# Primary Beamline
## Target Shield Pile Cooling Panel RAW System Preliminary Design Review

Technical Design Aspects

Raina Wang

February 19, 2020

# Purpose and Scope

- Preliminary design of the Target Shield Pile (TSP) Cooling Panel radioactive water (RAW) system to cool the inner layers of steel shielding of the target chase in Target Hall for 2.4MW beamline of LBNF project.
  - To supply and return cooling water for:
    - 36 cooling panels, 18 each side of the target chase
    - 8 small panels - attached to the bottom of some t-blocks

# Purpose and Scope – Cont.

- A stand along skid: equipment, pipes, valves, fittings, and field installed instruments
- Piping and piping components between the skid and the nozzles of 44 panels
- First valve between:
  - LBNF TH Exchange System and
  - Intermediate Water System, which covers the pipes
- Mechanical techniques for mitigating radiation risks
- All other EHS related radiation dose rate evaluations and control are excluded from this system
  - They are the work scope of ESH or Radiation Physicist Department

# Purpose and Scope – Cont.

**Picture 1: TSP Cooling Panel RAW Skid Location in Target Hall Complex**

# Design Standards and Codes

- ASME B31.3 Code for Normal Fluid Service
- ASME BPVC Section IX for Welding Process Specifications (WPS's) and welders & pipefitters' Personal Weld Qualifications
- Both piping and vessels will adhere to FESHM Chapter 5031, as well as the Fermilab Engineering Manual
- Numi/Nova systems' general operational feedbacks for improvement

# Design Requirements

- Safe, Reliable, and Economic
- Convenient for operation and maintenance
- Meet water quality and capacity of operational requirements for:
  - 1.2MW beamline – first phase
  - 2.4 MW beamline – $2^{nd}$ phase
- Design depth – sufficient for cost estimating for Project Budget

# Design Requirements – Process

## By Matt Slabaugh and Joseph Angelo

# LBNF Target Shield Pile Cooling Panel Fluid Requirements and Specifications

The LBNF Target Shield Pile Cooling Panel (TSP panels) function to intercept energy deposited on the inner layers of steel shielding of the target chase. The TSP panels consist of two layers of 2in steel plate, with a Trantor Style 30 Platecoil clamped between them. Eighteen TSP panels line each side of the target chase, for a total of 36 panels. In addition to these panels, there are 8 small panels attached to the bottom of some t-blocks

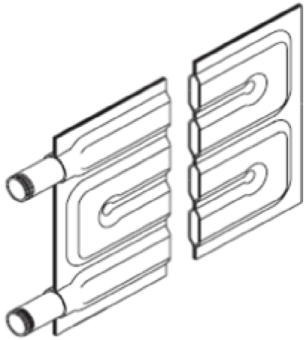


Fig. 20-3
Serpentine Style

*Figure 1 Trantor Platecoil (not full size)*

## General Requirements

1. Supply systems shall use components and fabrication techniques appropriate for a radiation environment and carrying RAW wherever possible.
2. Each TSP panel location shall have provision for isolating both supply and return of the panel.
3. Supply system shall be galvanically compatible with 304SS platecoils.
4. Supply piping system shall be capable of operating at flow rates at least 30% higher than the specified range, due to uncertainty in temperature requirements.
5. Supply system shall be capable of handling heat loads from both 1.2 MW and 2.4 MW beam running.
6. Supply piping system shall be integrated in the Target Shield pile CAD model to allow fitment within and around other elements of the shield pile.

## Specifications

| | | |
|---|---|---|
| Total number of panels | 36+8 | Design |
| Total heat load @ 1.2 MW beam | 280 kW | From DUNE-doc-13256-v1 Table III |
| Total heat load @ 2.4 MW beam | 550 kW | From DUNE-doc-13256-v1 Table III |
| Pressure drop across each panel | 65 PSI | From panel mfr. data |
| Supply temperature | 30°C | Design |
| Flow rate each panel | 3-8 GPM | Calculated flow requirement for an optimal steel temperature between 100C and 160C, as requested by Jim Hylen July 2019. Assumes Style 30 large pass platecoil. |
| Fluid volume each panel | ~7 Gal | 1.05 sq.in cross section X 11 passes X 144 in height = 1663 cu.in or ~ 7 Gal. The 8 small panels will be less |

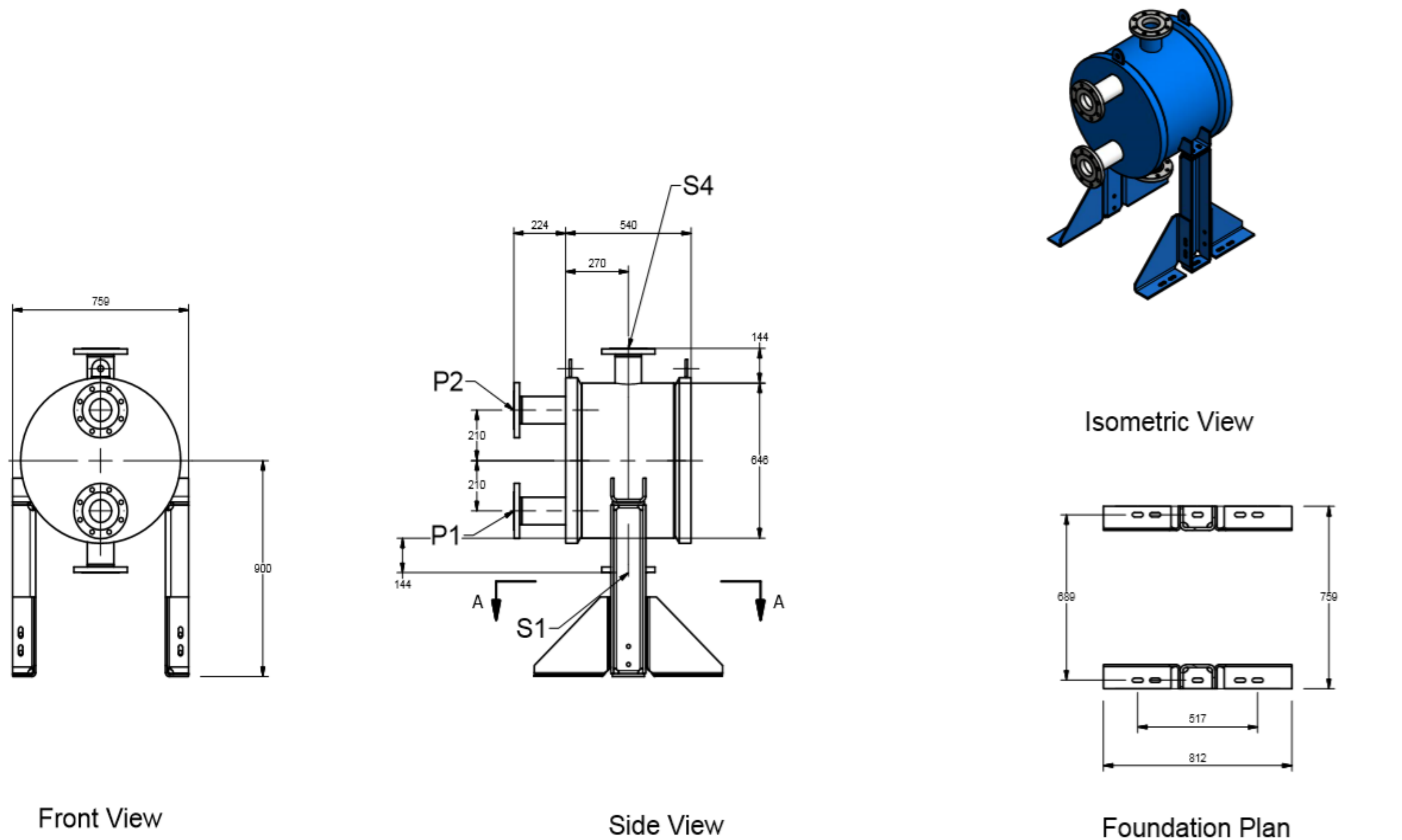
# Design Capacity – 450 GPM

| Table -1 Cooling Load and Design Capacity | | | | | | |
|---|---|---|---|---|---|---|
| | Unit | Operating | | Design | | |
| Beamline capacity | | 1.2 MW | 2.4MW | 1.2MW | 2.4MW | Safety factor |
| Total big panel | KW | 280 | 550 | 364 | 715 | 1.3 per process rqmts |
| Total small panel | KW | 56.7 | 113.4 | 73.71 | 147.42 | 1.3 per process rqmts |
| Pump | KW | | 23 | | 27.6 | 1.2 |
| Total | KW | | 686 | | 890 | |
| RAW supply temperature, $T_{in}$ | °F | 85 | 85 | | | |
| RAW return temperature, $T_{out}$ | °F | 95 | 100 | 95 | 100 | |
| Big panel total flow rate | GPM | 191.1 | 250.3 | | 325.4 | |
| Big panel Quantity | | 36 | 36 | 36 | 36 | |
| Big panel single flow rate | GPM | 5.31 | 6.95 | | 9.04 | |
| Small panel total flow rate | GPM | 38.70 | 51.60 | | 67.09 | |
| Small panel single flow rate | GPM | 4.83 | 6.45 | | 8.38 | |
| Small panel quantity | | 8 | 8 | 8 | 8 | |
| Intermediate cooling water temperature in | °F | 65 | 65 | 65 | 65 | |
| Intermediate cooling water temperature out | °F | 77 | 77 | 77 | 77 | |
| Total Mass flow rate calculated | GPM | 229.83 | 301.89 | | 392.5 | |
| Total Mass flow rate (Matt Slabaugh provided) | GPM | 146.7 | 339.6 | | 441.5 | 1.3 per process rqmts |

# Equipment Selection and Sizing - Heat Exchanger

- Capacity: 900 KW, actual 950KW
- Type: Tranter Superchanger plate and frame unit
  - a welded unit
  - eliminate leaking
- Material: SS
  CS shell and cover - optional
- ASME code compliance
- Design condition: 150Psig @ 200ºF
- MAWP: ≥200 Psig
- MMDT: -20 deg. F
- Hot side: Temperature – ΔT = 15deg.
  Tin = 85 deg. F Tout = 100 deg. F
  Flow rate – 435 GPM
- Cold side: temperature - ΔT = 12 deg.
  Tin = 65 deg. F Tout = 77 deg. F
  Flow rate – 490 GPM

# Equipment Selection and Sizing – Heat Exchanger




ıring tolerances as per ISO 13920-C

| NOZZLE TABLE | | | |
|---|---|---|---|
| Nozzle | In/Out | Size | Flange Description |
| S4 | Out | DN100 | ASME Flange - DN100 [4] SA105 150lb RFSO |
| S3 | | | |
| S2 | | | |
| S1 | In | DN100 | ASME Flange - DN100 [4] SA105 150lb RFSO |
| P4 | | | |
| P3 | | | |
| P2 | In | DN100 | ASME Flange - DN100 [4] SA182F 150lb RFSO |
| P1 | Out | DN100 | ASME Flange - DN100 [4] SA182F 150lb RFSO |

| | |
|---|---|
| DRAWN BY | CDIII Engine |
| CHK BY | CDIII Engine |
| APPD BY | CDIII Engine |
| DATE | 11-27-2019 |
| SCALE | 1:16 |

THIRD ANGLE PROJECTION

ALL DIMENSIONS ARE IN MILLIMETERS UNLESS OTHERWISE SPECIFIED. DIMENSIONS IN BRACKETS ARE IN INCHES.

SHEET SIZE A3

TRANTER The heat transfer people

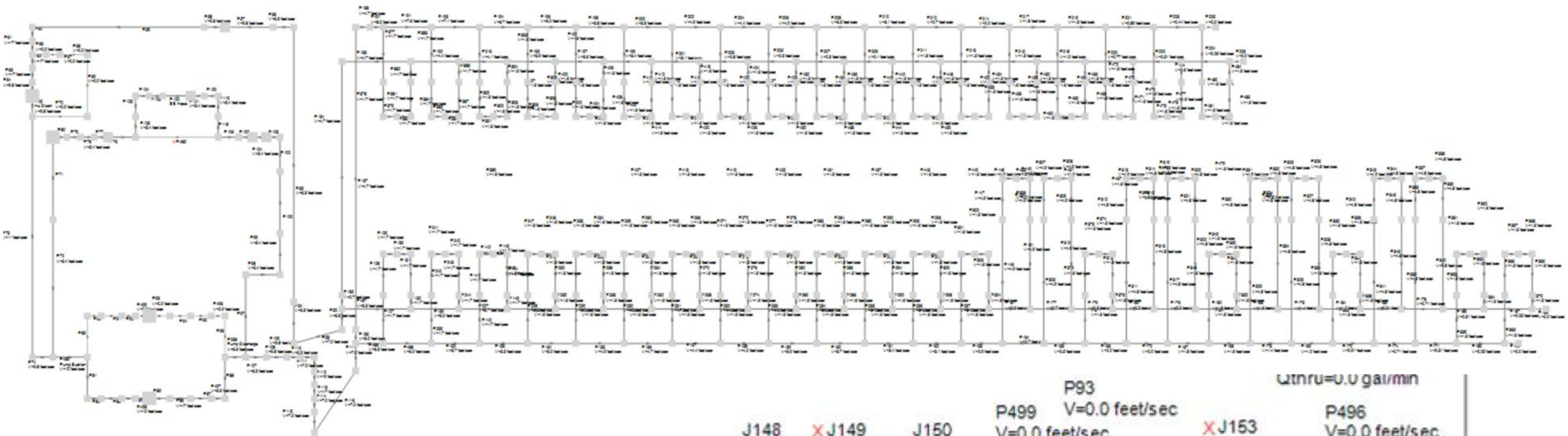
TITLE: General Arrangement Drawing

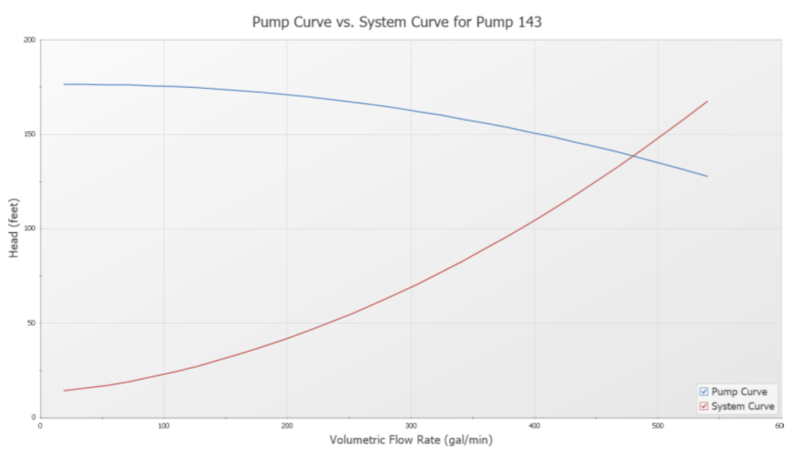
| MODEL NO. | DRAWING NO. | SHEET | REV. |
|---|---|---|---|
| SPW-055-H-08-108-1-1-W | 1187387 | 1 of 1 | 0 |

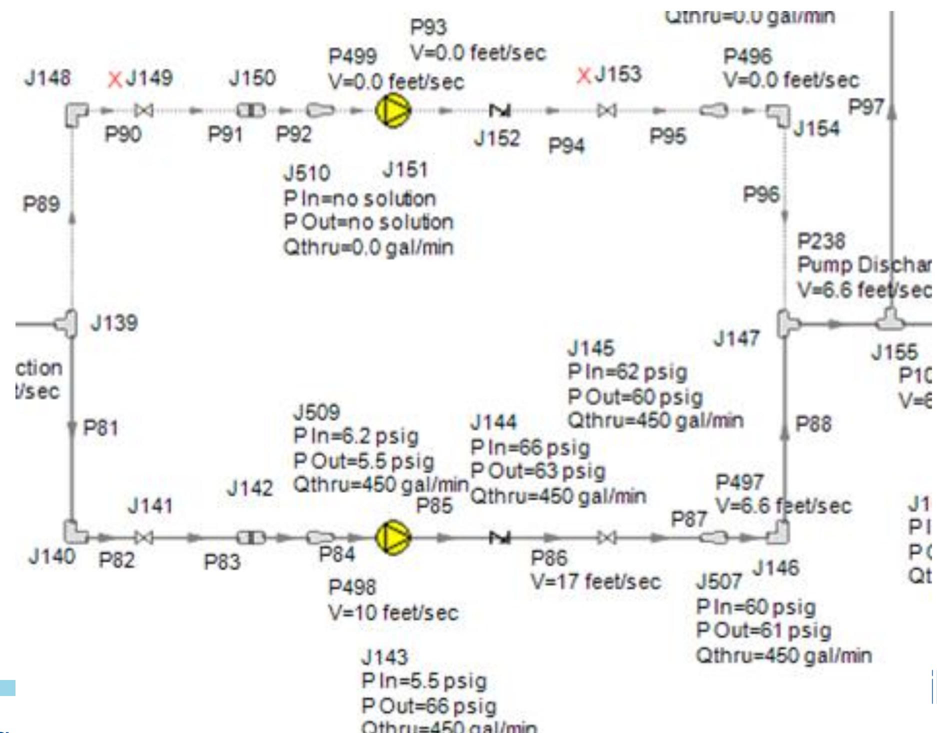
# Equipment Selection and Sizing – Pumps, Piping, Control Valves

- Sizing method: Hydraulic simulation
- Sizing technology: AFT Fathom software, version 9
- Multiple operation modes simulated:
  - Design condition (2.4MW beamline): 450 GPM
  - 1.2MW beamline condition: 147 GPM
- Results:
  - Pump:  450 GPM @ 143 ft TDH
  - Pipe header: 5” NPD and branch head 4” NPD
  - Control valve: 3”

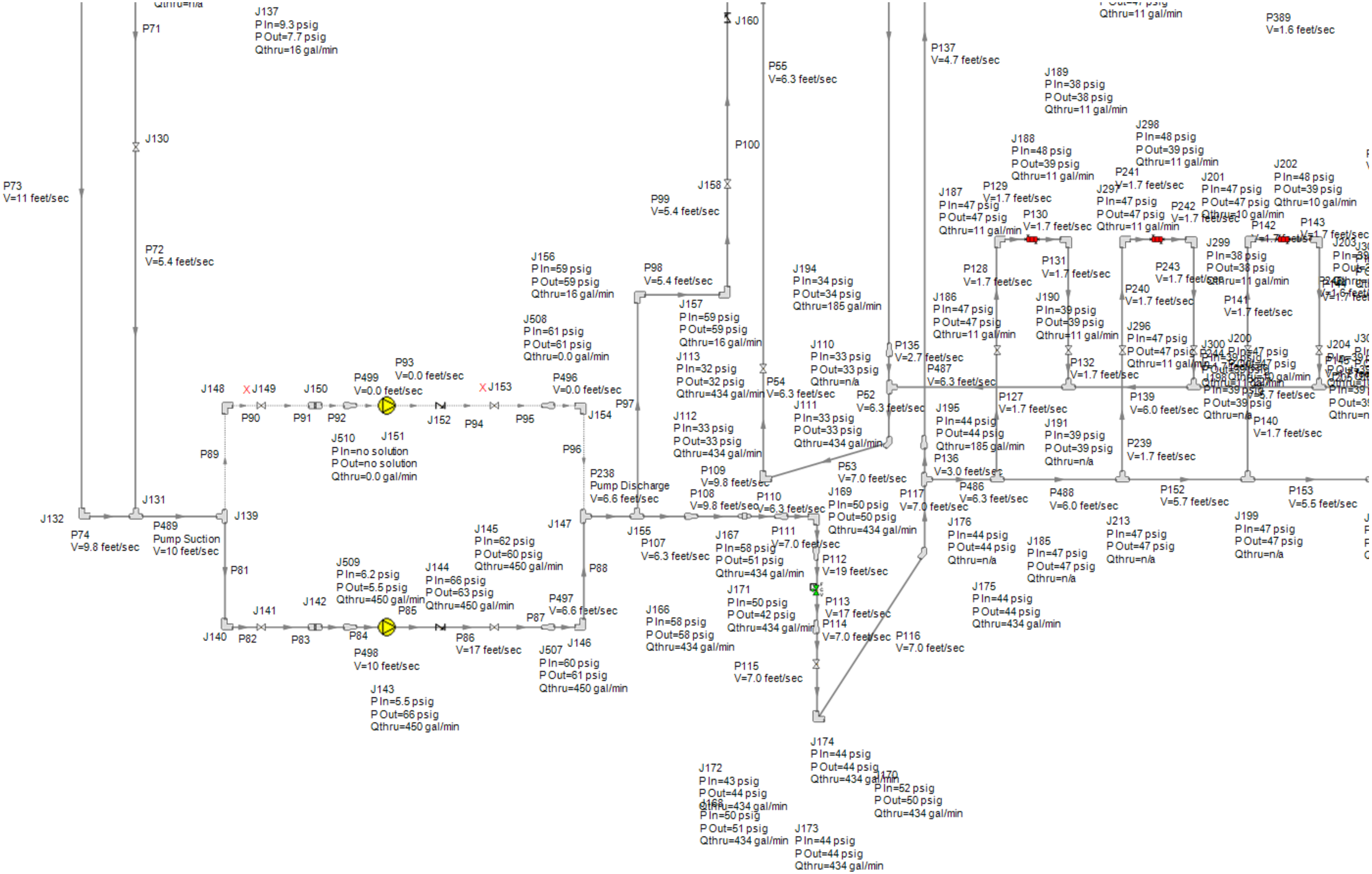
# Equipment Selection and Sizing – Cont.
# - AFT Fathom Simulation Results



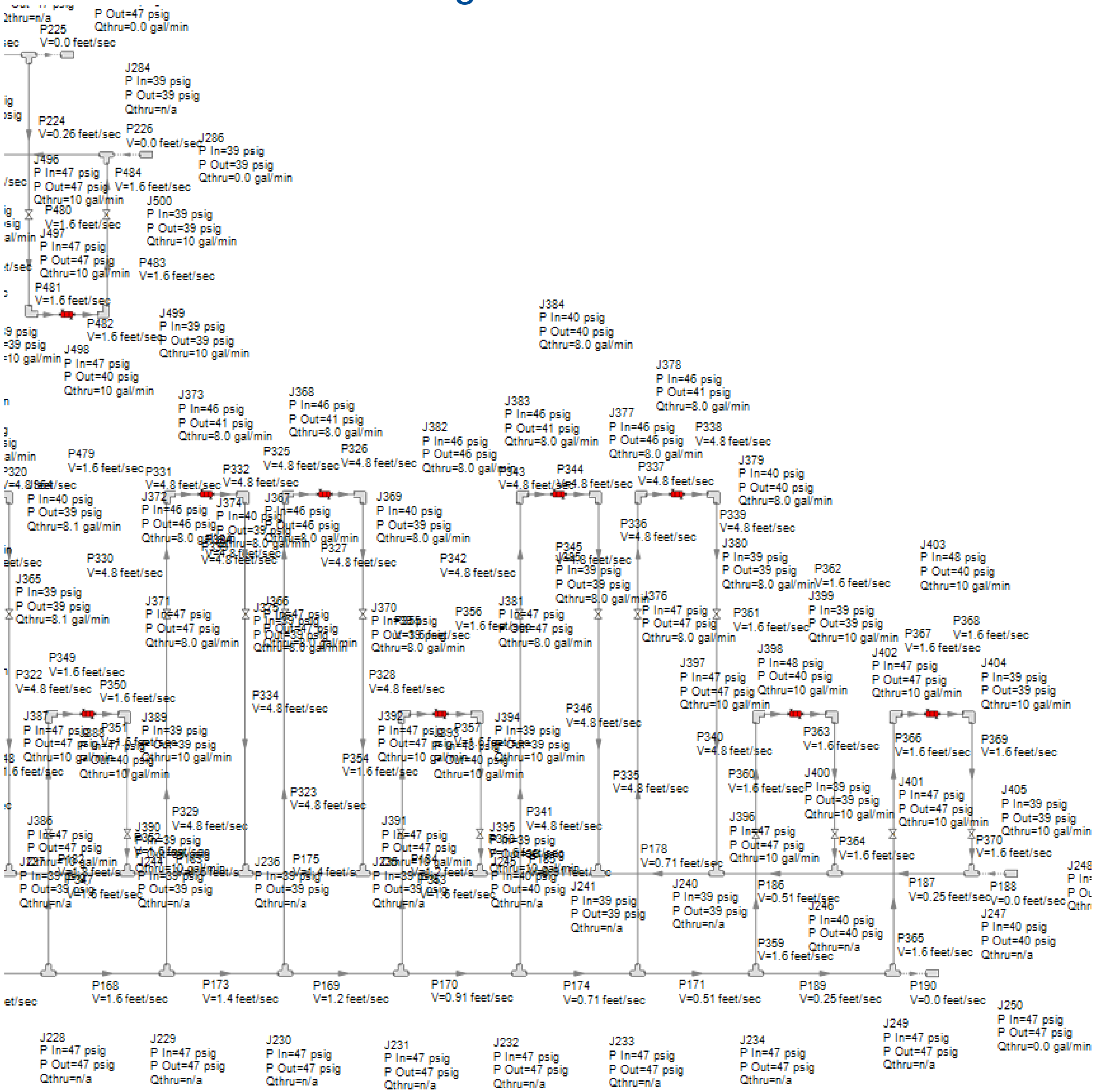


# Equipment Selection and Sizing – Cont.
# - AFT Fathom Simulation Results



# Equipment Selection and Sizing – Cont.: - AFT Fathom Simulation Results



# Equipment Selection and Sizing – Cont.
# - Pump Selected, Sized

- Two Centrifugal Pumps: one op / one standby
- Type: Canned motor centrifugal pumps – Sealless
- Capacity Index:
  - 450 GPM @143 ft TDH, meet max. flow requirements of 2.4MW
  - Min. flow: 110 GPM
  - Min. flow meet 1.2 MW beamline requirements: 147 GPM
  - Cut off flow: 100 GPM
  - Shut off head: 175 ft
- Variable speed control: Benefit and radiation degradation

  - based on Numi operation experience

# Equipment Selection and Sizing – Cont.
# - Pump Selected, Sized

NIKKISO Products and Services Research and Development About Us Investor Relations

HOME > Products and Services > Pumps and Systems > Canned Motor Pumps

## Canned Motor Pumps (Non-Seal® Pumps)

NIKKISO Non-Seal® Pumps
Leak-free pumps best suited for use with high-temperature and dangerous liquids

Features Specifications Applications Product Lineup

Contact Us Request for Brochure Model Numbers

### Features

Sealless pumps with leak-proof construction with the pump and motor integrated into one housing.

**Main features**

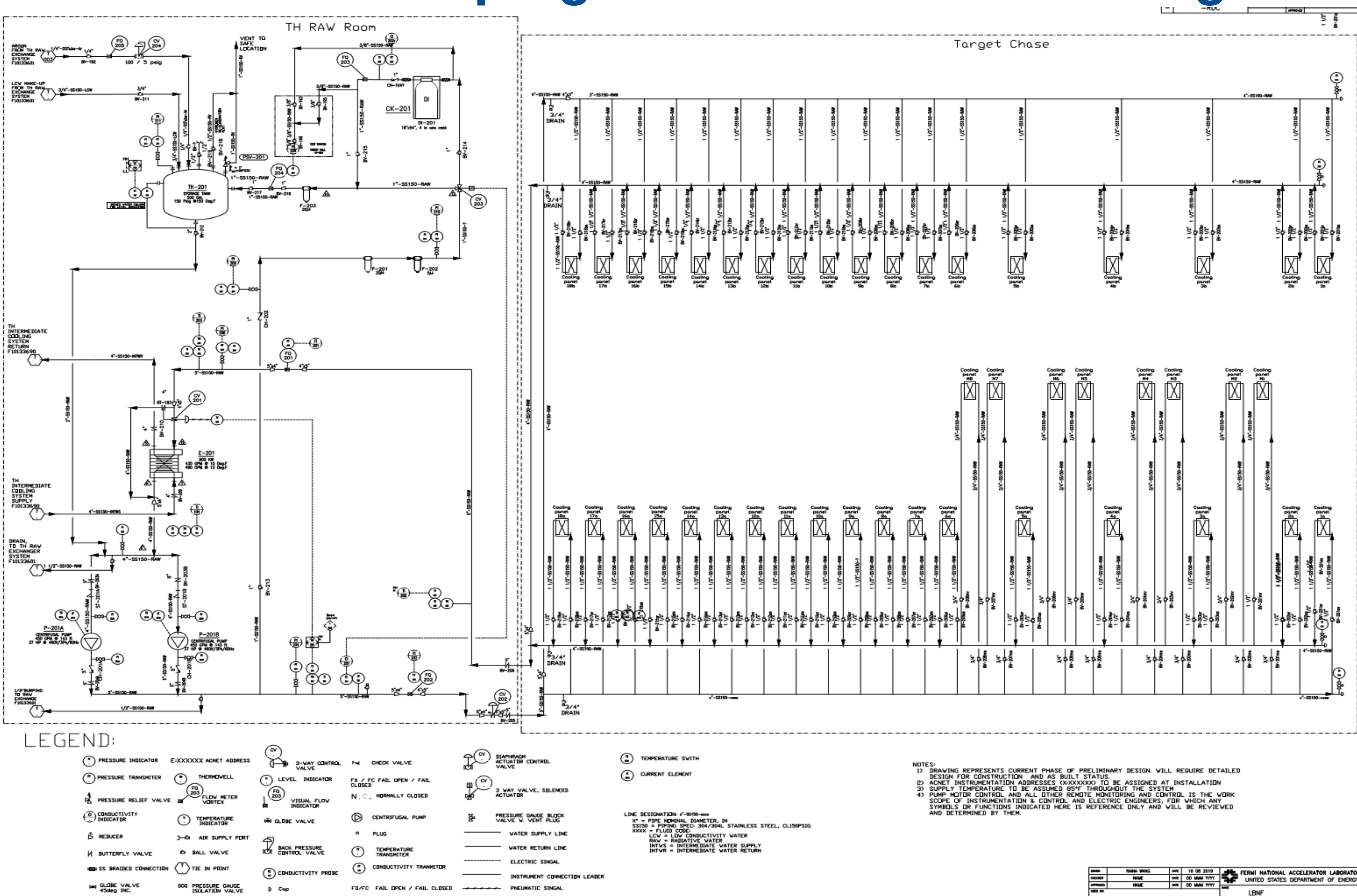
- Leak-free
- Adaptable to a wide range of pressures and temperatures
- Easy to assemble and
- Compact, space saving design
- Low vibration and noise
- Compliant with international and national standards

# Equipment Selection and Sizing – Cont.
# - Detailed Equipment List and Spec

**LBNF Target Shield Pile Cooling Panel RAW System - Equipment List and Specification**

| # | Tag # | Name | Quantity | Type or model number | Operating / Design Condition | | | | | | | Materials | Cost ($) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Service Fluid | Flow rate (GPM) or volume | | Pressure (Psig) | | Temperrature ( °F) | | | | |
| | | | | | | Operating | Design | Operating | Design | Operating | Design | | Unit | Sub-total |
| 1 | TK-201 | Storage tank | 1 | SST-500 gallons vertical economy finish vessel<br>60" dia x 42" s/s x 86" OAH<br>w. nozzles per P&ID | Radioactive water | | 500 Gallon | 5 | 150 Psig internal / full vacuum external Per ASME BPVC VIII. Div. I, stamped | 55 - 85 | 200 | 304L SS | $29,252 | $29,252.00 |
| 2 | P-201A/B | Canned Motor Pumps Centrigugal | 2 | NC Series, Model NC-A70-8-N5-1S, seal-less, centrifugal, canned motor pump<br>450 GPM @ 143 TDH,<br>37 Hp motor @460V/3Phase/60Hz, 3600 RPM,<br>Inlet/outlet nozzle size: 4" / 3" RF flangs<br>Radiation limit: 2 x $10^8$ rads | Radioactive water | 153 GPM @ 1.2MW beam line<br>355 GPM @ 2.4MW beam line | 450 GPM | 61 | 150 | 55 - 85 | 150 | SS316 body & shell; Bearings: Carbon Graphite Type B insert with 316 SS sleeve; Gaskets: 316 SS stainless steel / graphite spiral wound type; Electrical feed through: copper wire, PEEK insulation and spacers, Vespel SP-1 sealant | $56,500 | $113,000 |
| 3 | E-201 | Heat exchanger | 1 | Plate and frame heat exchanger<br>Tranter SPW-055-H-08-108-1-1-W<br>900 KW capacity, ΔP <=10 Psi @ hot<br>ΔP <=15 Psi cold side | Radioactive water @ hot side<br>LCW water @ cold side | 147 GPM @ 1.2MW beam line<br>340 GPM @ 2.4MW beam line | 435 @hot side<br>434@cold side | 0 - 30 @hot side<br>0 - 50 @cold side | 150 | 100 in / 85 out @hot side<br>70 in / 85 out @cold side | -20 / 200 | SS316 nozzles, plates & shell; viton gaskets | $38,708 | $38,708 |
| | | | | | | | | | | | | All SS316 | $53,283 | $53,283 |
| 4 | DI-201 | Deionization bottles | 4 | SF16 X 65-FER<br>Mixed Bed PEDI 16 x 65 PG tank, 6.5 Ft.³ w/new IRN-150 MIXED BED RESIN, ¾ NPT in/out, ¼ "vent, ¾" NPT riser | Radioactive water | 10 | 12 | 30 | 150 | 85 | 120 | Fibergass tank | $3,370 | $13,480 |
| 5 | CK-201 | DI bottle cask | 1 | 48" x 48" x 81 5/8" per Fermilab drawing # 8875.00-ME-488210 | N/A | Amb. | Amb. | Amb. | Amb. | Amb. | 150 | | $22,000 | $22,000 |
| 6 | F-201 | Signle cartridge filter - µ20 | 1 | Fulfl o® BSSB Filter Vessel<br>BSSB-30-1SD<br>1"NPT, VITON O-RINGS | Radioactive water | 10 | 15 | 85 | 150 | 85 | 140 | 316 SS | $1,060 | $1,060 |
| 7 | F-202 | Signle cartridge filter - µ5 | 1 | Fulfl o® BSSB Filter Vessel<br>BSSB-30-1SD<br>1"NPT, VITON O-RINGS | Radioactive water | 10 | 15 | 85 | 150 | 85 | 140 | 316 SS | $1,060 | $1,060 |
| 8 | F-203 | Signle cartridge filter - µ20 | 1 | Fulfl o® BSSB Filter Vessel<br>BSSB-30-1SD<br>1"NPT, VITON O-RINGS | Radioactive water | 10 | 15 | 85 | 150 | 85 | 140 | 316 SS | $1,060 | $1,060 |
| | | | | | | | | | | | | | | $0 |
| | | Total cost $ | | | | | | | | | | | | $234,195 |

# Process Flow – Piping & Instrumentation Diagram



# Water Quality Control

- Initial fill: LCW – from TH RAW Exchange System
- Impurity concentration increases with time
- Control:
  - Argon blanketing in storage tank
  - Periodic burping predetermined amount of RAW
  - Filtration:
    - DI loop: 2 stage filtration in series: one 20µm / one 5µm
      - Impurity particle size less than: 5µm
      - Extra filter guard in case DI problem: <=20µm
      - Fermi conventional DI bottle – 4 in one Cask
  - Maintaining Water resistivity: 4 – 8 $M\Omega \times cm$

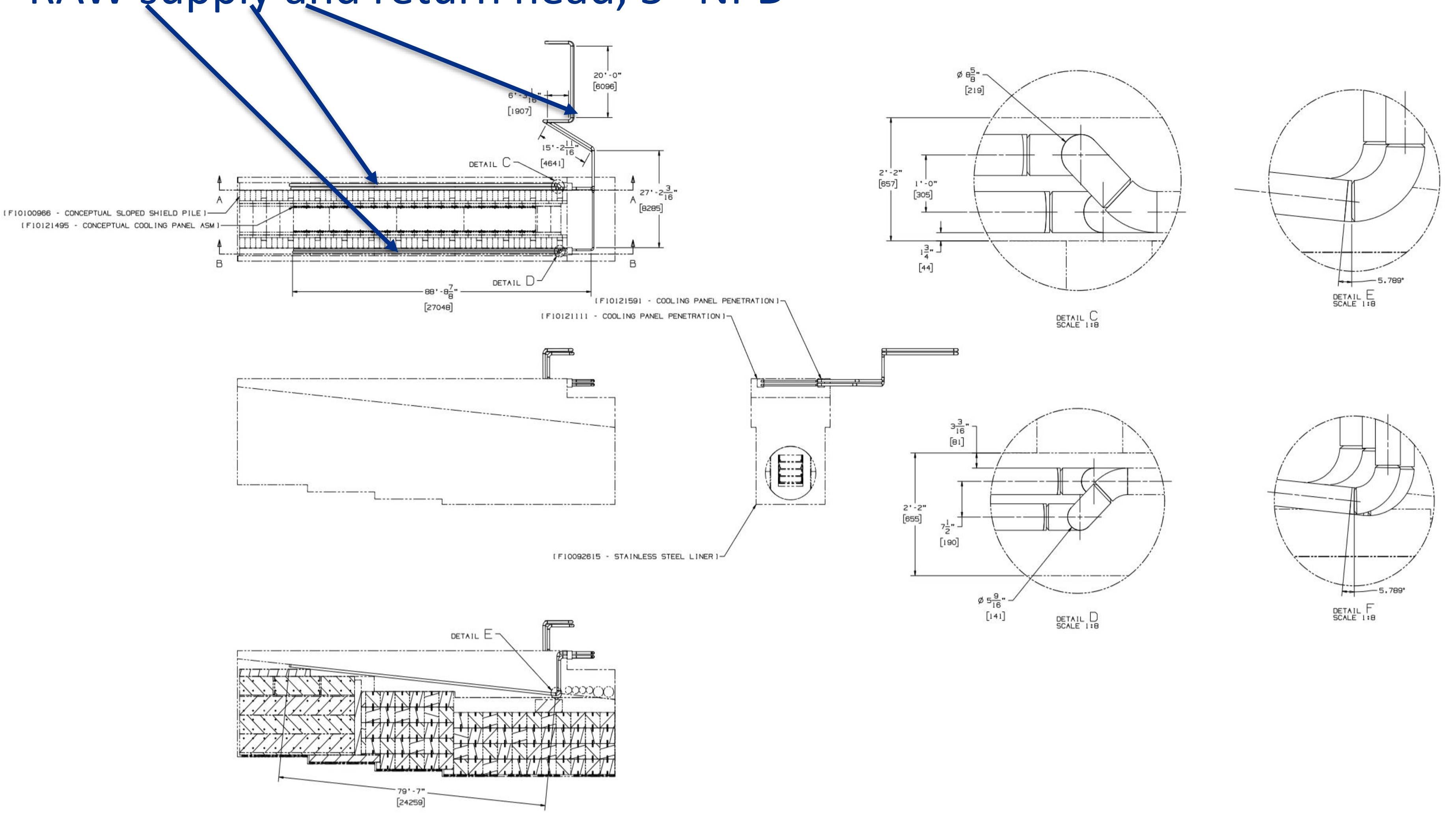
# ESH – Radiation Risk Control

- Risks:
  - Initial LCW - to be radioactiviated after short running – becoming RAW
  - The prompt radiation dose rates from the RAW skid – high!
  - Short-lived radionuclides, large concentrations of the tritium will build up in the systems
- Mechanical Controls:
- To prevent RAW from intermixing with the environment, the cold side cooling water of the heat exchanger is supplied by and discharged to an adjacent Intermediate Water System
- Clean in place containment - for RAW leakage, spill and tritium capture

  - preventing soil and surface water contamination
- Remotely controlled drainage and top up with fresh water - used to keep the tritium concentrations at manageable levels
- Wastewater will be disposed of as low-level radioactive waste after cooling-down or decayed
- Radiation hardened materials – equipment, piping components
- Electronic devices: P, T, Q, L transmitters - installed further away from high radiation area to prevent radiation degradation

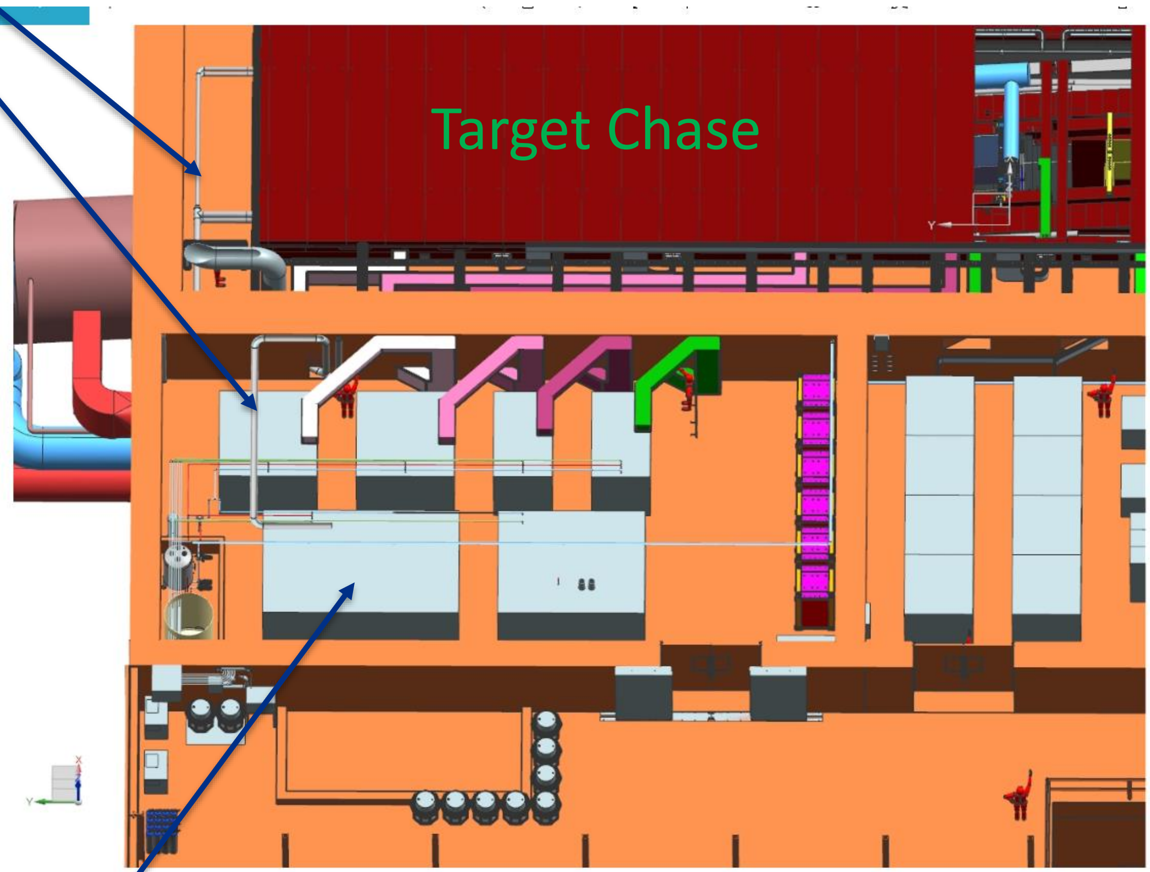
# Equipment and Piping Layout - Plan View

RAW supply and return head, 5” NPD



# Equipment and Piping Layout - 3D Top View

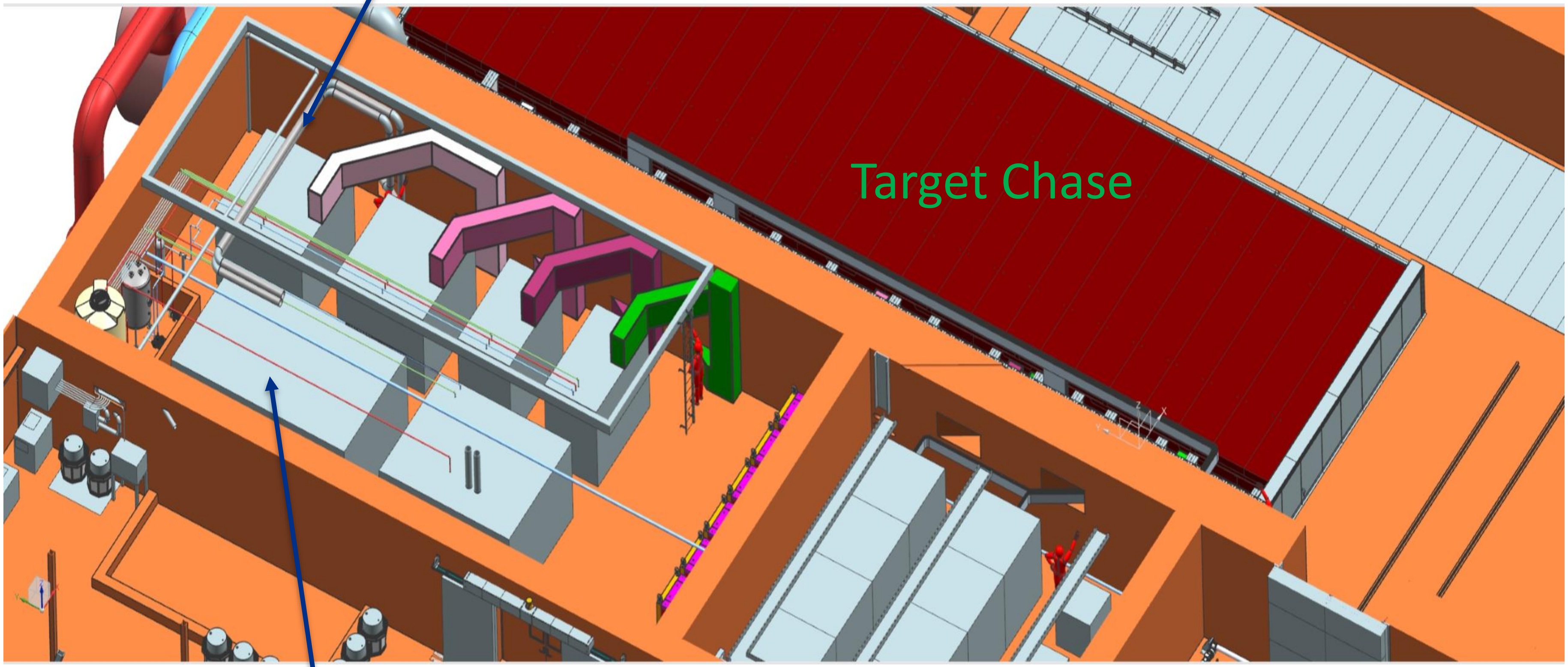
RAW supply and return head, 5” NPD




TSP Cooling Panel RAW Skid

# Equipment and Piping Layout - 3D View

RAW supply and return head, 5” NPD




TSP Cooling Panel RAW Skid

# Questions?

*Thank You!*

*By Raina Wang*

*Mechanical Beamline Engineer*

*Feb. 19, 2020*