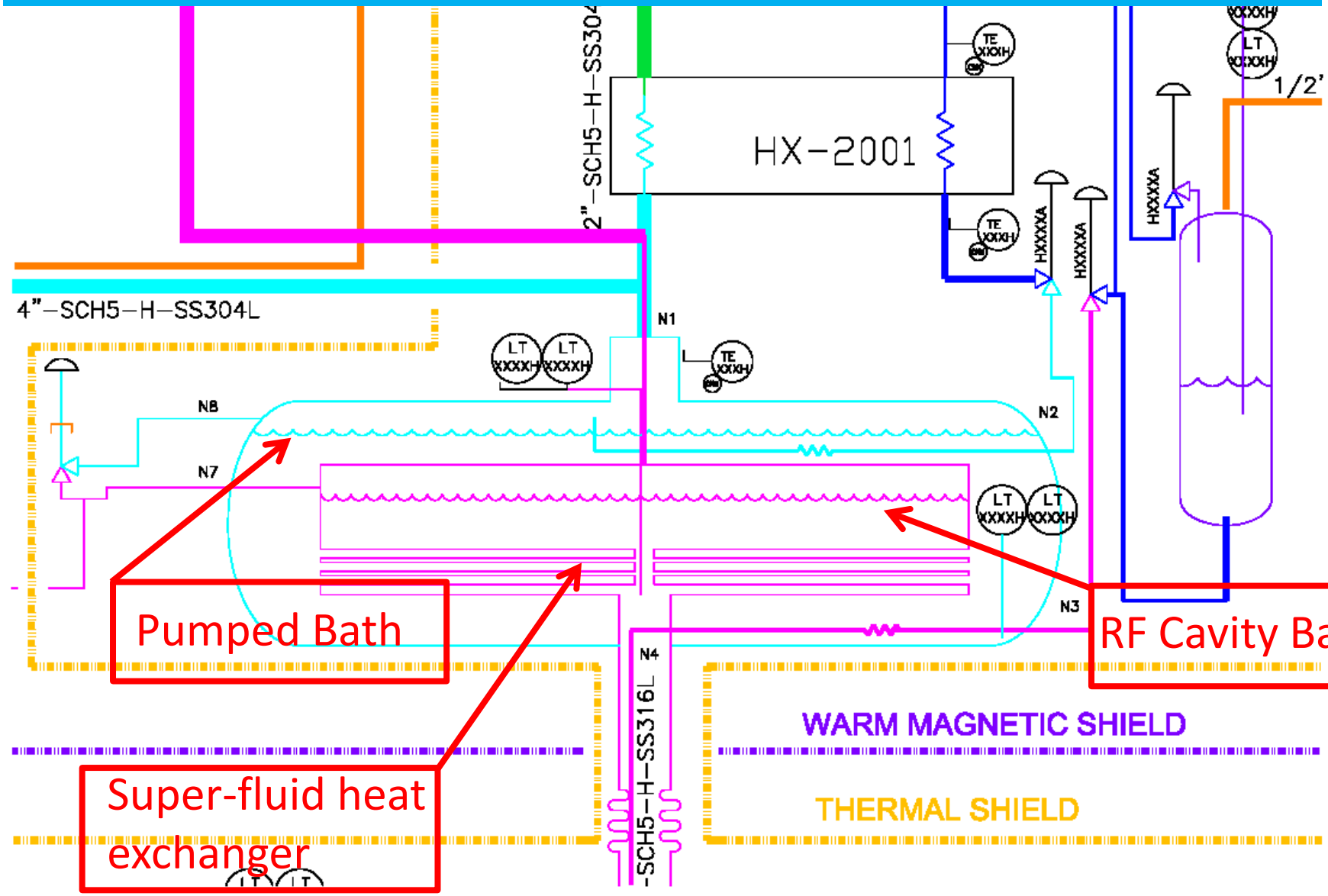


2B: 704 MHz Cryogenic System
Counter-flow Heat Exchanger

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



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

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
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

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

2C: Return transfer line to heating system

Description	Size	Design Pressure	Design Temperature	Manufacturing
18 mbar to 1 atm Return line from 704MHz Cryostat to heater	2½ x 4 VJ	Full vacuum to 50 psig	4K -120°F	Vendor

2E: Warm Return Piping System

	Size	Design Pressure	Design Temperature	Manufacturing
18 mbar to 1 atm Return line from Return Heater to vacuum pumps	8 NPS	FULL VACUUM to 50 psig	-20°F -120°F	BNL / Central shop or Vendor

2D: 18mbar Vapor Return Electric Heating System

RETURN HEATER & HOUSING

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

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

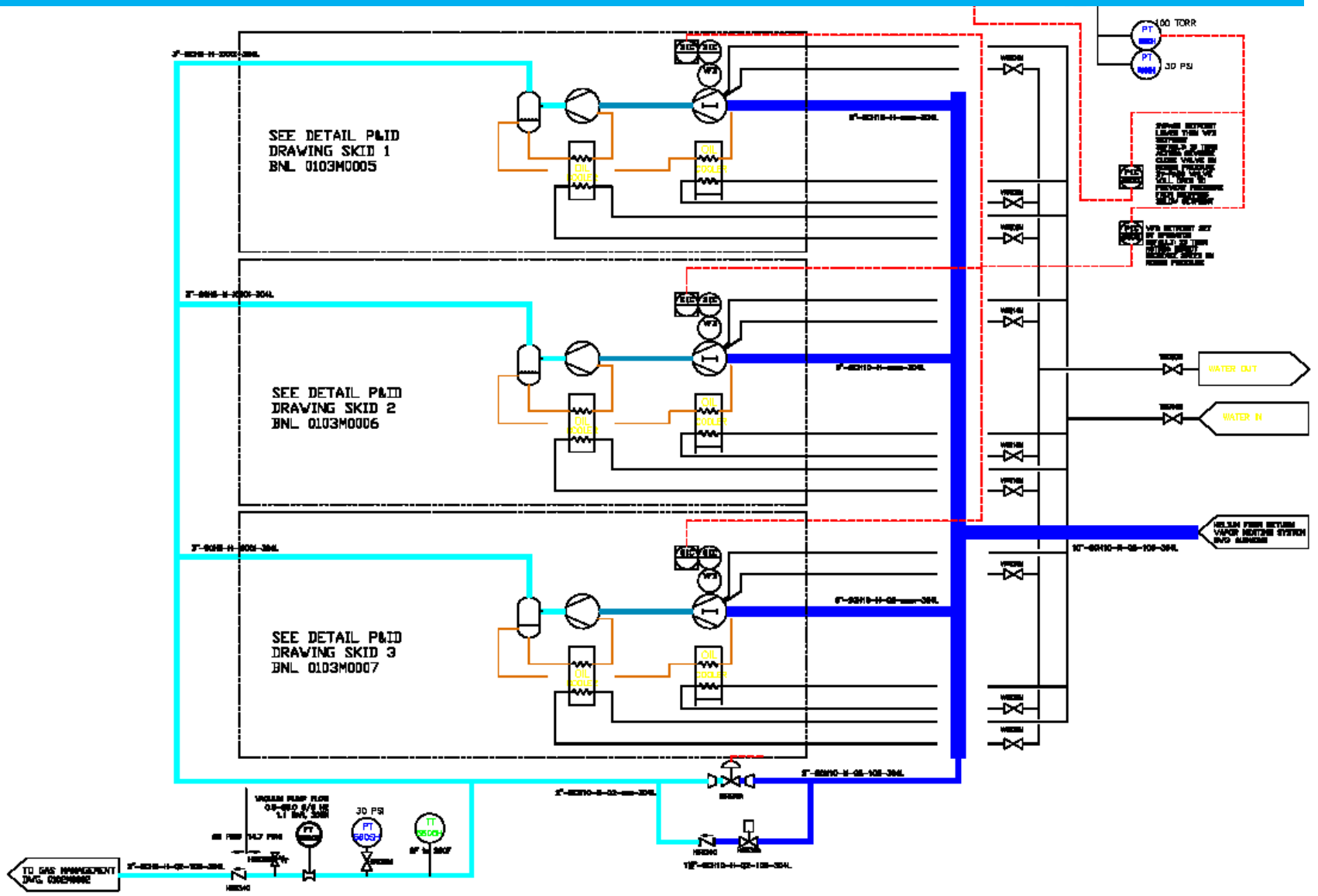
‘ 13. Are there any engineering controls or Personal Protective Equipment (PPE) required (i.e., ventilation, fume hoods, interlocks, HEPA filters/vacuum cleaners, respirators)? Yes:

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).

2F: Vacuum Pumping System



Coherent electron *Cooling* PoP

2F: Vacuum Pumping System

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 th 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

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

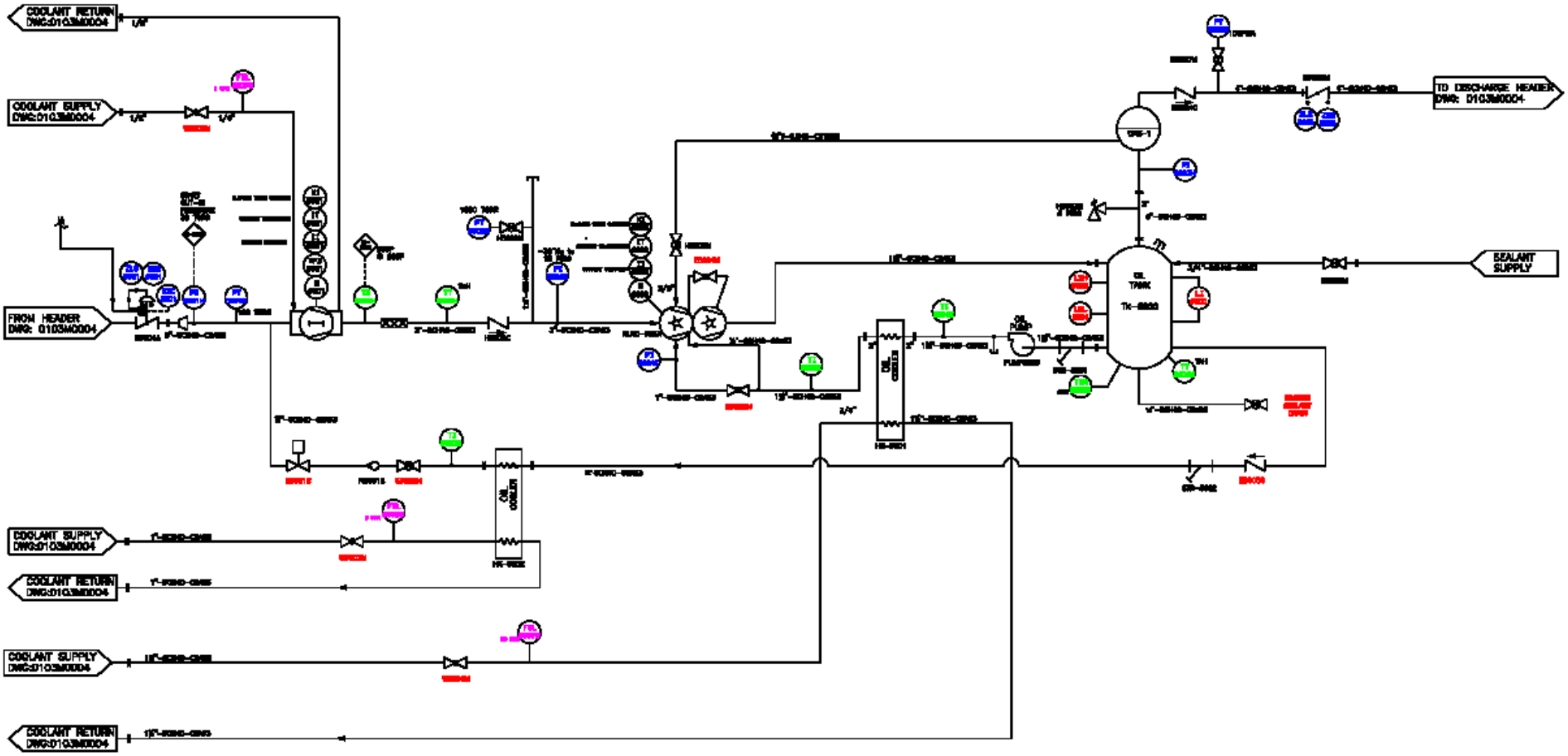
SKID NOISE:

>80 dB at 3 ft.

Survey when in operation

Requires double hearing protection

2F: Vacuum Pumping System P&ID



2F: Vacuum Pumping System

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

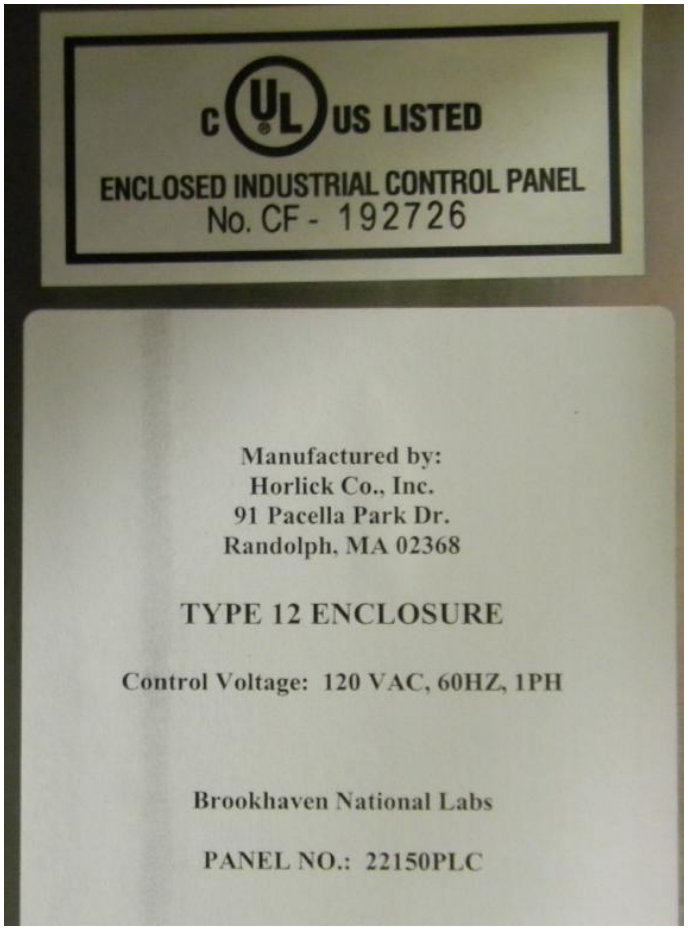
Low oil level switch.

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 6.2 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

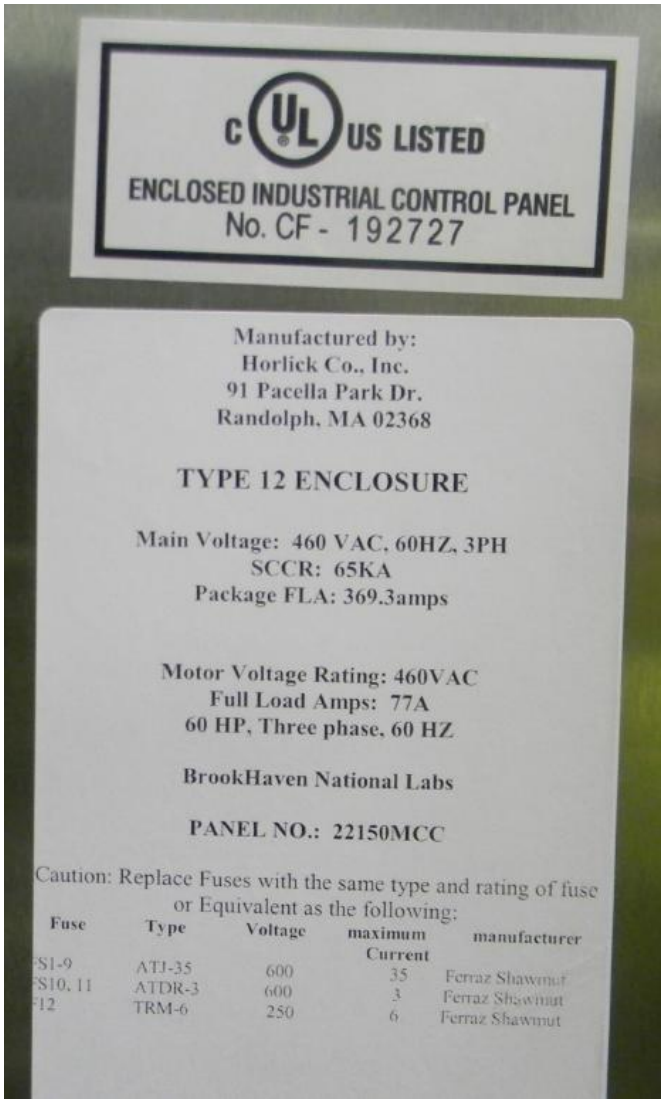
PF40 4-4.7 lb in control
PF40 26-33lb.in power

Relays

Base 7 lb in
IS Barrier 7 lb in

PLC Cards

1746 series 8 lb in



2G: Controls & Power

EQUIPMENT	LOCATION		
Quantum PLC Chassis & Rack	1002B building	120 VAC, 1-phase	
28 Volt power supplies: 4-20mA	1002B building	120 VAC, 1-phase	
Lakeshore 218S	1002B building	120 VAC, 1-phase	
AMI or Cryomagnetics Controller	1002B building	120 VAC, 1-phase	
Load heaters for 112MHz and QHS	112 MHz and QHS cryostats	120 VAC, 1-phase	

POWER

EQUIPMENT	LOCATION	
MCC, Tuthill vacuum skids	1002A building, mezzanie	480 VAC, 3-phase, 100kW, 369 FLA
PLC Panel, Tuthill vacuum skids	1002A building, floor level	120 VAC, 1-phase, 2 kW