CMTF Cryogenics

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Outline

- CMTF cryogenic system scope
- Goals
- Key functional requirements
- Conceptual layout
- Cryoplant
- Current status
- Summary

Scope

The CMTF cryogenic system includes:

- Cryogenic plant
- Cryogenic distribution system
- Ancillary systems (purification system, cryogenic storage, etc.)

Goals

- Support operation of superconducting components of:
  - Cryomodule Test Stand (CMTS)
  - Project X Injector Experiment (PIXE)
- CMTS is operational in Q1 FY16

Key Functional Requirements

- The cryogenic distribution system will be designed to meet the requirements of PXIE and CMTS
- Superfluid cryogenic plant will be used to support both PIXE and CMTS operation
- PXIE consists of the following superconducting elements: a 162.5 MHz Halfwave Resonator (HWR) cryomodule and a 325 MHz Single Spoke Resonator (SSR1) cryomodule operating in CW mode

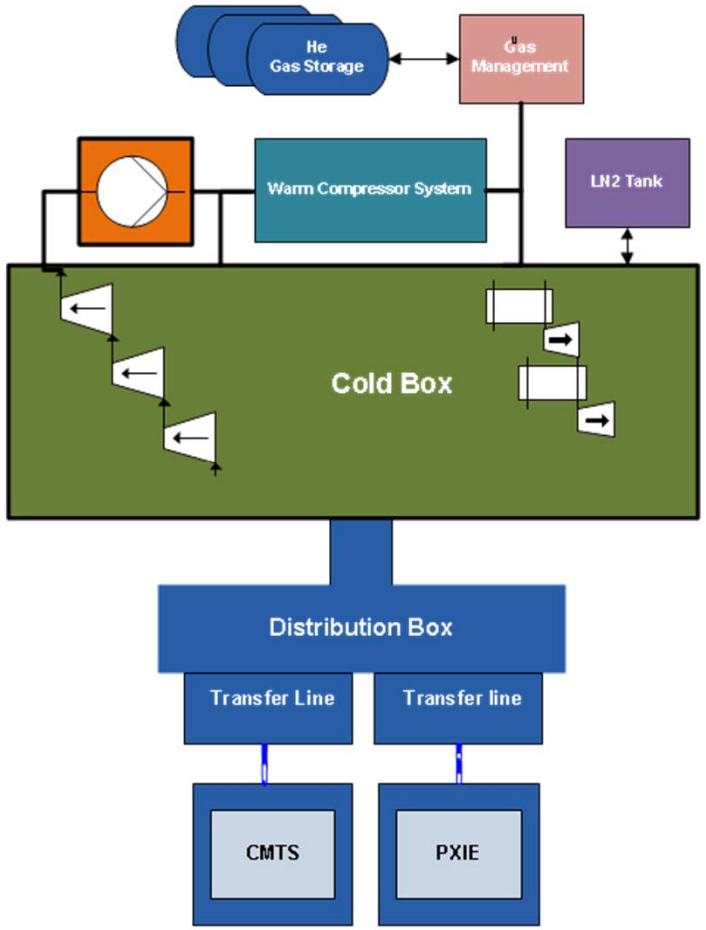
Key Functional Requirements

- PXIE
  - Provide for full segmentation of the Linac
  - Cover all possible operating scenarios
  - Support cryogenic loads at various temperature levels
  - Cope with the load fluctuations
  - Maintain stable pressure to minimize microphonics
  - Reduce system perturbations during fault conditions
  - Rapid cool-down and warm-up of cryomodules

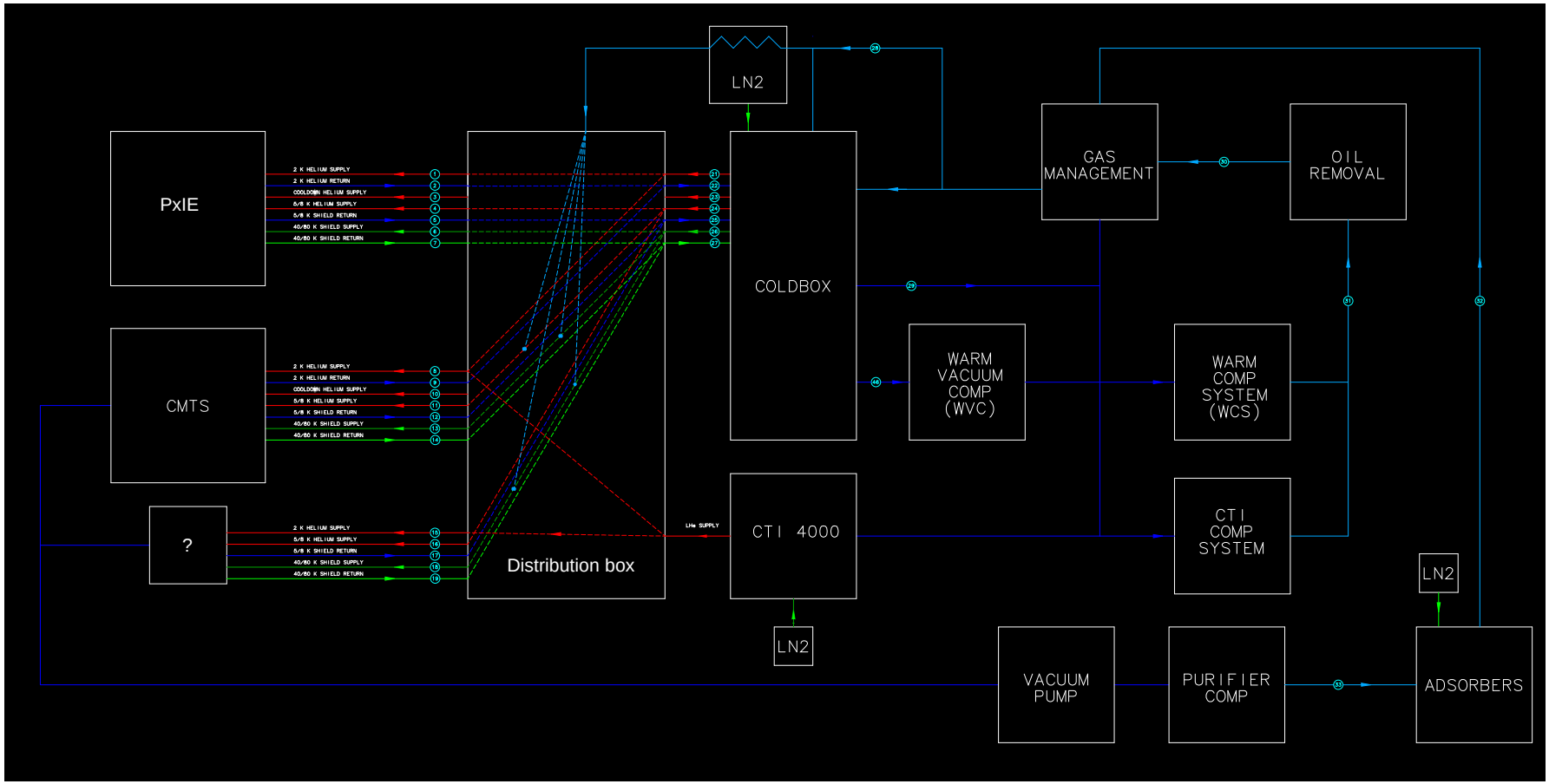
Key Functional Requirements

- CMTS
  - CMTS will be used to test one LCLS–II cryomodules (the CM) at a time
  - The CM will have flanged connections for each circuit
  - The CM has cooldown speed constraints
  - Support up to 200 W heat load to the CM cavity circuit
  - Heat Load measurements
    - 2K, 5/8 K and 40/80 K

Conceptual layout



Cryogenic System Diagram

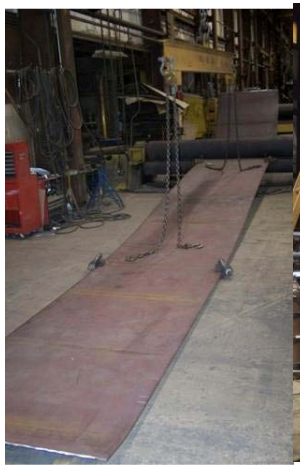


Compressors

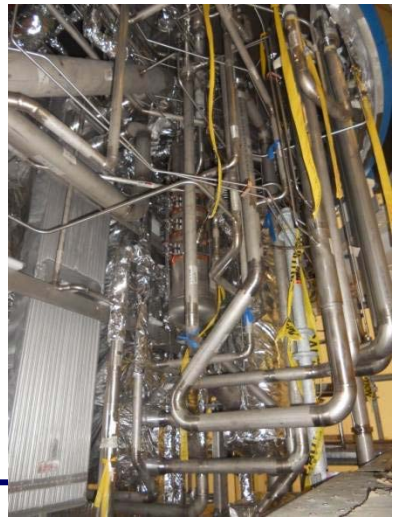
Helium gas storage

LN2 System

FABRICATION



ASSEMBLY

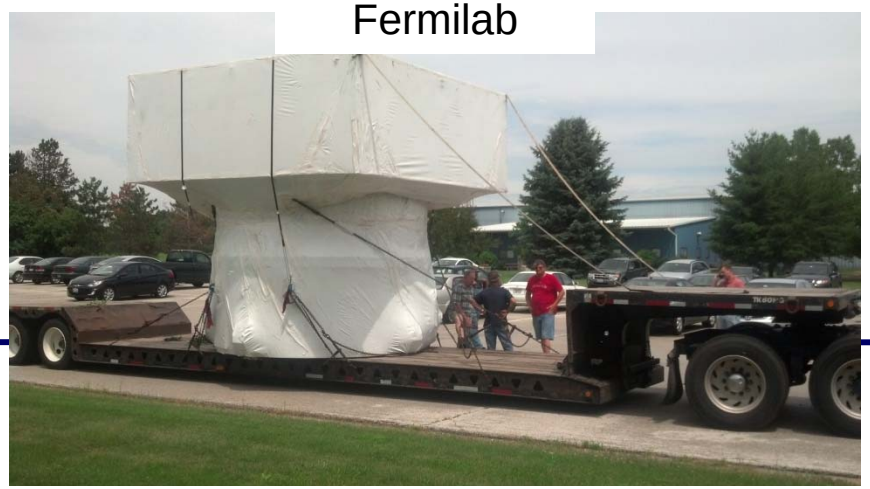


INSULATION

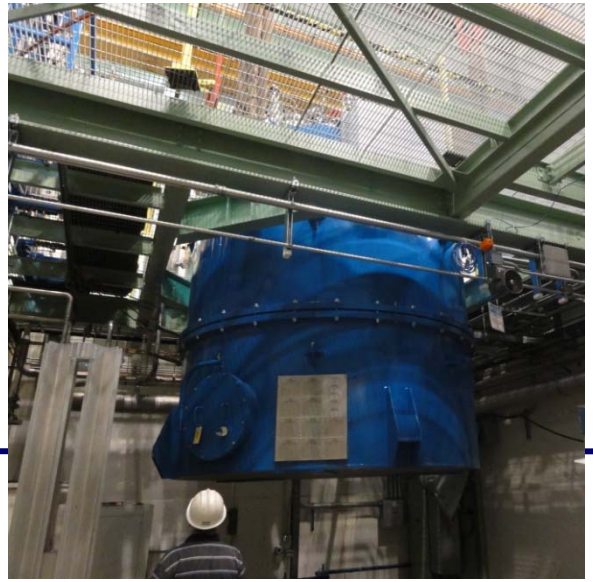
SHIPPING

Catoosa, OK

Fermilab



INSTALLATION



Commissioned

- Recently commissioned superfluid refrigerator
  - **760** [l/hr of LHe] (**4.47** K) @ **1.25** [bar]
    - or
  - **523** [W] @ 24 [mbar] (**1.91 K**) + **619** [W] @ 5/8 K + **6.1** [kW] @ 40/80 K
    - or
  - **257** [W] @ 14.8 [mbar] (**1.77 K**) + **619** [W] @ 5/8K + **6.1** [kW] @ 40/80 K
    - or
  - **221** [W] @ 12.6 [mbar] (**1.73 K**) + **619** [W] @ 5/8K + **6.1** [kW] @ 40/80 K

Performance Acceptance

- The guaranteed performance of the Cryoplant was demonstrated in a series of acceptance tests
- Key parameters were datalogged and displayed in real time for parameter verification
- Heater outputs were independently measured and verified
- Tests were witnessed by MSS and CSS Chairs, and observed by DOE FSO
- Upon completion of each acceptance test, an **Acceptance Test Certificate** was used to document the test results

Acceptance Tests

- Liquefaction mode
- 2K Mode @ Saturation pressure
- 2K Mode @ According to TS diagram
- 1.8K Mode @ Saturation pressure
- 1.8K Mode @ According to TS diagram
- Coldbox cooldown mode
- Warm Vacuum Compressor (WVC) start-up and normal shutdown
- Cold Compressor (CC) start-up and normal shutdown
- Normal plan shutdown
- CC trip
- WVC Trip
- Turbine string trip from utility outage
- Other trips shown with controls logic
- Adsorber regeneration and connection
- Emergency shutoff
- Utility outage – instrument air
- Turbine / CC replacement

Sample Test Spec

9.4 2 K Mode (Mode IV) – according to TS diagram

9.4.1 Process description

The test shall be carried in accordance to each test procedure for the individual modes and tests. During testing the plant and process data will be adapted to this load.

Testing time: 3 hours

9.4.2 Guaranteed performance items

The guaranteed performance of the helium refrigeration plant measured during the acceptance test with the test set-up at steady state conditions is:

Item	Description	Signal TAG	Value
1	Pressure 2K	PI3394-1	24±0.6 mbar
2	2K refrigeration capacity	R3193 R3395 R3396	≥500W
3	Pressure 5K to 8K	PI3196	>2.5±0.35 bar
4	5K to 8K refrigeration capacity	R3195	≥600W
5	Pressure 40K to 80K	PI3128	>3±0.35 bar
6	40K to 80K refrigeration capacity	R3146 R3149	≥5000W

9.4.3 Acceptance test certificate

The acceptance test is reported and confirmed by the attached acceptance test certificate in the section below.

The results of the acceptance performance test are documented by the acceptance test certificates and/or by the attached trend data.

Sample Acceptance Test Certificate

Test run	2 K Mode (Mode IV) – according to TS diagram											
Start date / time	2/24/14 // 8:00 AM			End date / time	2/24/14 // 11:00 AM							
Parameters	Description	TAG	Unit	Design Value	Measured Value							
					Max	Average	Min	Difference			Min total Power	
	Pressure 2K	PI3394-1	mbar	24±0.6	24.322	23.915	23.400	0,922				
	2K refrigeration capacity	R3193 ~~R3396~~ R3395	W	≥500	23153 320	R3193 313,5W	23193 308,5		23395 183.9	23396 31,2	523,6 W	
	Pressure 5K to 8K	PI3196	bar	>2.5 ± 0.35	3,24	3,16	3,10	0,14				
	Temp. 5K to 8K stability	TI3296	K	< ±0.5 K	7,30	7,20	7,10	0,20				
	5K to 8K refrigeration capacity	R3195	W	≥600		(626,2)			23195 619,2		619,2 W	
	Pressure 40K to 80K	PI3128	bar	>3 ± 0.35	16,81	16,61	16,42	0,39				
	Temp. 40K to 80K stability	TI3151	K	< ±5 K	78,03	77,40	76,69	1,33				
	40K to 80K refrigeration capacity	R3146 R3149	W	≥5000					23146 2053 W	23145 4083 W	6136 W	
Trend record attached in Annex #												
Comments	~~See separate document: Comments for test run: 2K Mode (Mode IV) - @ 2K sat. pr.~~											
Performance guarantee matched	☒ Yes				☐ No							
Acceptance participants	FNAL: 13923 N 13853 N 45941				Linde: Matthias Kocher Philipp Treite							

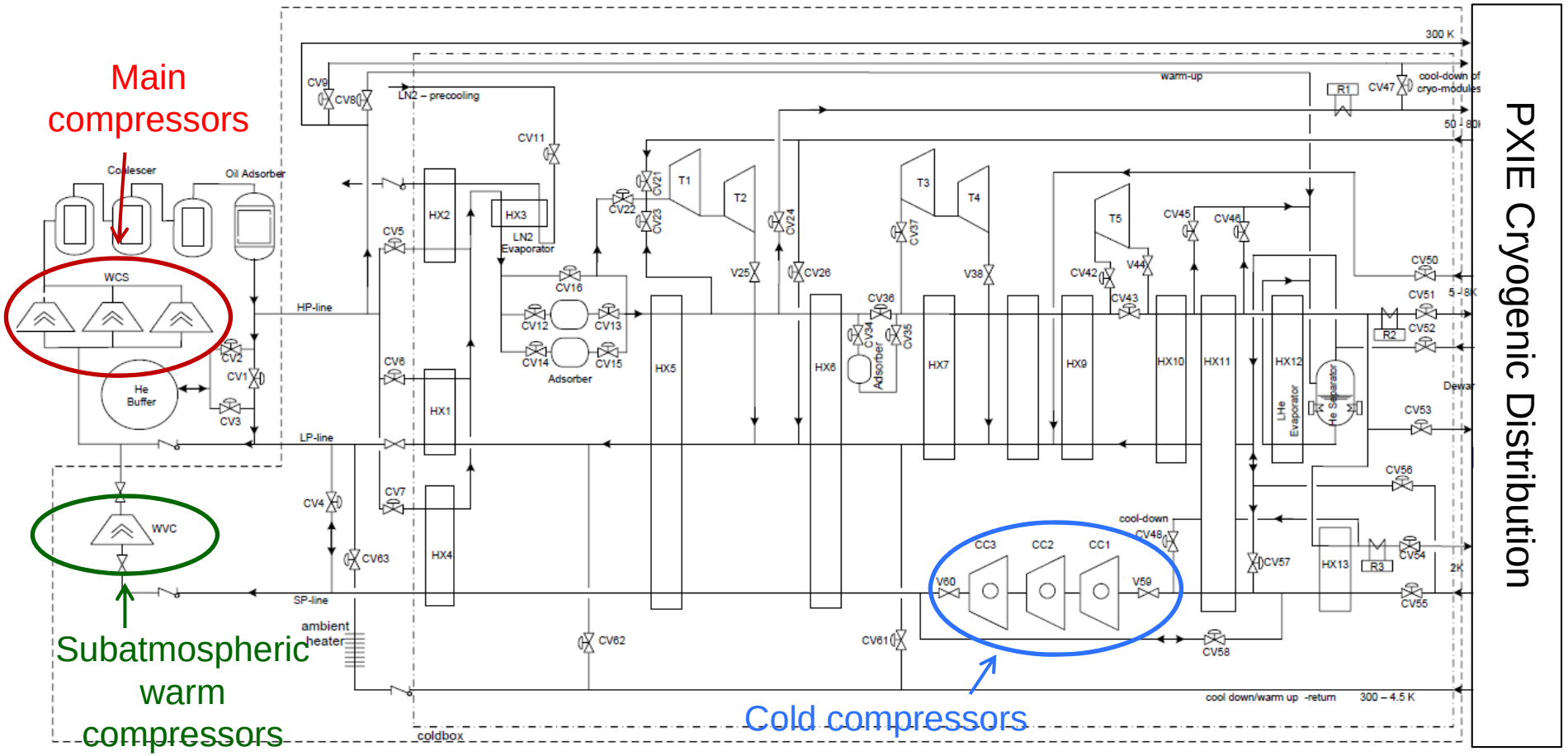
Load Output Verification

Linde SCP TS Diagram Test - 2.0 K

2/24/2014 - R. Bossert, M. Nylund

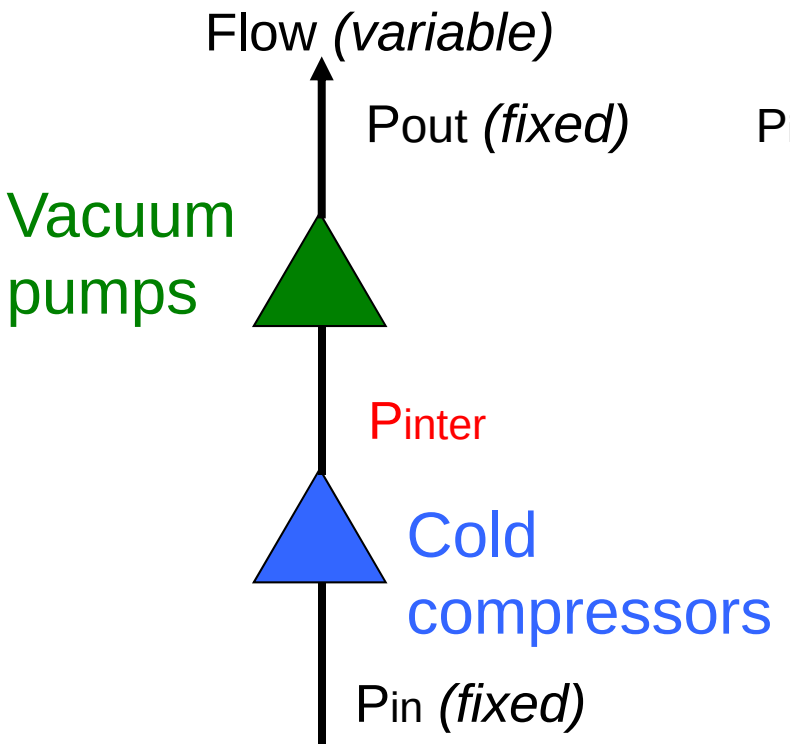
Heater No.	Measured Volts	Measured Amps	Calculated Watts	Linde setpoint	Linde readout
R3146 (3 ph)	474.3 (average)	2.5 (average)	2053.7	100%	1640 W
R3149 (3 ph)	462.3 (average)	5.1 (average)	4083.8	100%	2117 W
R3193	187/191	1.65/1.68	308.5/320	50/52%	309/320 W
R3195	240	2.58	619.2	80%	619 W
R3395	283	0.65	183.9	ON	none
R3396	340W @ 9.2% duty cycle		31.2		

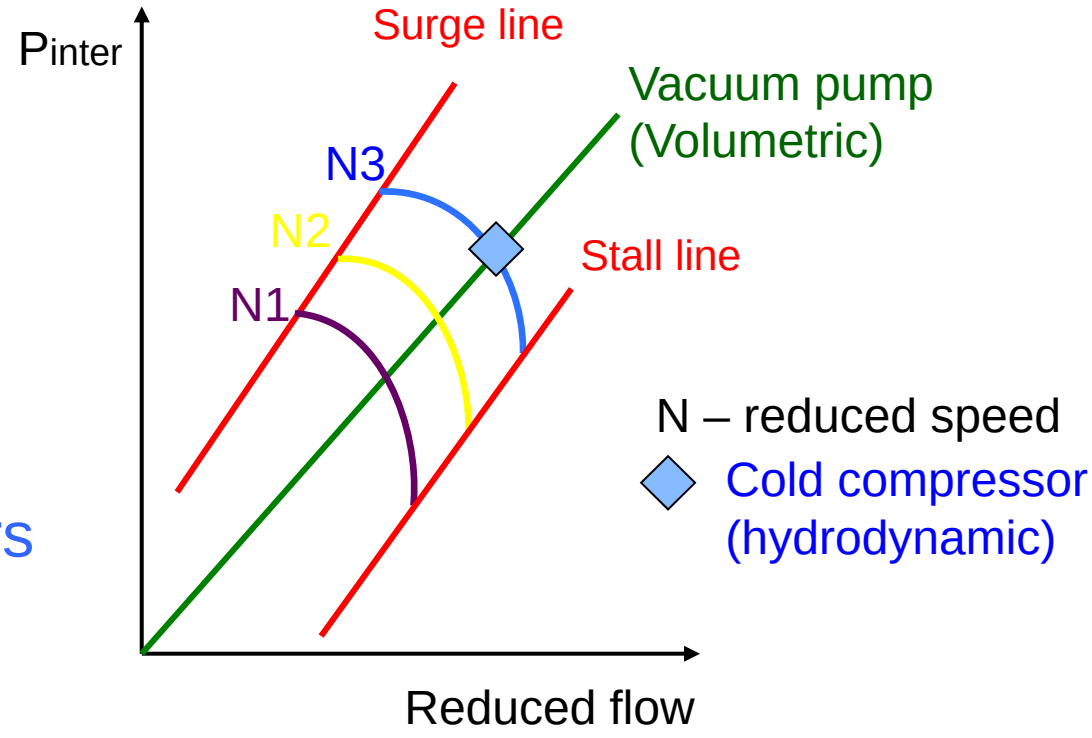
Hybrid cylce



Configuration (2)

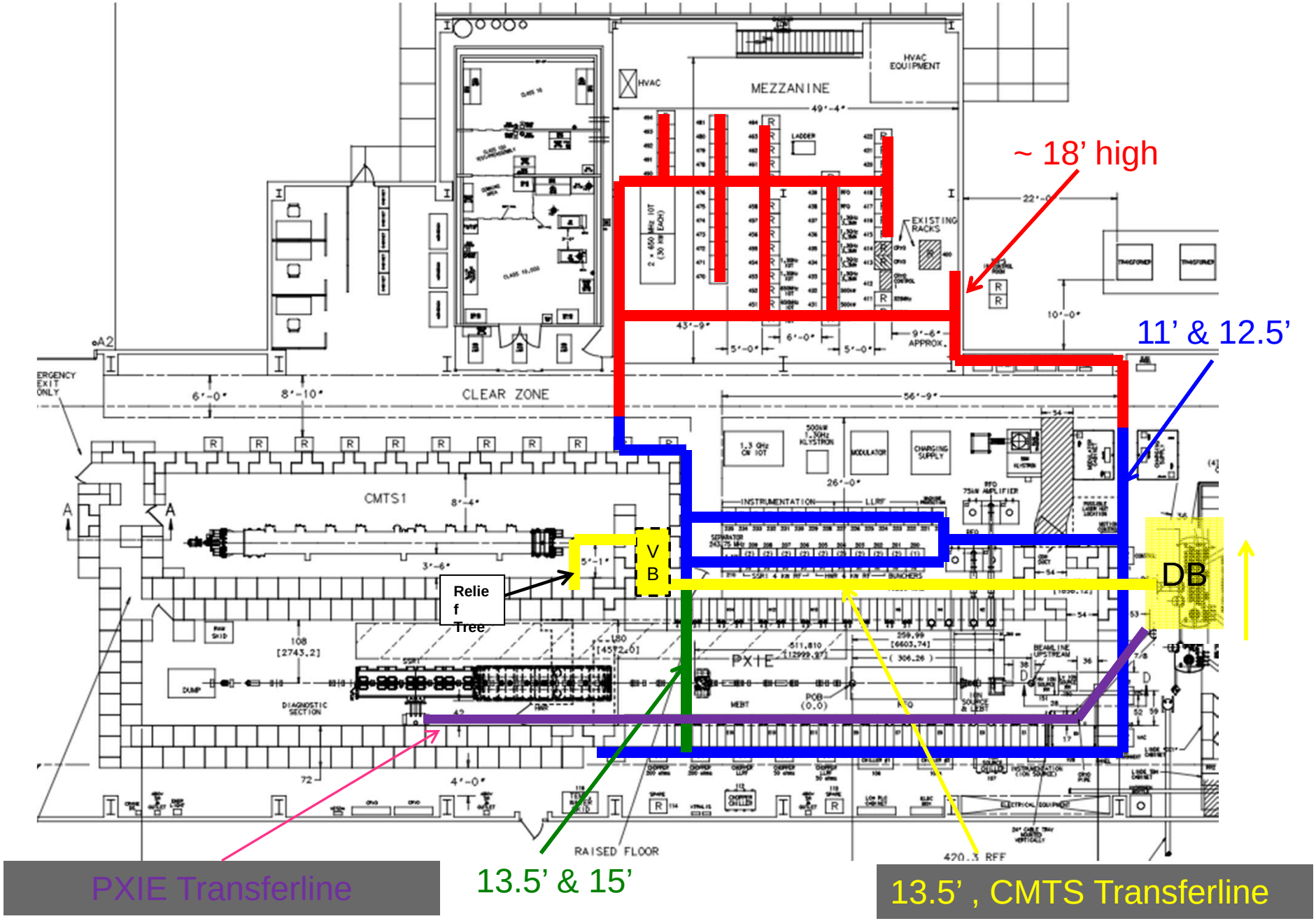
- Three stages of cold compressors and warm sub atmospheric helium compressors system (a.k.a. vacuum pumps) connected in series
- Vacuum pumps (qty 5) – volumetric machines
- Cold compressors (qty 3) - hydrodynamic machines
- Decrease of the warm vacuum pumps suction pressure enables to linearly reduce the cold compressors mass flow. This in turn allows the cold compressors to stay within their respective working hydrodynamic fields away from surge (ouch!) or stall areas



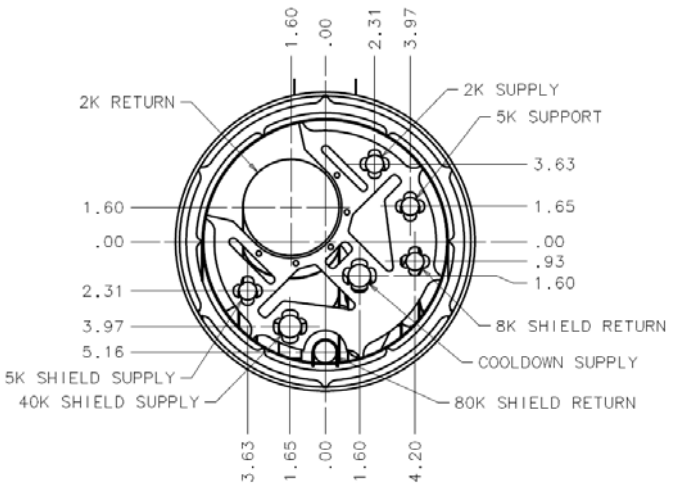


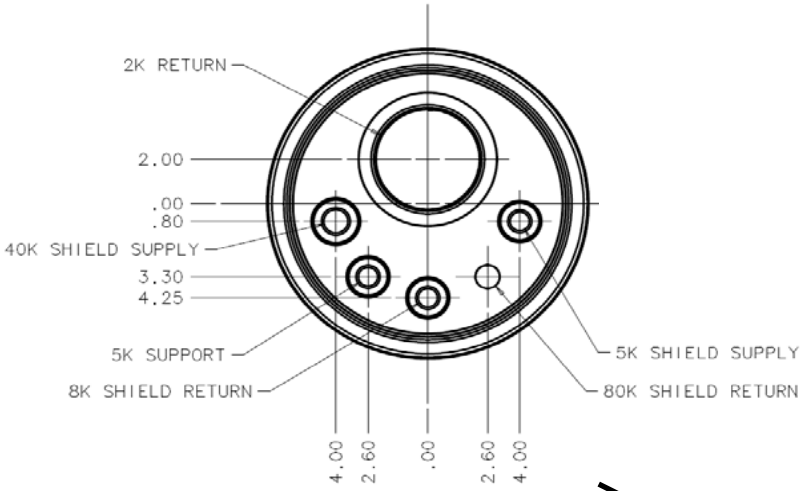
Coupling via Pinter maintains the operating point in the working field

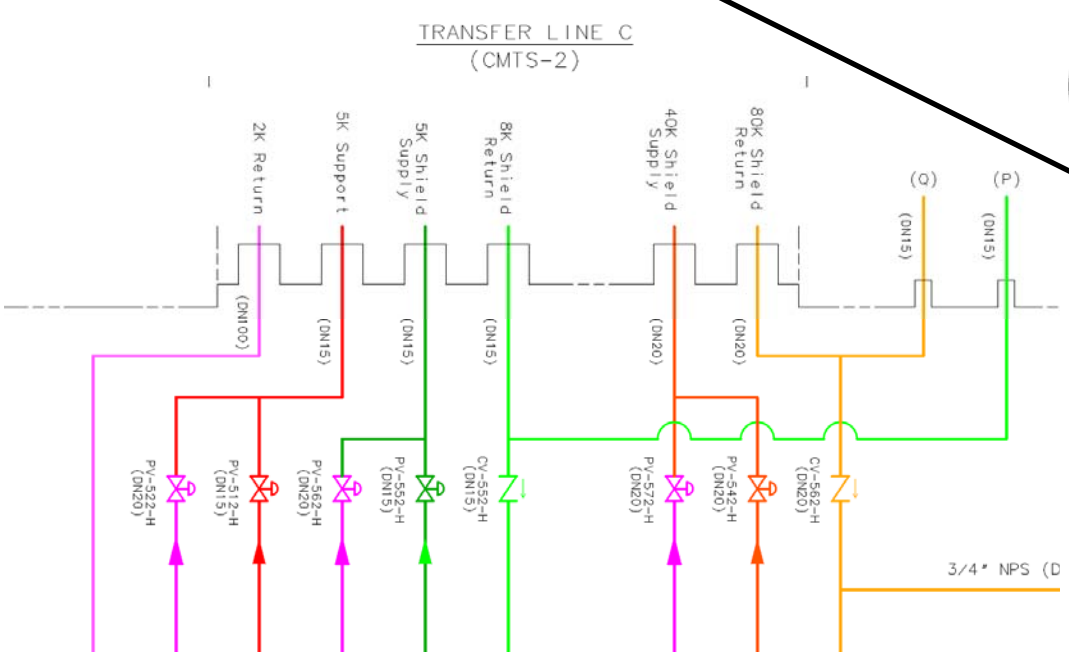
Transferline and Cable Tray Layout

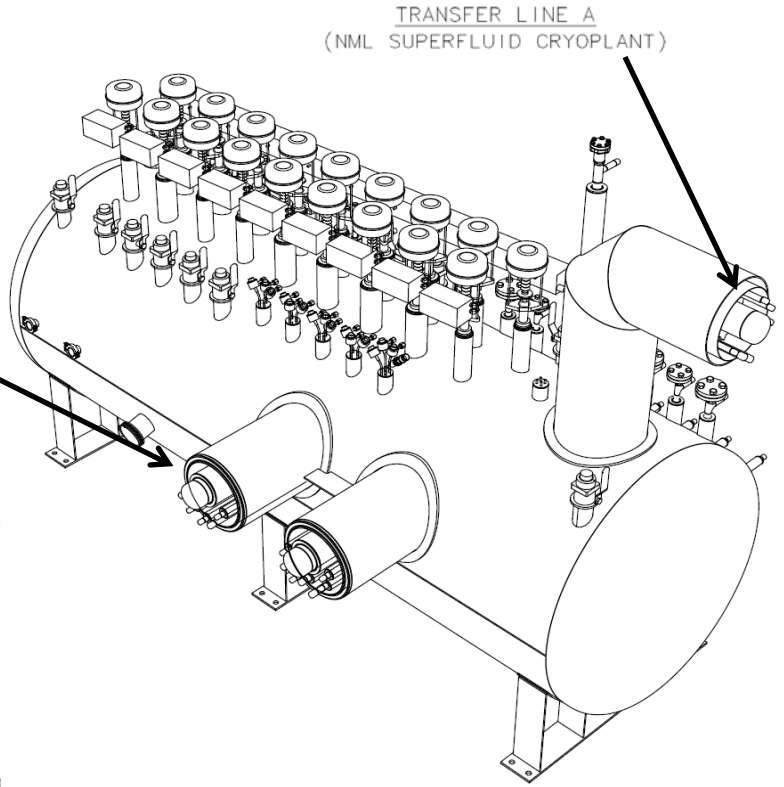


Distribution Box





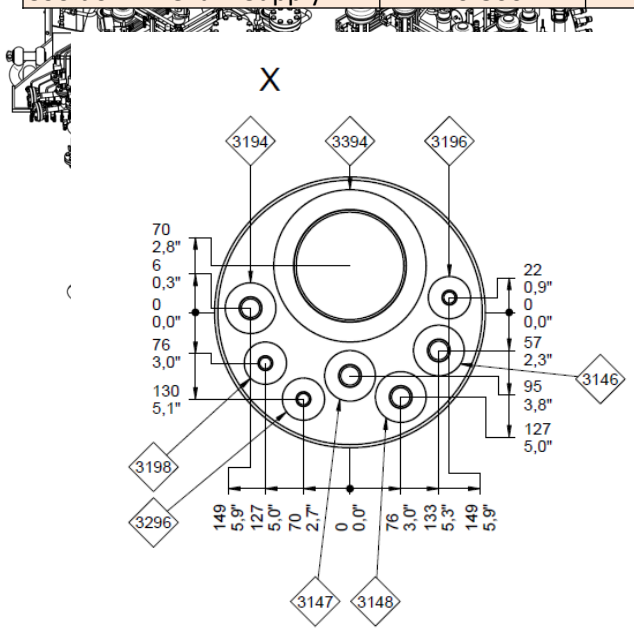


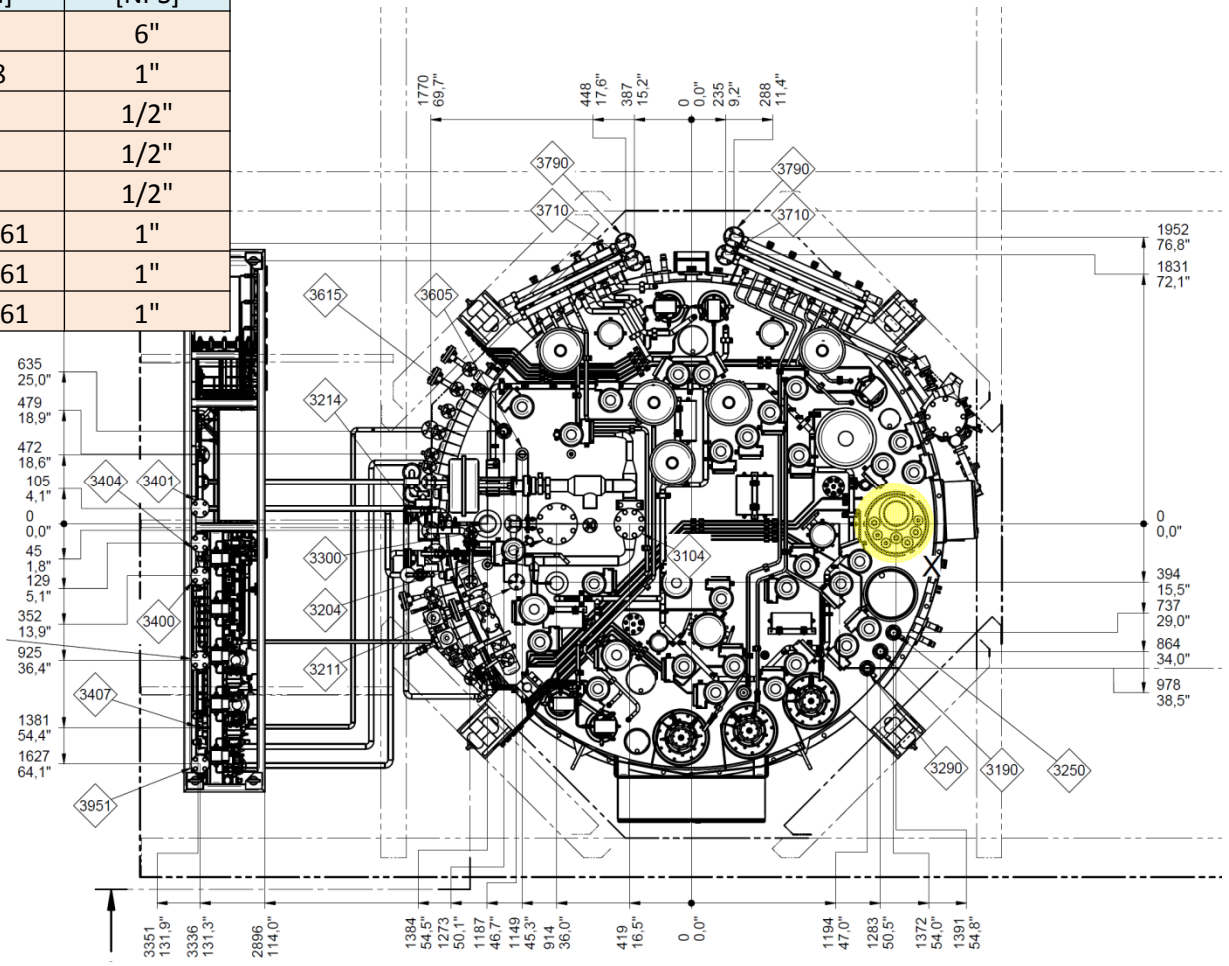



PHPK
TECHNOLOGIES

SCP to DB Connection

Circuit Description	Operating Temperature	Operating Pressure	Size at SCP
[-]	[K]	[psia]	[NPS]
2K Helium Supply	2	51	6"
2K Helium Return	2	0.18	1"
5K Support	4.6	51	1/2"
5K Helium Shield Supply	4.6	51	1/2"
8K Helium Shield Return	8	44	1/2"
40K Helium Shield Supply	40	145-261	1"
80K Helium Shield Return	80	145-261	1"
Cooldown Helium Supply	40-300	145-261	1"





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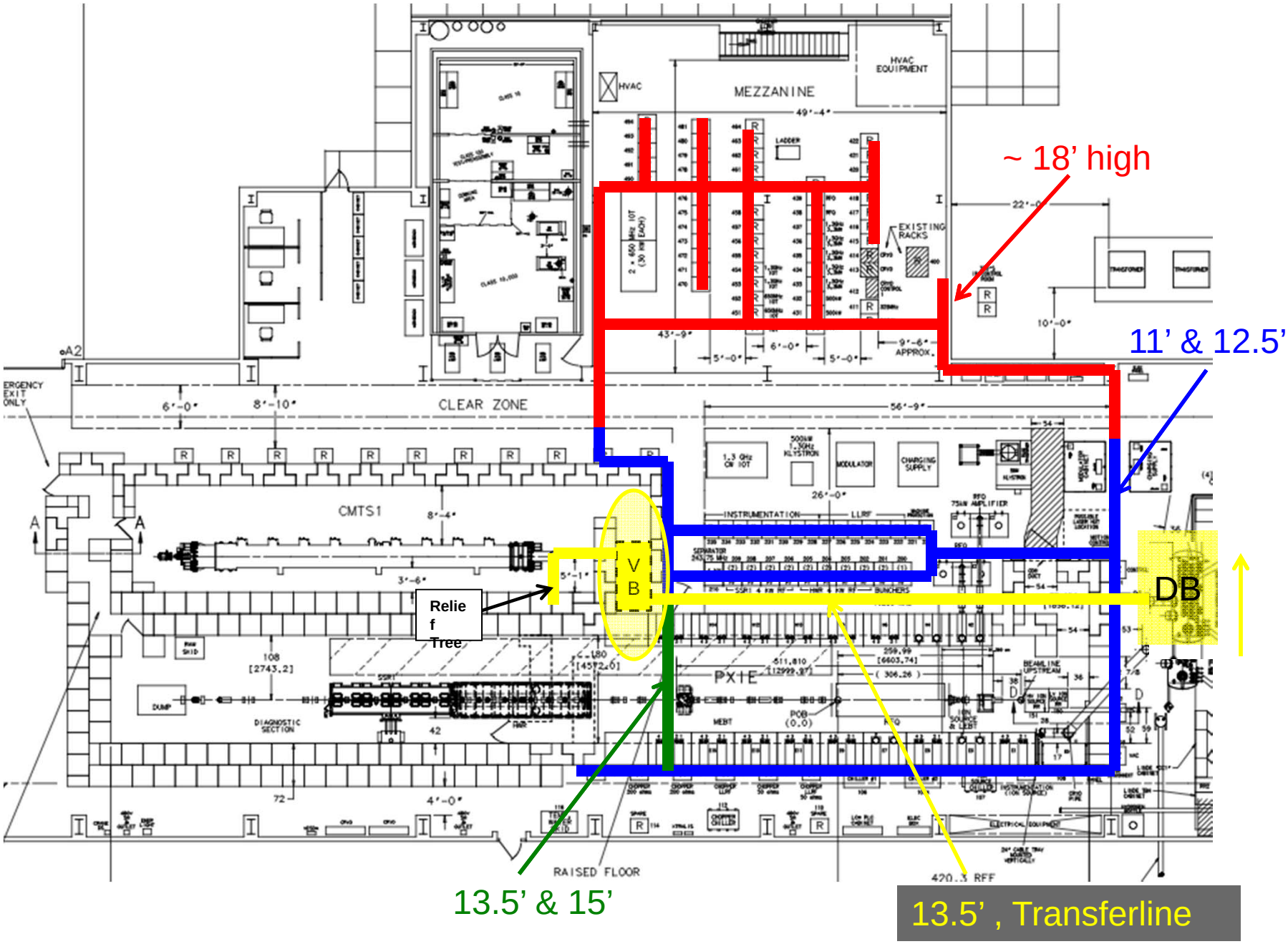

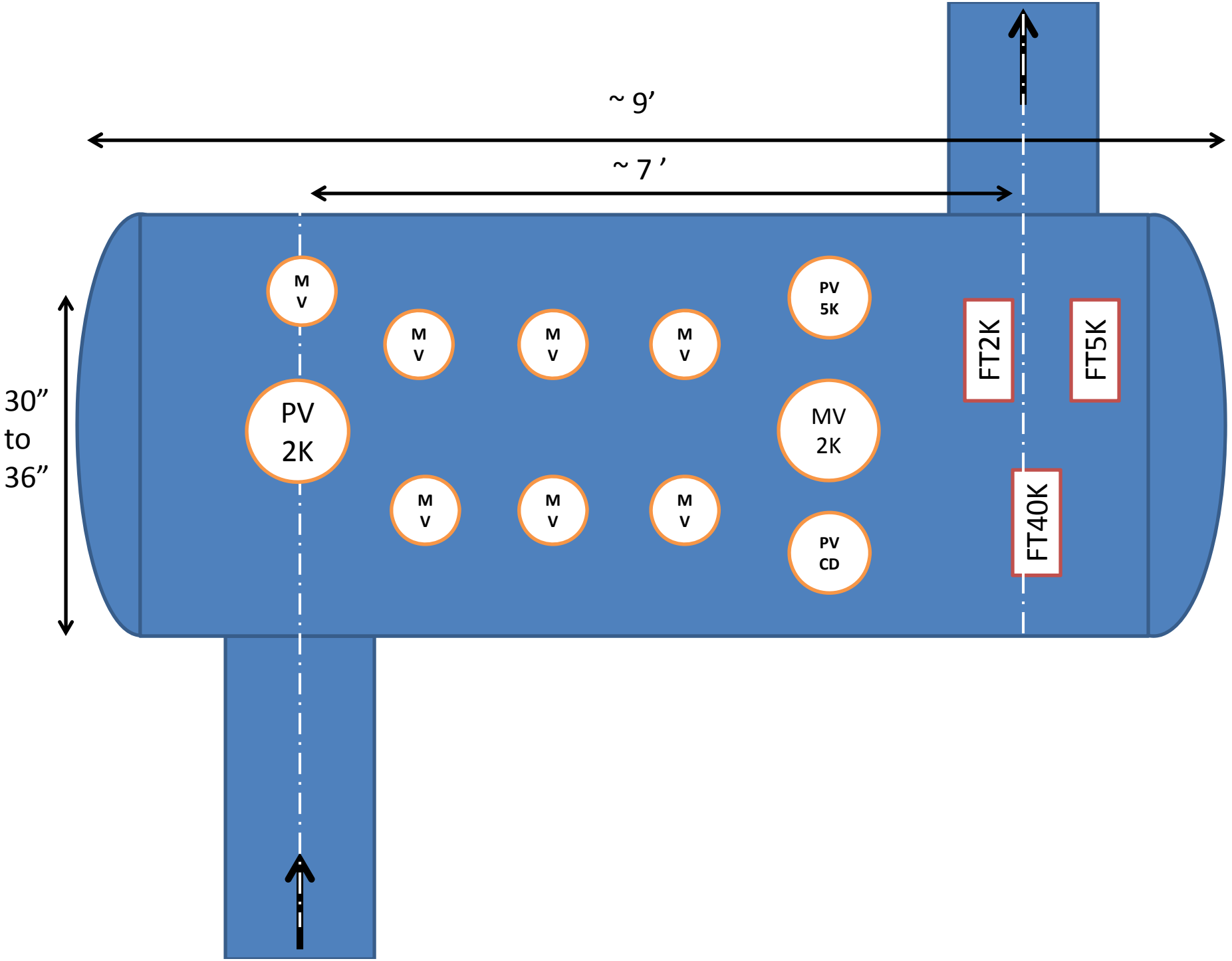
~ 9’
~ 7 ’
30”
to
36”
M
V
PV
2K
M
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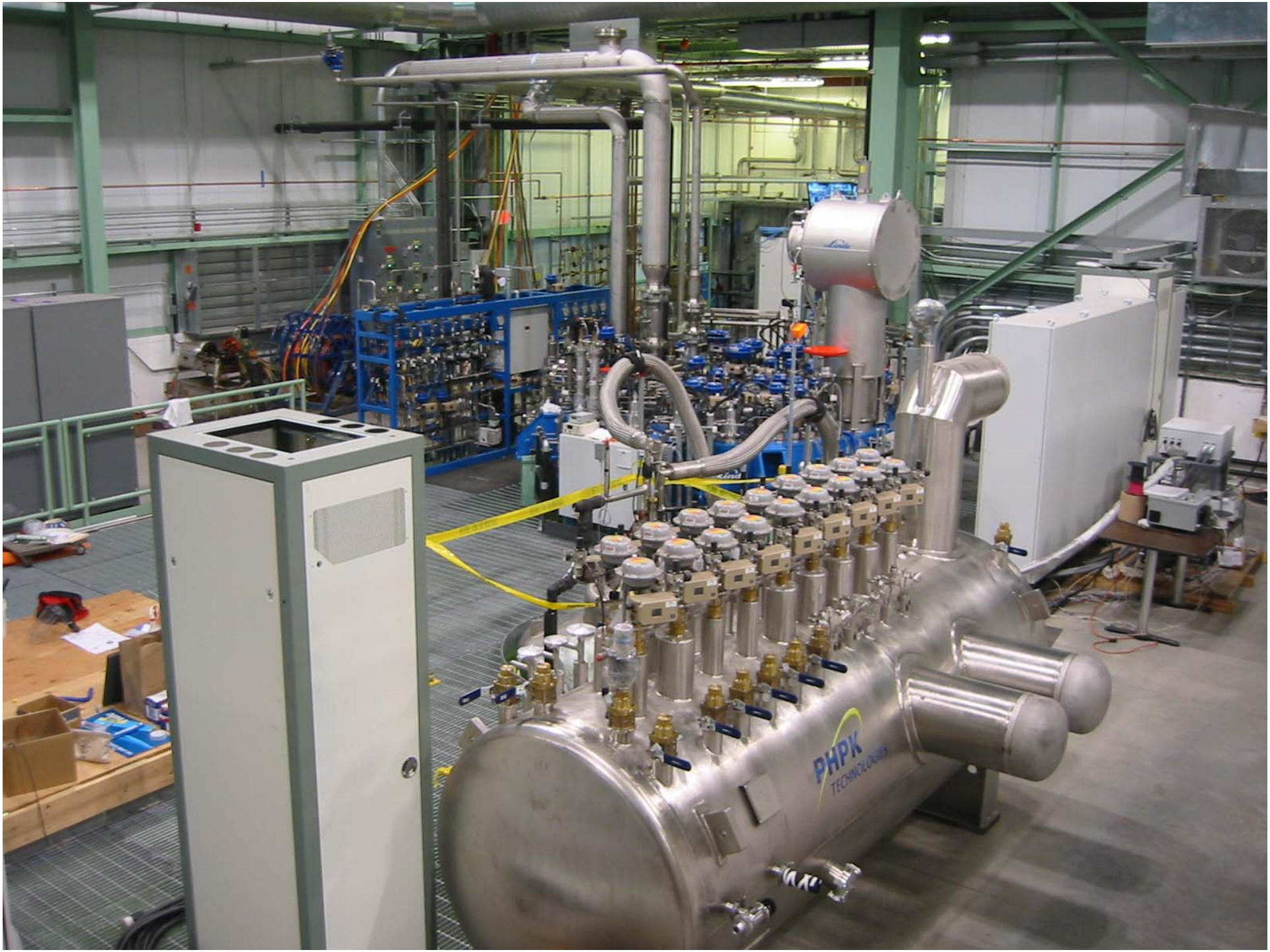
CD
FT2K
FT5K
FT40K


PHPK
TECHNOLOGIES

Summary

- Superfluid cryoplant is fully operational
- Cryomodule Test Stand ready - Q1 FY16
- PXIE cryogenic system is in design phase

Thanks!