Special Cooling Systems Design

Maurice Ball/Jerzy (Yurick) Czajkowski

PIP-II LINAC Complex Mechanical Fluid Systems PDR

April 21, 2021

A Partnership of:
- US/DOE
- India/DAE
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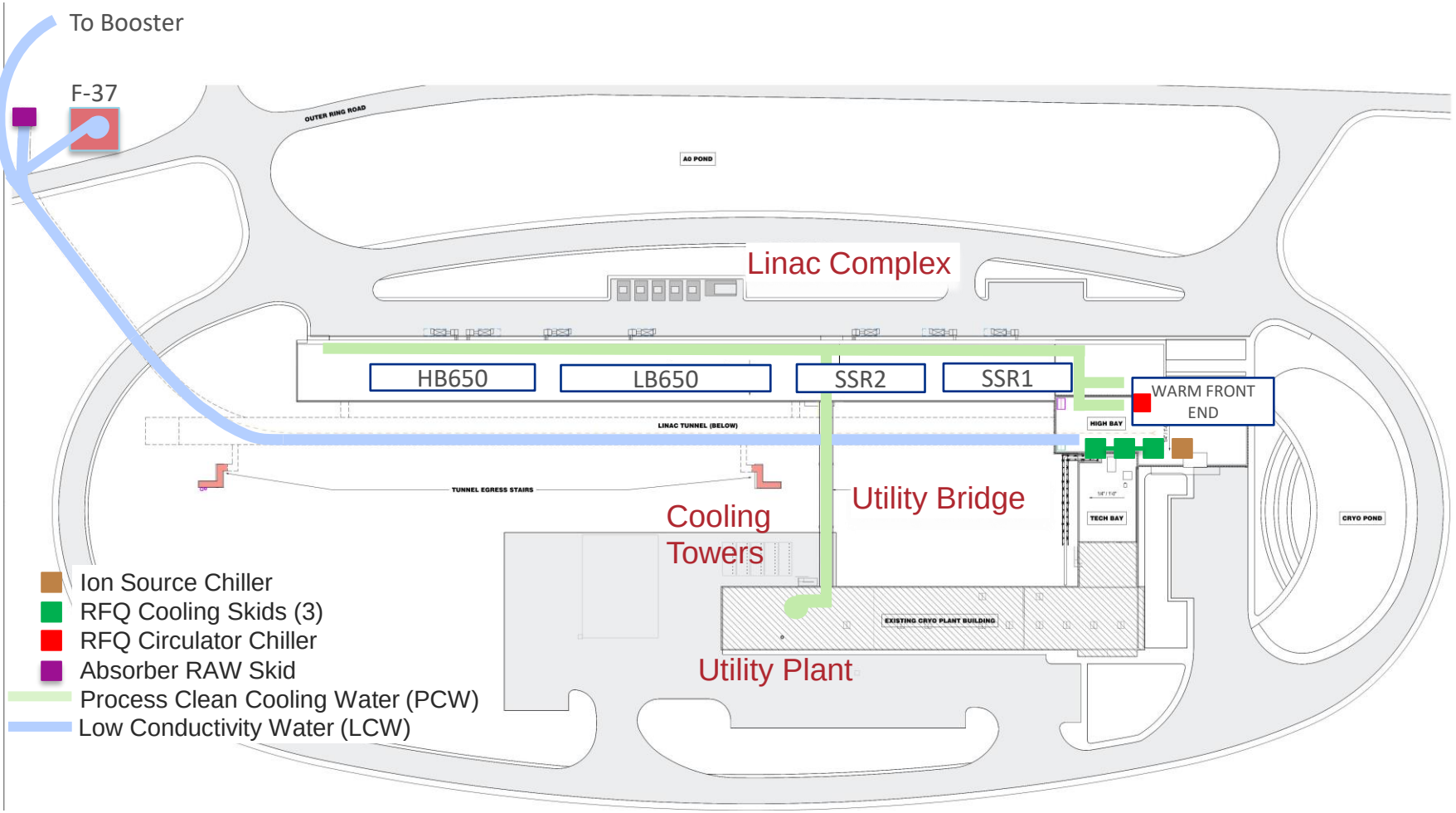

RFQ 3 Skid System Design

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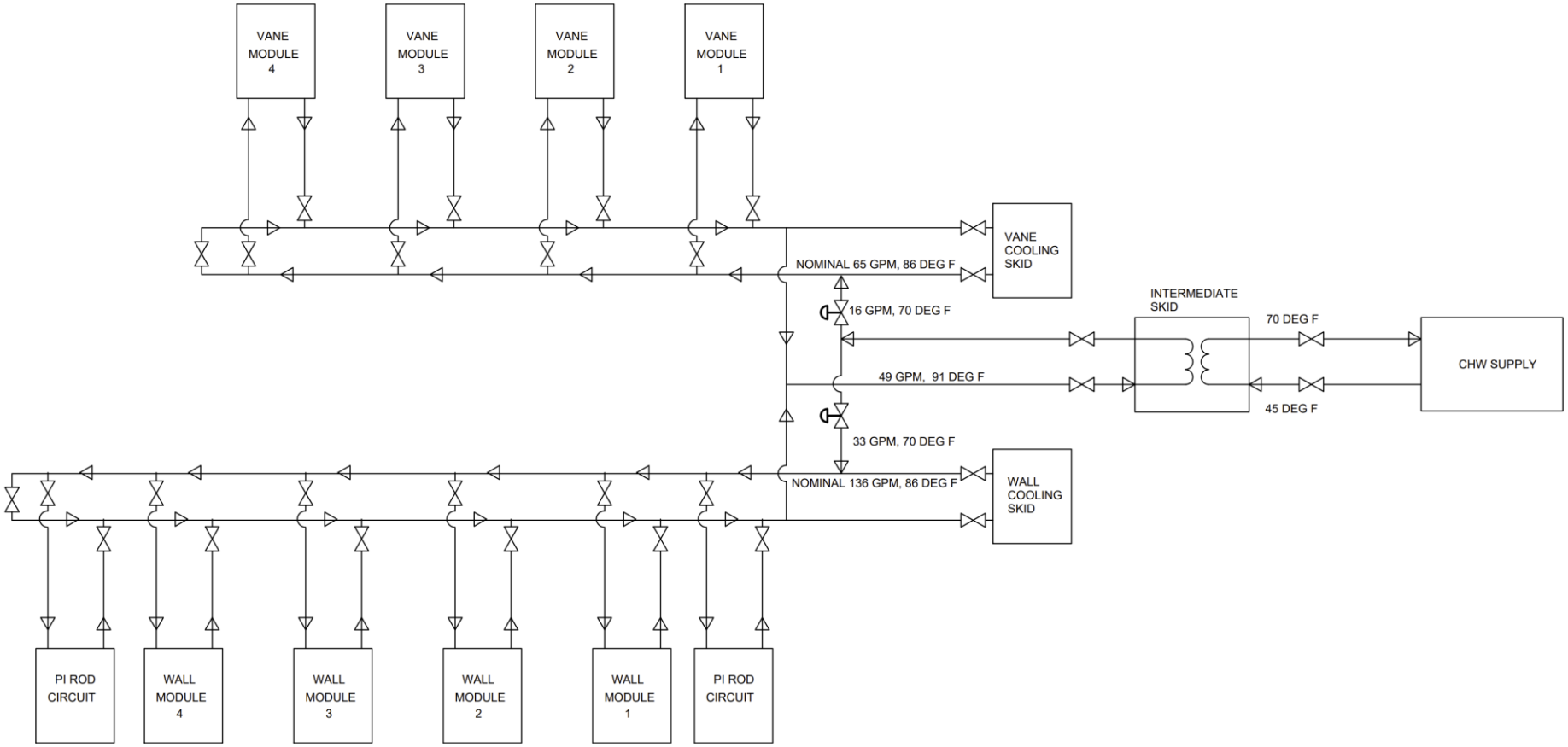
RFQ 3 Skid System - Highlights

- Three Separate cooling skids work together as one system
- 304 Stainless Steel and Copper piping material
- Vane and Wall Skids
  - Used during PIP2IT operations. Will be reused for PIP-II operations
  - Recirculate cooling water through Vane and Wall areas of the RFQ
  - Heat exchange with Intermediate skid
- Intermediate Skid heat exchanges with 45°F Facility Chilled Water
- Special flow control valve and flow meter under PLC program to provide tight +/- 0.5 °F tolerance requirement

Technical Requirements for RFQ Intermediate Skid

- Building Infrastructure shall provide the RFQ Intermediate cooling water skid according to the following specifications:
- Discharge Pressure = 100 PSIG
- Suction Pressure = 15 PSIG
- Supply Temperature = 70°F +/- 1.0 ºF
- Delta T (ΔT) = 21.0 Fº
- Total Heat Load = 71 KW
- Nominal Flow Required = 49 GPM
- Resistivity = 2 MOhm-CM
- Full flow Particulate filtration at 1 micron

RFQ 3 Skid LCW System Block Diagram



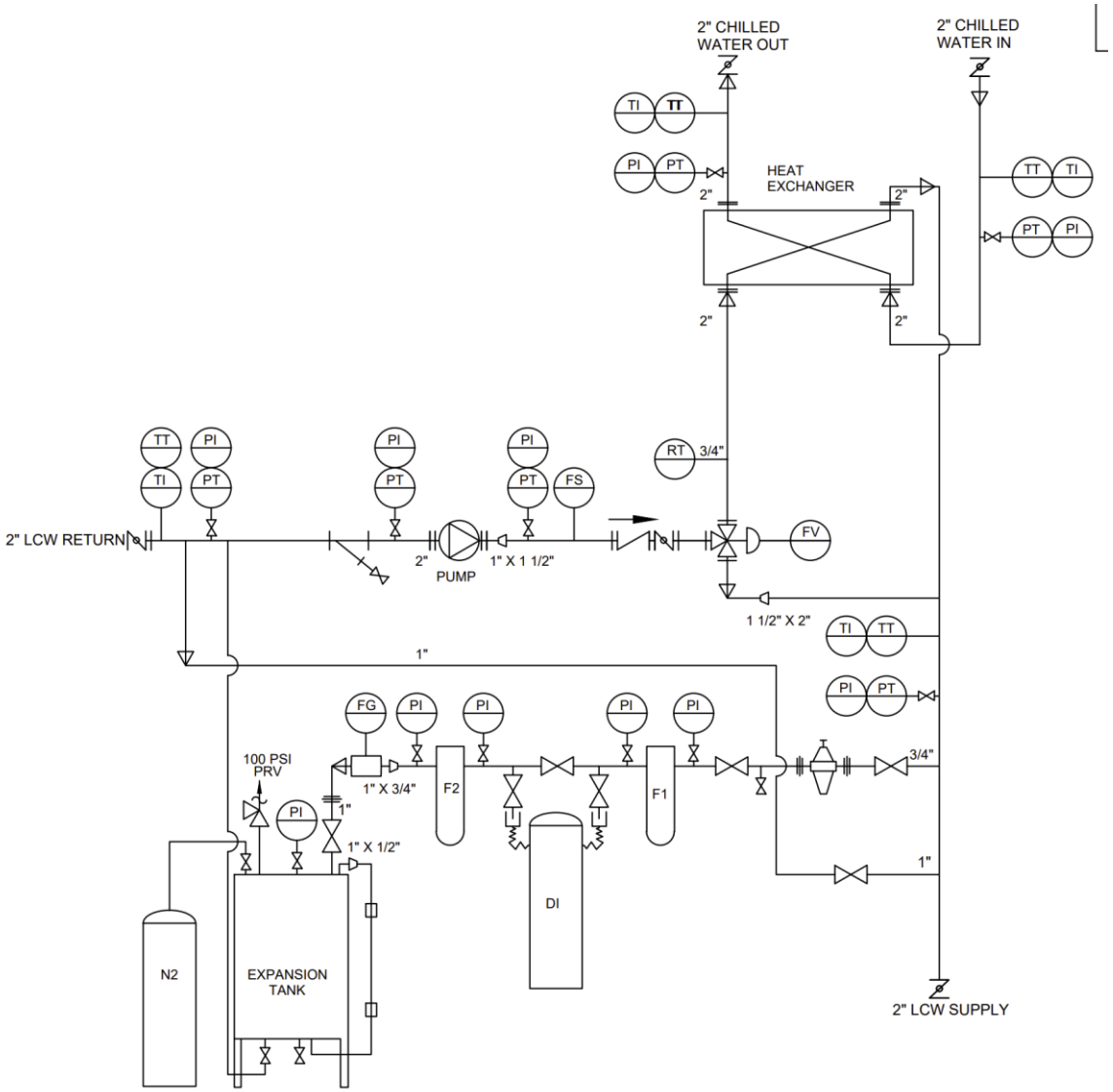
Technical Requirements for RFQ Vane Skid

- Building Infrastructure shall provide the RFQ Vane cooling water skid according to the following specifications:
- Discharge Pressure = 100 PSIG
- Suction Pressure = 15 PSIG
- Supply Temperature = 86°F +/- 0.5 ºF
- Delta T (ΔT) = 5.0 Fº
- Nominal Heat Load = 29 KW
- Nominal Flow Required = 65 GPM
- Resistivity = 2 MOhm-CM
- Full flow Particulate filtration at 1 micron

Technical Requirements for RFQ Wall Skid

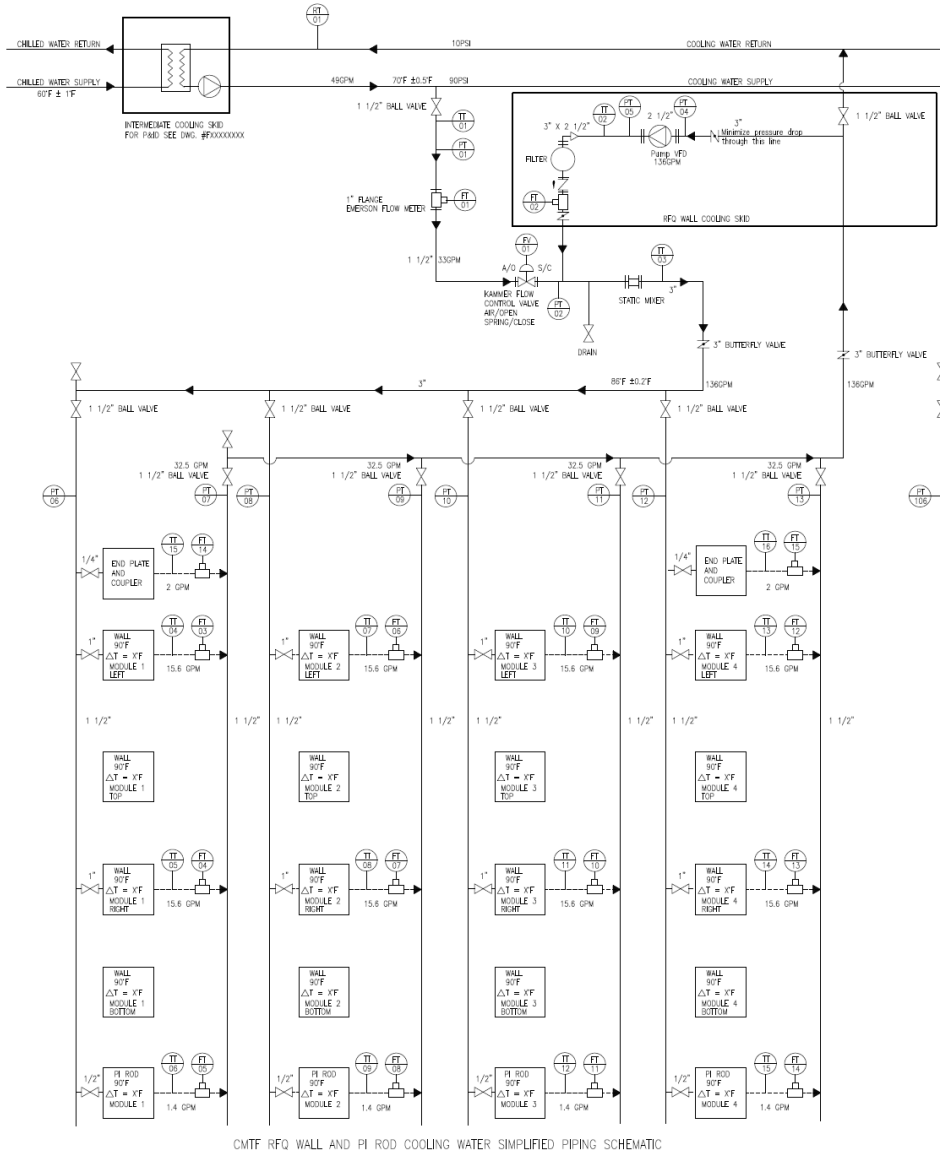
- Building Infrastructure shall provide the RFQ Wall cooling water skid according to the following specifications:
- Discharge Pressure = 100 PSIG
- Suction Pressure = 15 PSIG
- Supply Temperature = 86°F +/- 0.5 ºF
- Delta T (ΔT) = 5.0 Fº
- Nominal Heat Load = 50 KW
- Nominal Flow Required = 136 GPM
- Resistivity = 2 MOhm-CM
- Full flow Particulate filtration at 1 micron

Intermediate RFQ LCW Skid P&ID



Legend:
PT – Pressure Transmitter
PI – Pressure Indicator
TT – Temperature Transmitter
TI – Temperature Indicator
RT – Resistivity Transmitter
DI – DI Bottle
F1 – Pre-Filter
F2 – After-Filter
FG – Flow Indicator
PRV – Pressure Relief Valve

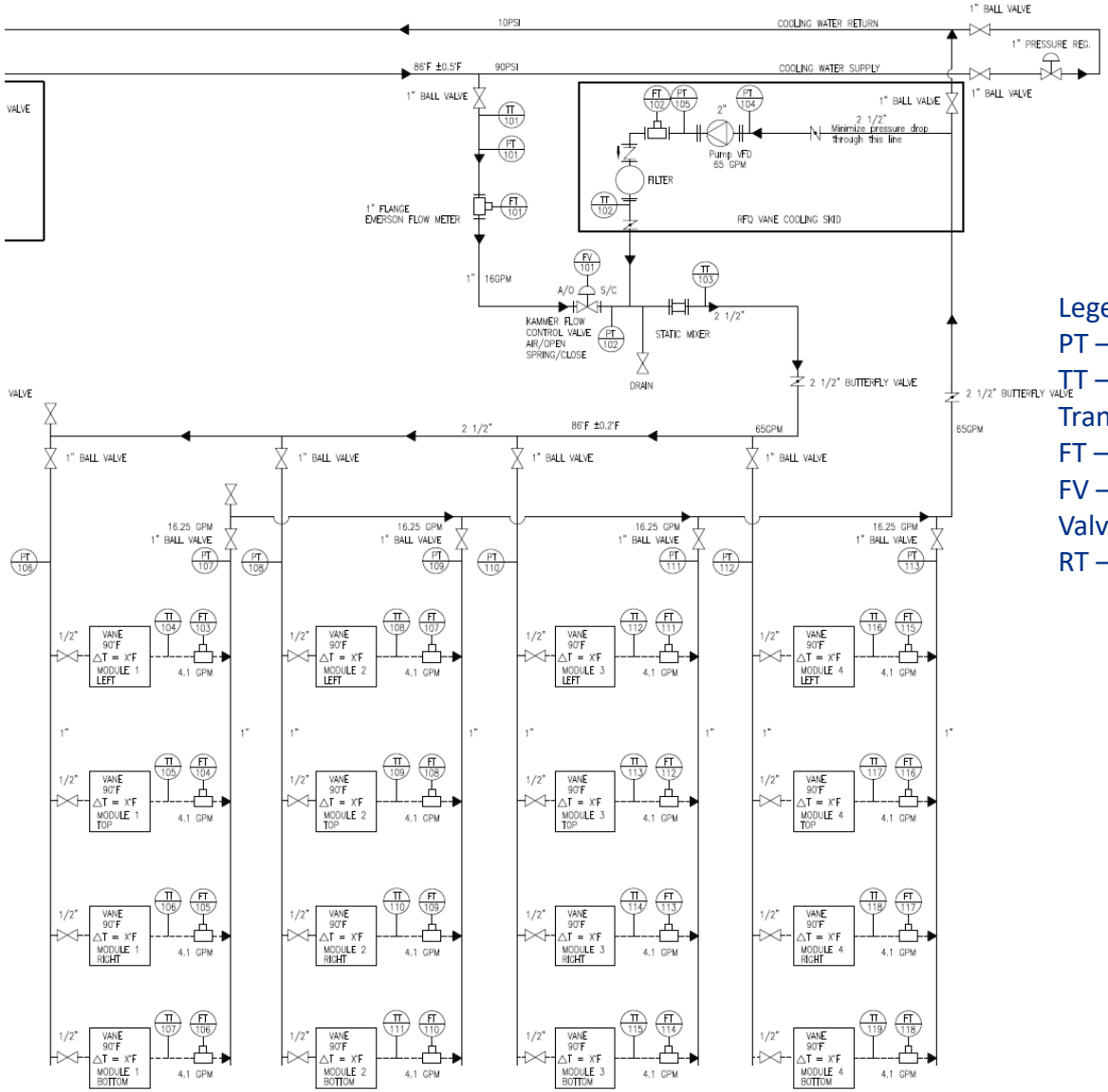
RFQ WALL LCW Skid & Intermediate Skid



CMTF RFQ WALL AND PI ROD COOLING WATER SIMPLIFIED PIPING SCHEMATIC

Legend:
PT – Pressure Transmitter
TT – RTD Temperature Transmitter
FT – Flow Meter/Transmitter
FV – Flow/Temperature Control Valve
RT – Resistivity Transmitter

RFQ VANE LCW Cooling Skid



Legend:
PT – Pressure Transmitter
TT – RTD Temperature Transmitter
FT – Flow Meter/Transmitter
FV – Flow/Temperature Control Valve
RT – Resistivity Transmitter

Installation Plan

- Reusing the Vane and Wall skids from PIP2IT
- After RFQ testing completed, Vane and Wall skids disconnected and moved to storage
- For PIP-II installation, Vane and Wall skids brought out of storage and installed in High Bay ground floor in cooling skid alcove
- Piping manifolds and hose assemblies from PIP2IT operation reused
- New Intermediate Skid will be built to replace existing skid.
- Once cooling skids, piping manifolds, and hose assemblies are installed and connected, perform pneumatic and hydrostatic pressure tests

Photo Image - RFQ Vane Wall Skids at CMTF

Photo Image - RFQ Wall skid at CMTF

Photo Image - RFQ Vane skid at CMTF

Photo Image - RFQ Vane Wall Flowmeters at CMTF

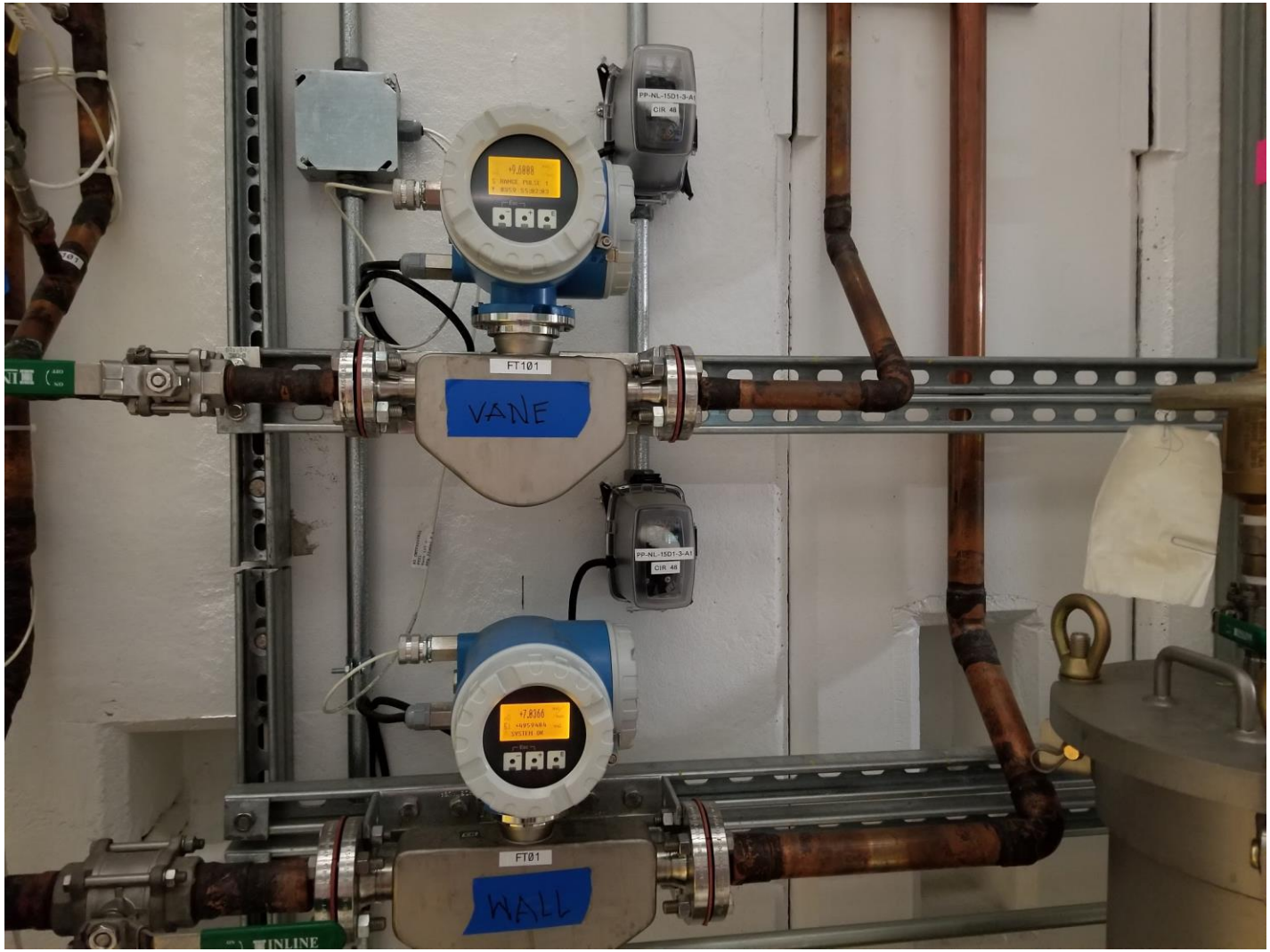


Photo Image - RFQ Intermediate skid at CMTF

Photo Image - RFQ Intermediate skid at CMTF

RFQ Circulator/Loads Chiller System Design

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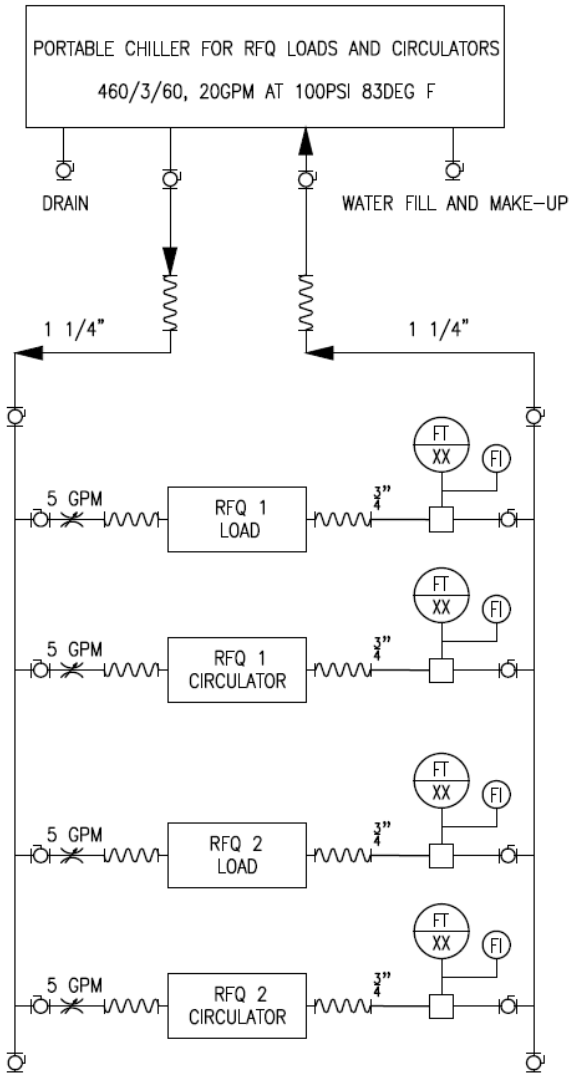
RFQ Circulator Chiller Highlights

- Off the shelf portable chiller
- Self-contained
- Air-cooled chiller
- Special supply temperature control needs (83°F)
- RFQ amplifiers cooled separately using PCW System

Technical Requirements for RFQ Circulator Chiller

- Building Infrastructure shall provide the cooling water system, including supply and return piping, valves, and instrumentation, for the RFQ circulator and loads according to the following specifications:
- Discharge Pressure = 100 PSIG
- Suction Pressure = 15 PSIG
- Supply Temperature = 83°F +/- 1.0 ºF
- Delta T (ΔT) = 10 Fº
- Total Heat Load = 29 KW
- Total Flow Required = 20 GPM
- Resistivity = n/a

PIP-II RFQ Circulator/Loads Chiller P&ID



LEGEND:

- FLEXIBLE HOSE
- BALL VALVE
- FT FLOW TRANSMITTER
- FI FLOW INDICATOR
- FLOW RESTRICTOR

Installation Plan

- Procure and install portable chiller
- Connect flexible hose assemblies to manifolds and then to Circulators and Loads
- Once chiller and hose assemblies are installed and connected
- Pneumatic and hydrostatic pressure tests will be performed

Beam Absorber Skid and Piping System Design

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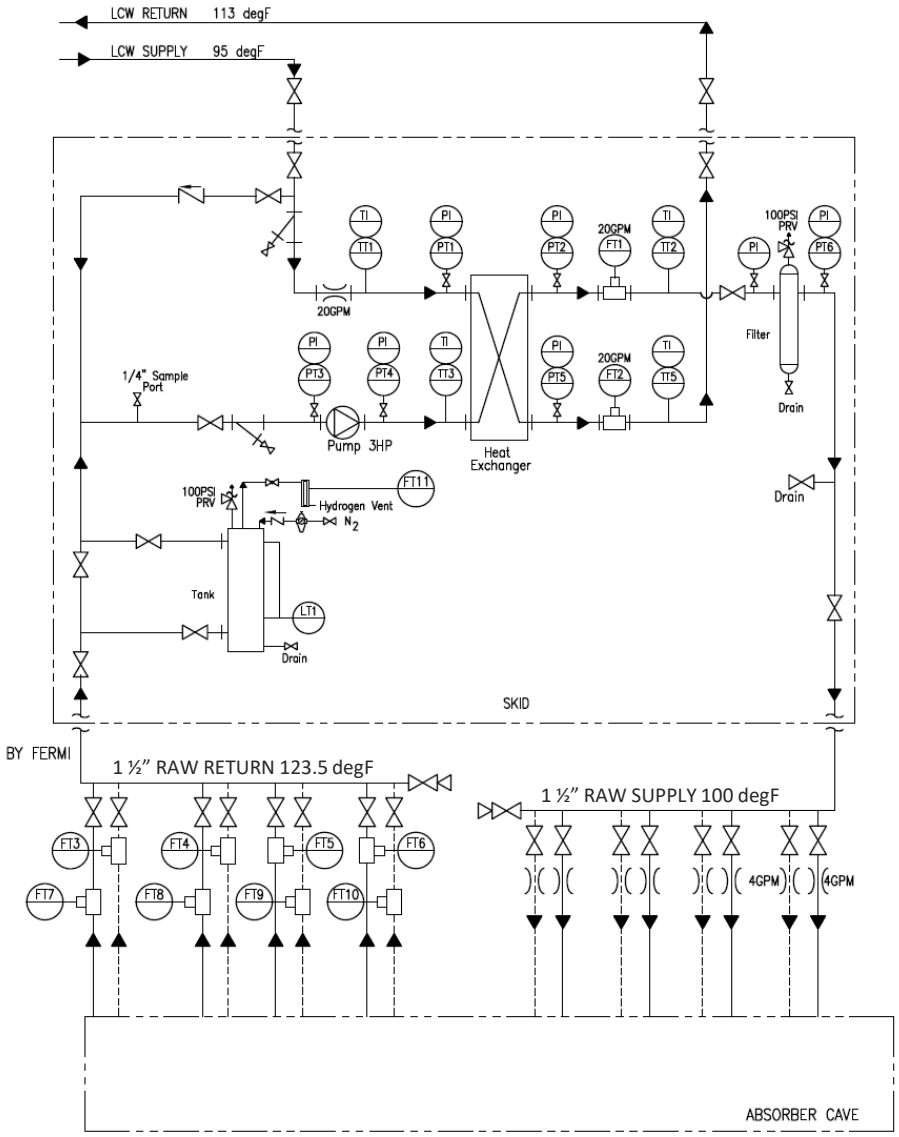
Beam Absorber RAW Skid - Highlights

- Radioactive Water system
- Cools the Beam Absorber located in the Beam Transfer Line (BTL)
- Normal Fluid Service
- Nitrogen gas used as tank blanket and to purge Hydrogen gas from system
- Magnetically driven circulating pump, no leaky seals
- Containment basin located under RAW skid, sized to contain entire RAW system volume

Technical Requirements for Beam Absorber RAW Skid

- Building Infrastructure shall design the Absorber RAW cooling system, including supply and return piping, valves, and instrumentation for the Absorber according to the following specifications:
- Discharge Pressure = 100 PSIG
- Suction Pressure = 15 PSIG
- Supply Temperature = 100°F +/- 1 ºF
- Delta T (ΔT) = 23.5 Fº
- Total Heat Load = 25 KW
- Total Flow Required = 20 GPM
- Resistivity = n/a
- Full flow particulate filtration at 5 micron

Beam Absorber Skid and System P&ID



Legend:
PI – Pressure Indicator
TI – Temperature Indicator
LT – Level Transmitter
PT – Pressure Transmitter
TT – Temperature Transmitter
FT - Flow Meter/Transmitter

BALL VALVE

FT4 WATER FLOW METER

20GPM FLOW RESTRICTOR

Y STRAINER

PRESSURE RELIEF VALVE

MASS HYDROGEN/NITROGEN FLOW METER

NEEDLE VALVE

PRESSURE REGULATOR

Beam Absorber RAW Skid – Highlights (Continued)

- Example of a similarly designed Absorber RAW Skid at NML

Preliminary Analysis Of Designed Absorber RAW Piping

PIP-II RAW LOW CONDUCTIVITY WATER (LCW) MATERIAL TYPE AND SIZES

PRESSURE DESIGN OF COMPONENTS (FROM ASME B31.3 – 304)

Minimum Pipe Thickness is given by,

$$t_m = t + c \qquad (2)$$

Here,

$$t = \frac{PD}{2(SEW + PY)} \qquad (3b)$$

Nomenclature used in equations:

c = sum of the mechanical allowances thread depth plus corrosion and erosion allowances.

D = outside diameter of pipe

d = inside diameter of pipe

E = quality factor from Table A-1A or Table A-1B

P = internal design gage pressure

S = stress value for material from Table A-1 or Table A-1M

T = pipe wall thickness

t = pressure design thickness in accordance with para. 304.1.2

t_m = minimum required thickness, including mechanical, corrosion, and erosion allowances

W = weld joint strength reduction factor in accordance with para. 302.3.5(e)

Y = coefficient from Table 304.1.1, valid for t < D/6

Preliminary Analysis Of Designed Absorber RAW Piping (Continued)

CALCULATIONS:

Pipe:

Material Specification: 304/304L SS

Design Pressure (P): 100 psig

Design Temperature: 118 ºF

Pipe Thickness Calculation Parameters:

Coefficient Y = 0.4

Stress Value for Material, S = 16,700 psi

Quality Factor, E = 0.8

Weld Joint Strength Reduction Factor, W = 1

Primary piping wall thickness (T) exceeds minimum wall thickness (t_m) requirements

Nominal Pipe Size	Outer Diameter, D	Schedule	Thickness, T	Inner Diameter, d	Thread Height, h	Mechanical Allowance, c	Pressure Design Thickness, t	Is t < D/6?	t_m	Is T > t_m?
in	in		in	in	in	in	in		in	
1 1/2	1.900	40S	0.145	1.610	0.06957	0.07457	0.00709	Yes	0.08166	Yes
1	1.315	40S	0.133	1.049	0.06957	0.07457	0.00491	Yes	0.07948	Yes
3/4	1.050	40S	0.113	0.824	0.05714	0.06214	0.00392	Yes	0.06606	Yes
1/2	0.840	40S	0.109	0.622	0.05714	0.06214	0.00313	Yes	0.06527	Yes
3/8	0.675	40S	0.091	0.493	0.04444	0.04944	0.00252	Yes	0.05196	Yes
1/4	0.540	40S	0.088	0.364	0.04444	0.04944	0.00201	Yes	0.05145	Yes

Installation Plan

- Coordinate delivery of RAW skid to Absorber RAW Room
- Supply stainless steel piping interconnecting Absorber to RAW cooling skid
- Once both skid and piping system are installed and connected, pneumatic and hydrostatic pressure tests will be performed.

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Ion Source Chiller and Piping System Design

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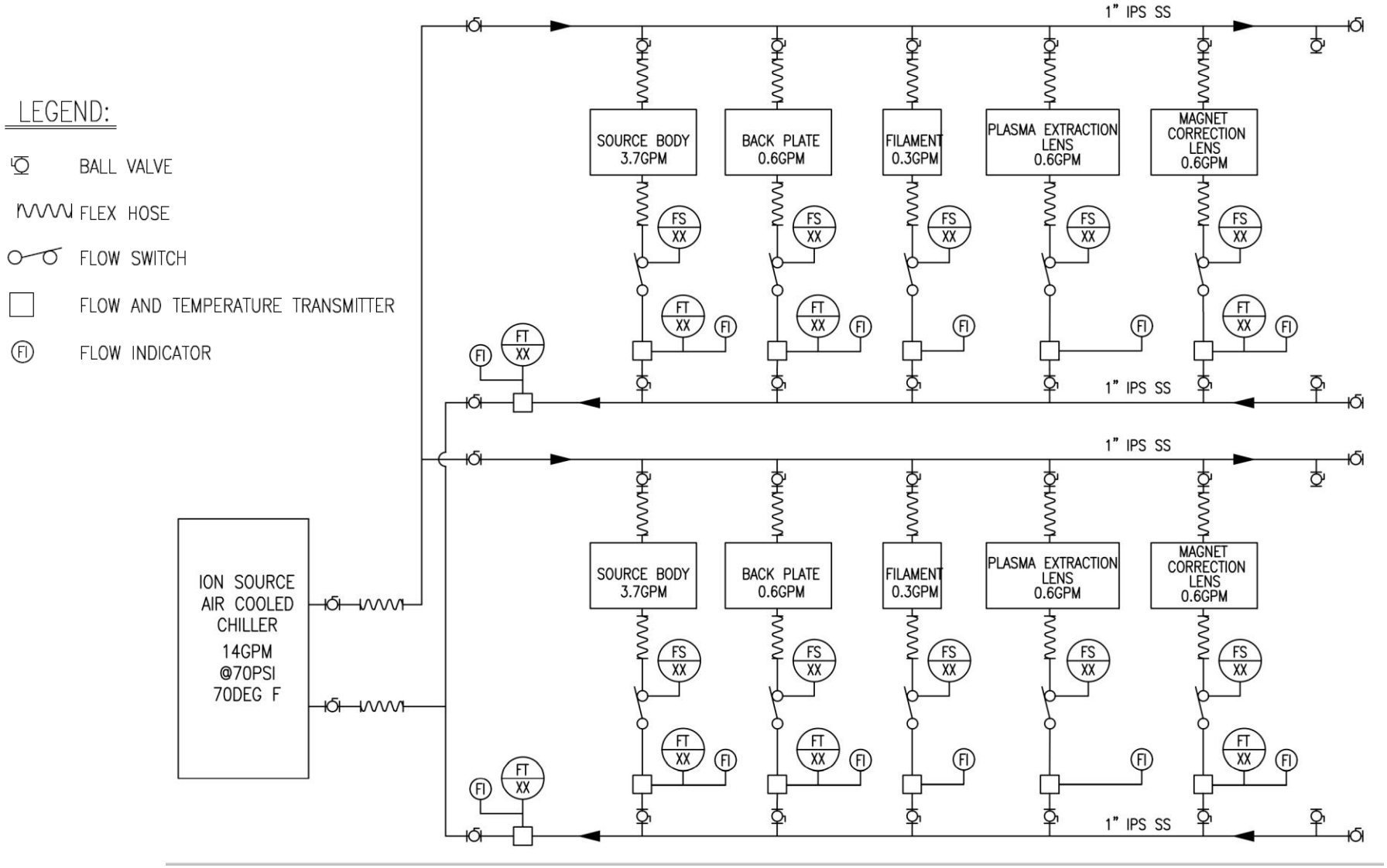
Ion Source Chiller Highlights

- Used during PIP2IT
- Will be reused in PIP-II
- Self-contained
- Air-cooled chiller
- Piping manifold will be reused in PIP
- Special supply temperature control needs (70°F)

Technical Requirements for Ion Source Chiller

- Building Infrastructure shall provide the Ion Source LCW System according to the following specifications:
- Discharge Pressure ≥ 70 PSIG
- Suction Pressure = 15 PSIG
- Supply Temperature = 70ºF +/- 1.0ºF
- Delta T (ΔT) = 7.2 Fº
- Total Heat Load = 12 KW
- Total Flow Required = 14 GPM
- Resistivity = 4 MOhm-CM
- Built-in particulate filtration at 5 micron

PIP-II Ion Source Skid and System P&ID



Installation Plan

- Reusing the Ion Source Chiller from PIP2IT
- After Ion Source testing completed, chiller disconnected and moved to storage
- For PIP-II installation, chiller brought out of storage and installed in High Bay ground floor in cooling skid alcove
- Piping manifolds from PIP2IT operation reused.
- New hose assemblies created
- Once chiller, piping manifolds, and hose assemblies are installed and connected, pneumatic and hydrostatic pressure tests will be performed

Photo Image - Ion Source Skid at CMTF

Photo Image - – Ion Source to LEBT Transition at CMTF

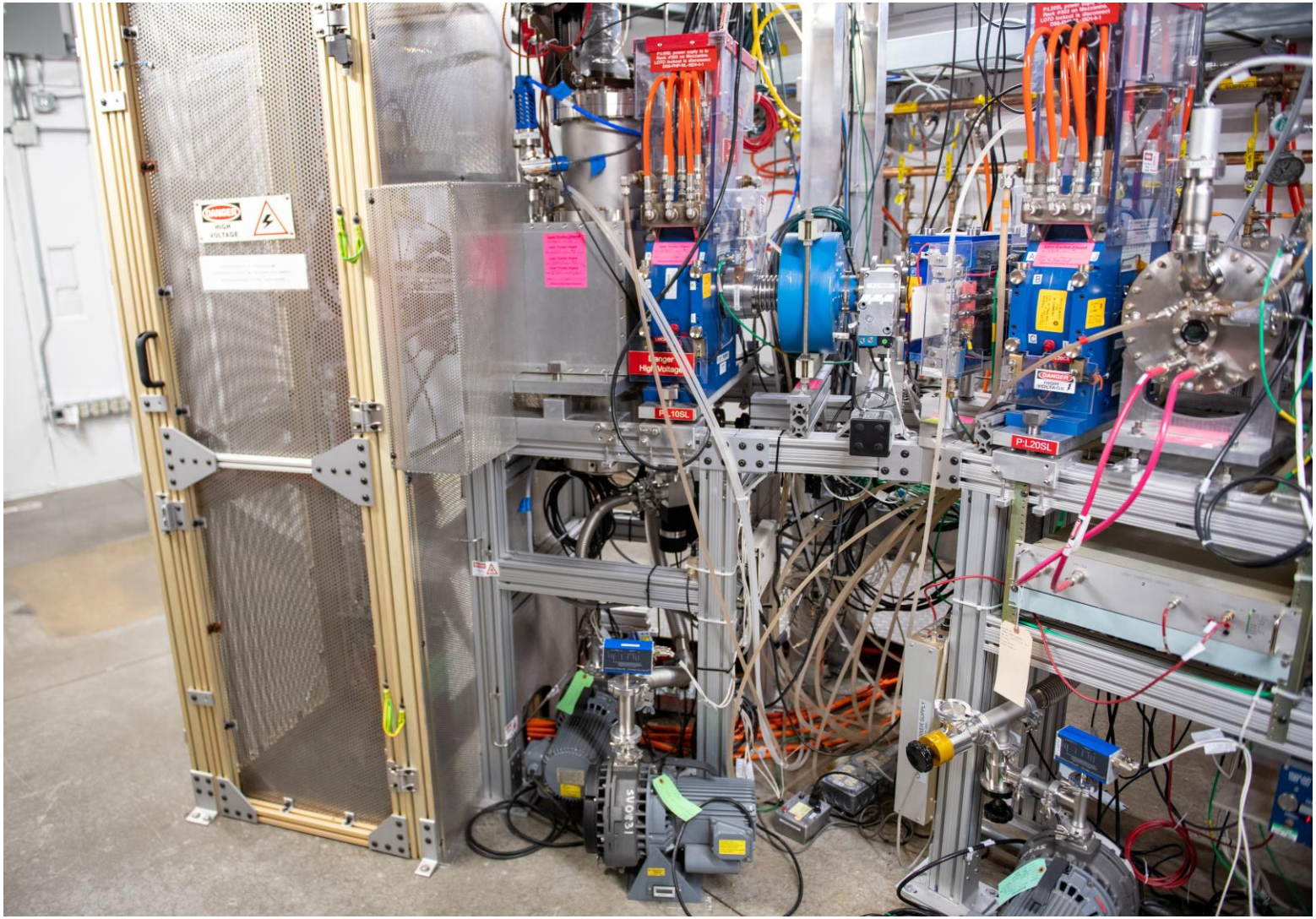


Photo Image – LEBT to RFQ Transition at CMTF

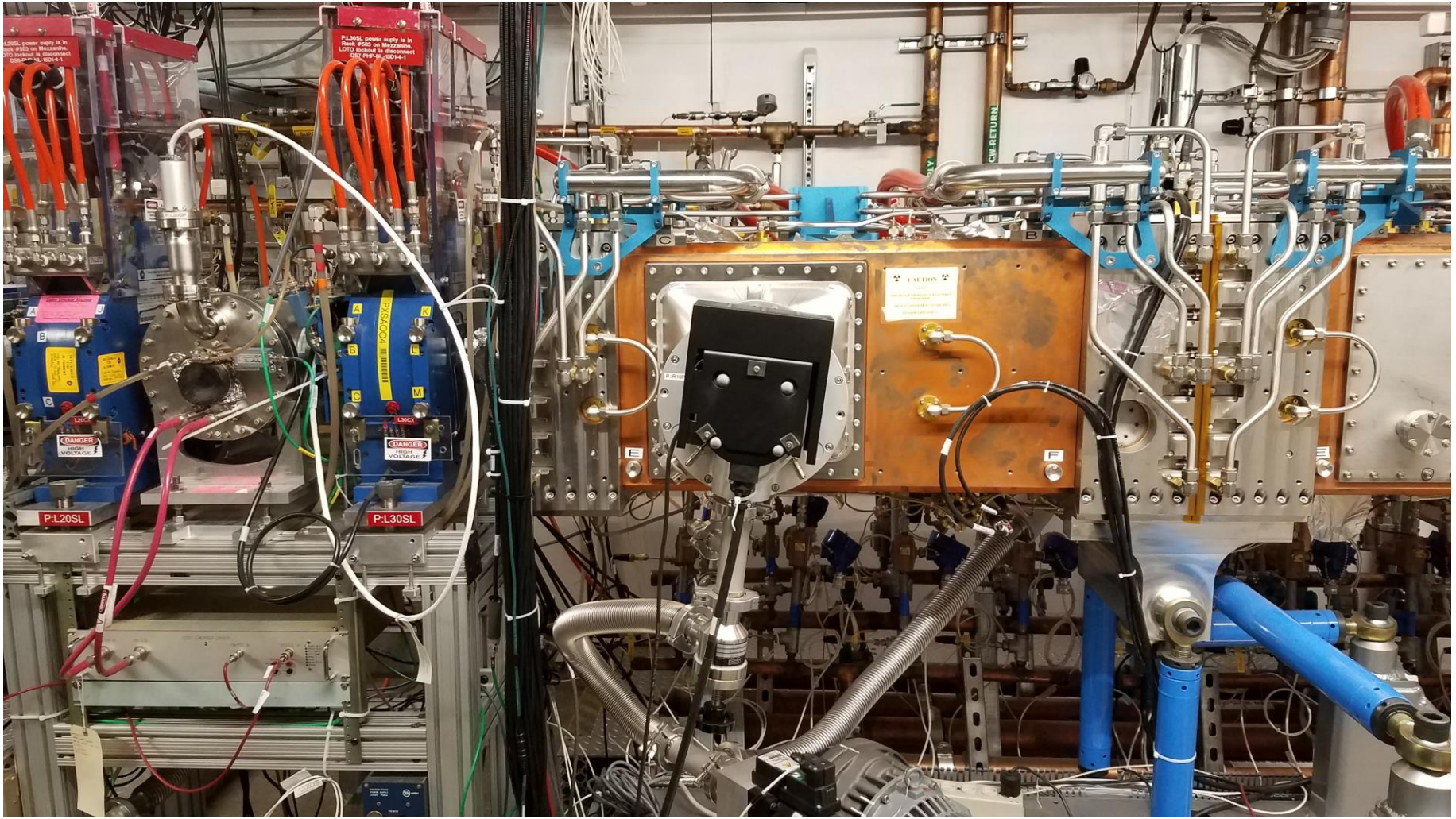


Photo Image – RFQ at CMTF

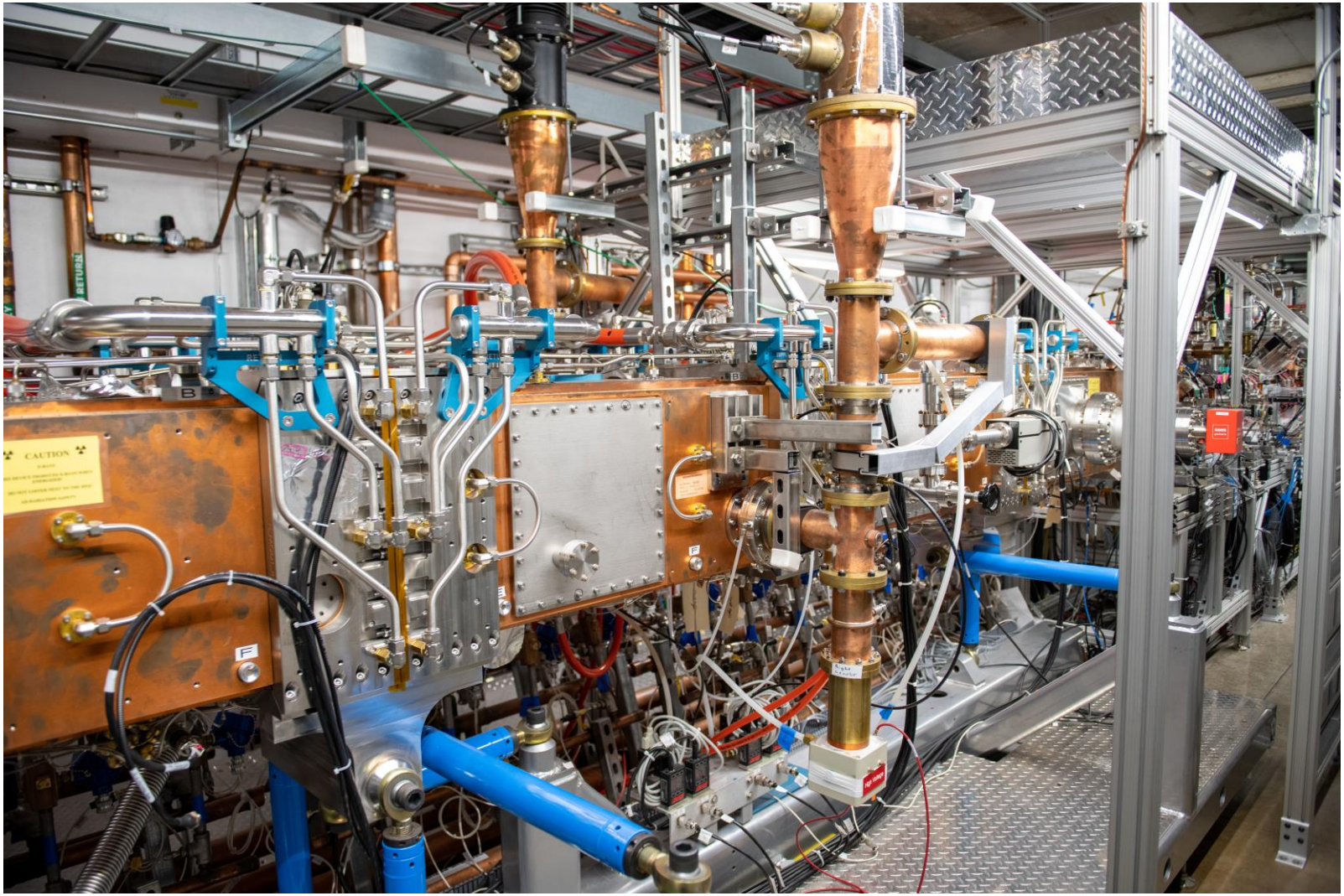


Photo Image – East Wall CMTF Cave

- RFQ Cooling (Right image)
- LEBT Cooling (Bottom image)

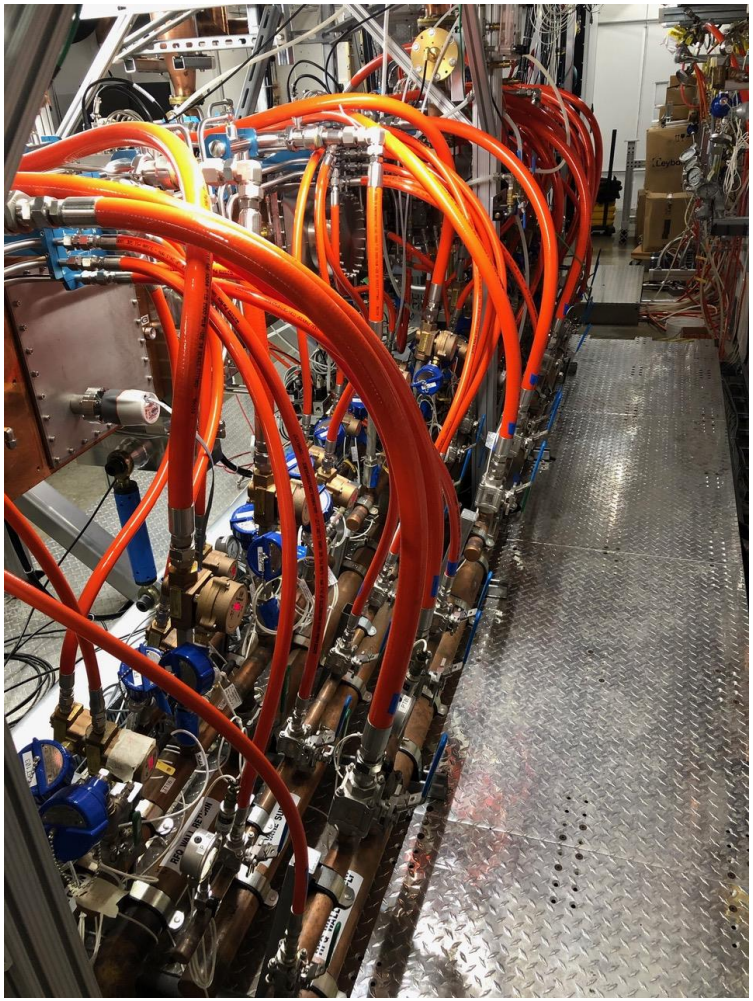


Photo Image - Warm Front End Process Fluids Cooling at CMTF

- MEBT Cooling (Right and Bottom)