Primary Beamline Target RAW System Preliminary Design Review

Technical Design Aspects

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February 19, 2020

Purpose and Scope

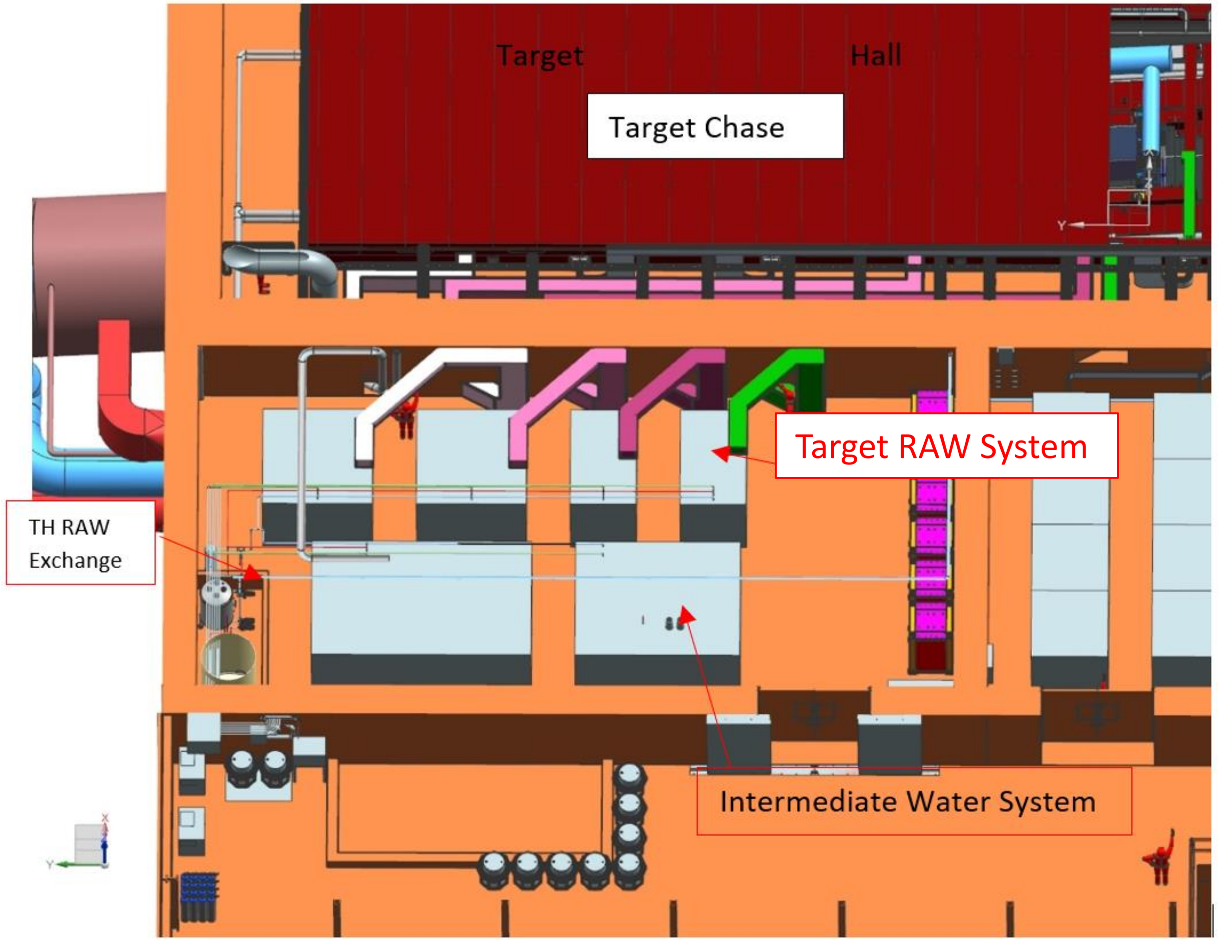
- Preliminary design of the Target radioactive water (RAW) system for 2.4MW beamline of LBNF project
  - To supply and return cooling water to and from:
    - Target Mount
    - Target Heat Exchanger
    - Baffle Hanger, and
    - Baffle of the Target Chase

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 4 users
- 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: TH RAW System Skid Location in Target Hall Complex



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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 – 2nd phase as Designed phase
- Design depth – sufficient for cost estimating for Project Budget

Design Standards and Codes

- Follow basis established in conceptual design report for this system
- Numi/Nova systems' general operational experience or feedbacks for improvement modifications
- 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

Design Capacity: Target & Baffle RAW System - Heat Loads
(Conceptual Design, October 2017)

- Total heat load: 77 KW
Target Hall RAW System – Heat Loads

Optimized Beam *			
1.2MW		2.4MW	
RAW	Helium	RAW	Helium
2.0		4.0	
5.0		10.0	
22.5	12.5	45.0	25.0
2.4		4.8	
3.0		6.0	
3.5		7.0	
38.4		76.8	

Required Flows (units gpm)

Optimized Beam			
1.2MW		2.4MW	
RAW	Helium	RAW	Helium
2.0		2.0	
5.0		10.0	
10.3	45 g/s	20.6	90 g/s
3.0		5.0	
10.0		10.0	
0.0		0.0	
3.0		4.8	
26.3		40.4	

As of October 2017; values may have changed

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Design Capacity: Cooling Load – Volume Flow Rate Calculation Result

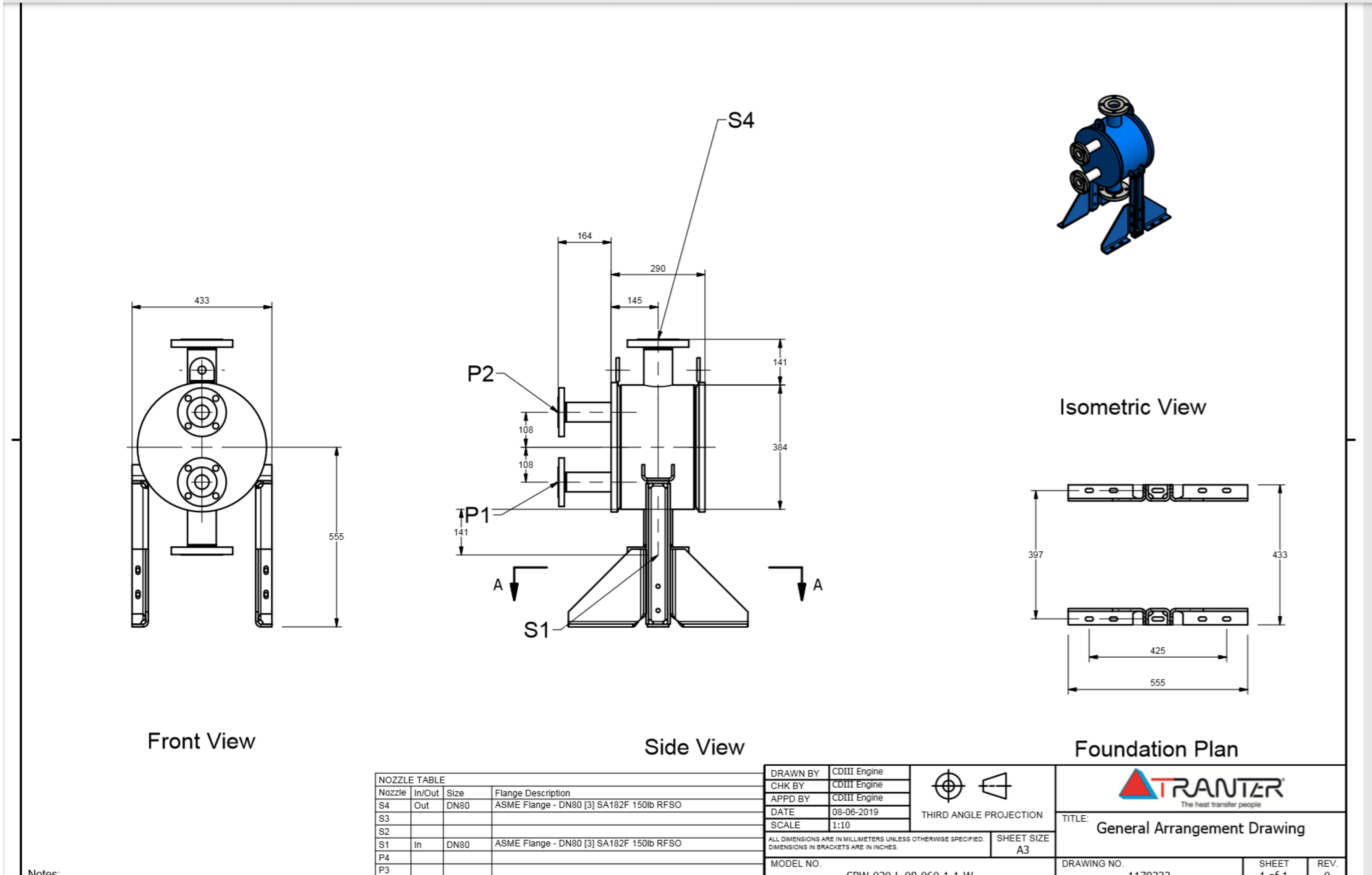
Design Capacity – volume rate: 57 GPM

Table – 1 Cooling Water Flow Rate of Target RAW System (GPM)				
Flow source	1.2 MW		2.4 MW	
	RAW	Helium	RAW	Helium
Hanger	2		2	
Mount	5		10	
Target Total (2 lines)	10.3	45g/s	20.600	90g/s
Baffle	3		5	
Filter / DI loop	10		10	
Subtotal	30.3		47.600	
Margin: 20%	6.06		9.520	
Total	36.36		57.120	

Major Equipment Selection and Sizing - Heat Exchanger

- Capacity: 77 KW
- 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 = 11deg.
  Tin = 96 deg. F   Tout = 85 deg. F
  Flow rate – 50 GPM
- Cold side: temperature - ΔT = 12 deg.
  Tin = 65 deg. F   Tout = 77 deg. F
  Flow rate – 45 GPM

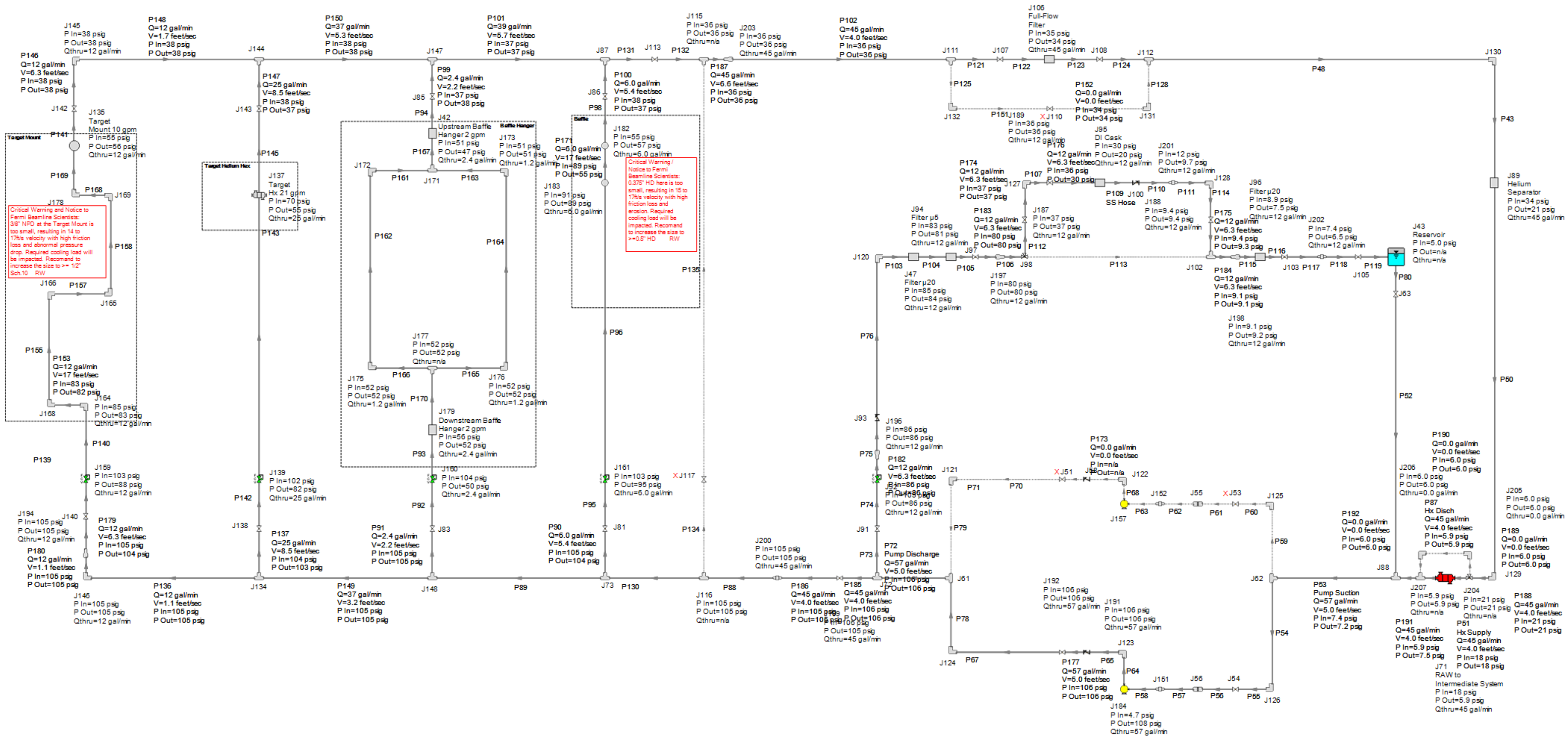
Equipment Selection and Sizing – Heat Exchanger



Equipment Selection and Sizing – Pumps & Piping

- Sizing method: Hydraulic simulation
- Sizing technology: AFT Fathom software, version 9
- Multiple operation modes simulated:
  - Design condition: 57 GPM
  - Operating condition: 48 GPM
  - A special condition for concerns of tubing size of Target mount and Baffle – increasing tubing size from 0.375” HD to 0.5”

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



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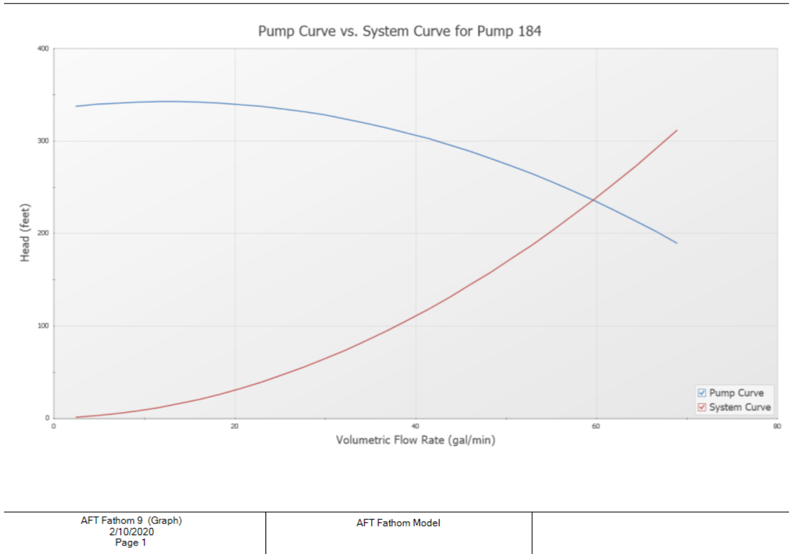
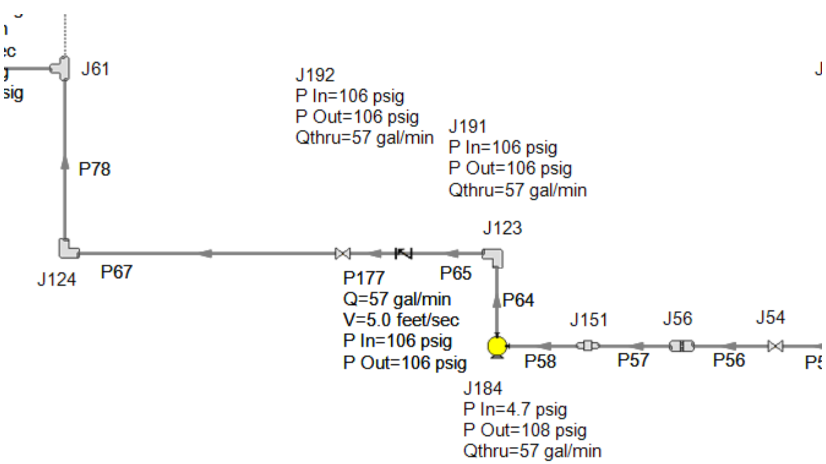
Equipment Selection and Sizing - Pumps

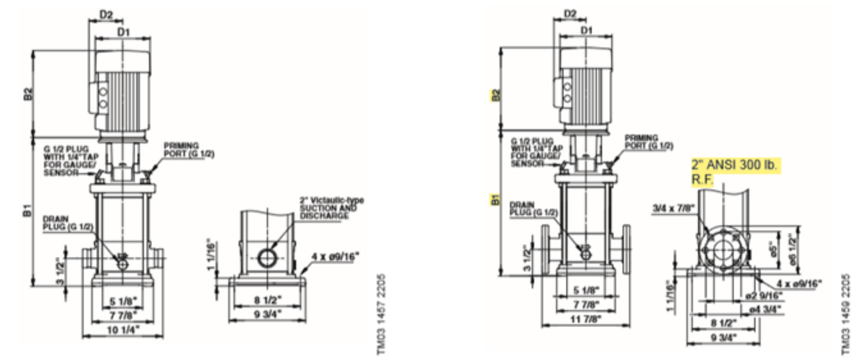




50 GRUNDFOS

CR, CRI, CRN Technical data

CRN 10



Pump type	P2 [Hp]	Ph.	PJE*	ANSI dimensions [inch (mm)]							Ship. wt. [lbs (kg)]
				B1	TEFC			ODP			
					D1	D2	B1+B2	D1	D2	B1+B2	
CRN 10-1	3/4	1	•	15.20 (387)	6.19 (158)	5.18 (132)	25.11 (638)	-	-	-	106 (49)
		3	•	15.20 (387)	5.55 (141)	4.57 (117)	22.64 (576)	-	-	-	97 (44)
CRN 10-2	1 1/2	1	•	15.20 (387)	7.19 (183)	5.73 (146)	26.88 (683)	-	-	-	121 (55)
		3	•	15.20 (387)	5.55 (141)	4.57 (117)	23.82 (606)	-	-	-	99 (45)
CRN 10-3	3	1	•	17.13 (436)	8.60 (219)	6.87 (175)	31.78 (808)	-	-	-	176 (80)
		3	•	17.13 (436)	7.01 (179)	4.33 (110)	30.36 (772)	-	-	-	147 (67)
CRN 10-4	3	1	•	18.31 (466)	8.60 (219)	6.87 (175)	32.96 (838)	-	-	-	176 (80)
		3	•	18.31 (466)	7.01 (179)	4.33 (110)	31.54 (802)	-	-	-	149 (68)
CRN 10-5	5	1	•	19.49 (496)	10.62 (270)	7.46 (190)	35.01 (890)	-	-	-	203 (93)
		3	•	19.49 (496)	8.66 (220)	5.28 (135)	35.00 (889)	-	-	-	199 (91)
CRN 10-6	5	1	•	20.67 (526)	10.62 (270)	7.46 (190)	36.19 (920)	-	-	-	205 (93)
		3	•	20.67 (526)	8.66 (220)	5.28 (135)	36.18 (919)	-	-	-	201 (92)
CRN 10-7	7 1/2	1	•	22.17 (564)	10.22 (260)	7.62 (194)	37.7 (958)	-	-	-	227 (103)
		3	•	22.17 (564)	8.66 (220)	5.28 (135)	37.68 (958)	-	-	-	214 (98)
CRN 10-8	7 1/2	1	•	23.35 (594)	10.22 (260)	7.62 (194)	38.88 (988)	-	-	-	229 (104)
		3	•	23.35 (594)	8.66 (220)	5.28 (135)	38.86 (988)	-	-	-	216 (98)
CRN 10-9	7 1/2	1	•	24.53 (624)	10.22 (260)	7.62 (194)	40.06 (1018)	-	-	-	232 (106)
		3	•	24.53 (624)	8.66 (220)	5.28 (135)	40.04 (1018)	-	-	-	218 (99)
CRN 10-10	7 1/2	1	•	25.71 (654)	10.22 (260)	7.62 (194)	41.24 (1048)	-	-	-	234 (107)
		3	•	25.71 (654)	8.66 (220)	5.28 (135)	41.22 (1047)	-	-	-	221 (101)
CRN 10-12	10	1	•	28.07 (713)	10.23 (260)	10.30 (262)	44.14 (1122)	-	-	-	346 (157)
		3	•	28.07 (713)	10.24 (261)	6.26 (160)	42.80 (1088)	-	-	-	225 (103)
CRN 10-14	15	3	•	32.95 (837)	12.36 (314)	8.00 (204)	51.49 (1308)	10.62 (270)	7.33 (187)	49.25 (1251)	403 (183)
CRN 10-16	15	3	•	35.31 (897)	12.36 (314)	8.00 (204)	53.85 (1368)	10.62 (270)	7.33 (187)	51.63 (1312)	413 (188)
CRN 10-17	15	3	•	37.68 (958)	12.36 (314)	8.00 (204)	56.22 (1428)	10.62 (270)	7.33 (187)	54.00 (1372)	418 (190)

All dimensions in inches unless otherwise noted.

* PJE flanged pump B1 and B1+B2 dimension is equal to ANSI flanged pumps and weight is approximately 9 lbs. less.

• Available.

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

- Two Centrifugal Pumps:
  one op / one standby
- Type: Centrifugal pumps w. MagDrive
  Power: 7.5 HP
- Capacity:
  - 59 GPM @ Head 242.8 ft, meet max. flow rqmt @ 2.4MW
  - Min. flow 5 GPM
  - Stable @26 GPM, meet 1.2 MW beamline requirements
- NPSHR (net positive suction head required): 13.33 ft
- NPSHA : 43.9 ft
- Variable speed control: benefit and radiation degradation

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

LBNF Target Hall RAW System - Equipment List and Specification														
#	Tag #	Name	Quantity	Type or model number	Operating / Design Condition							Materials	Manufacturer / Vendor	Notes
					Service Fluid	Flow rate (GPM) or volume		Pressure (Psig)		Temperarture (^{o}F)				
						Operating	Design	Operating	Design	Operating	Design			
1	TK-101	Storage tank	1	SST-200 gallons vertical e conomy finish vessel 36" dia x 48" s/s x84" OAH w. nozzles per P&ID	Radioactive water		200 Gallon	5	50 Psig internal / full vacuum external Per ASME BPVC VIII. Div. I	55 - 85	150	304L SS	BEFCO, Inc.	
2	P-101A/B	Centrigugal pump	2	Grundfos CRN10-7 58GPM @ 235 TDH, 7.5Hp mag. motor @460V/3Phase/60Hz Inlet/outlet nozzle size: 2" / 2"	Radioactive water	48	58		240FT W. TDH	55 - 85	150	SS316 body & PEEK neck ring	A-L Equipment Co.	Price includes shipping
3	E-101	Heat exchanger	1	Plate and frame heat exchanger Tranter SPW-030-L-08-060-1-1-W 77KW capacity, ΔP <=10 Psi @ hot or cold side	Radioactive water	38 @ hot side	50 @hot side 35@cold side	0 - 30 @hot side 0 - 50 @cold side	100	95.6 in / 85 out @hot side 70 in / 85 out @cold side	-20 / 130		Tranter / METERS CONTROLS	
4	DI-101	Deionization bottles	4	SF16 X 65-FER 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	Calco LTD	Price includes shipping
5	CK-101	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		Fermilab	
6	F-101	Signle cartridge filter - µ20	1	Fulfl o® BSSB Filter Vessel BSSB-30-1SD 1"NPT, VITON O-RINGS	Radioactive water	10	15	85	150	85	140	316 SS	Parker / Instrument Associates	
7	F-102	Signle cartridge filter - µ5	1	Fulfl o® BSSB Filter Vessel BSSB-30-1SD 1"NPT, VITON O-RINGS	Radioactive water	10	15	85	150	85	140	316 SS	Parker / Instrument Associates	
8	F-103	Signle cartridge filter - µ20	1	Fulfl o® BSSB Filter Vessel BSSB-30-1SD 1"NPT, VITON O-RINGS	Radioactive water	10	15	85	150	85	140	316 SS	Parker / Instrument Associates	
9	F-104	Multi-Cartridge Filter - µ20	1	Fulfl o® EH Multi-Cartridge Filter Vessel: EHG05T 5 x 30"	Radioactive water	38	75	33	150	85	140	316 SS	Parker / Instrument Associates	
		Total cost $												

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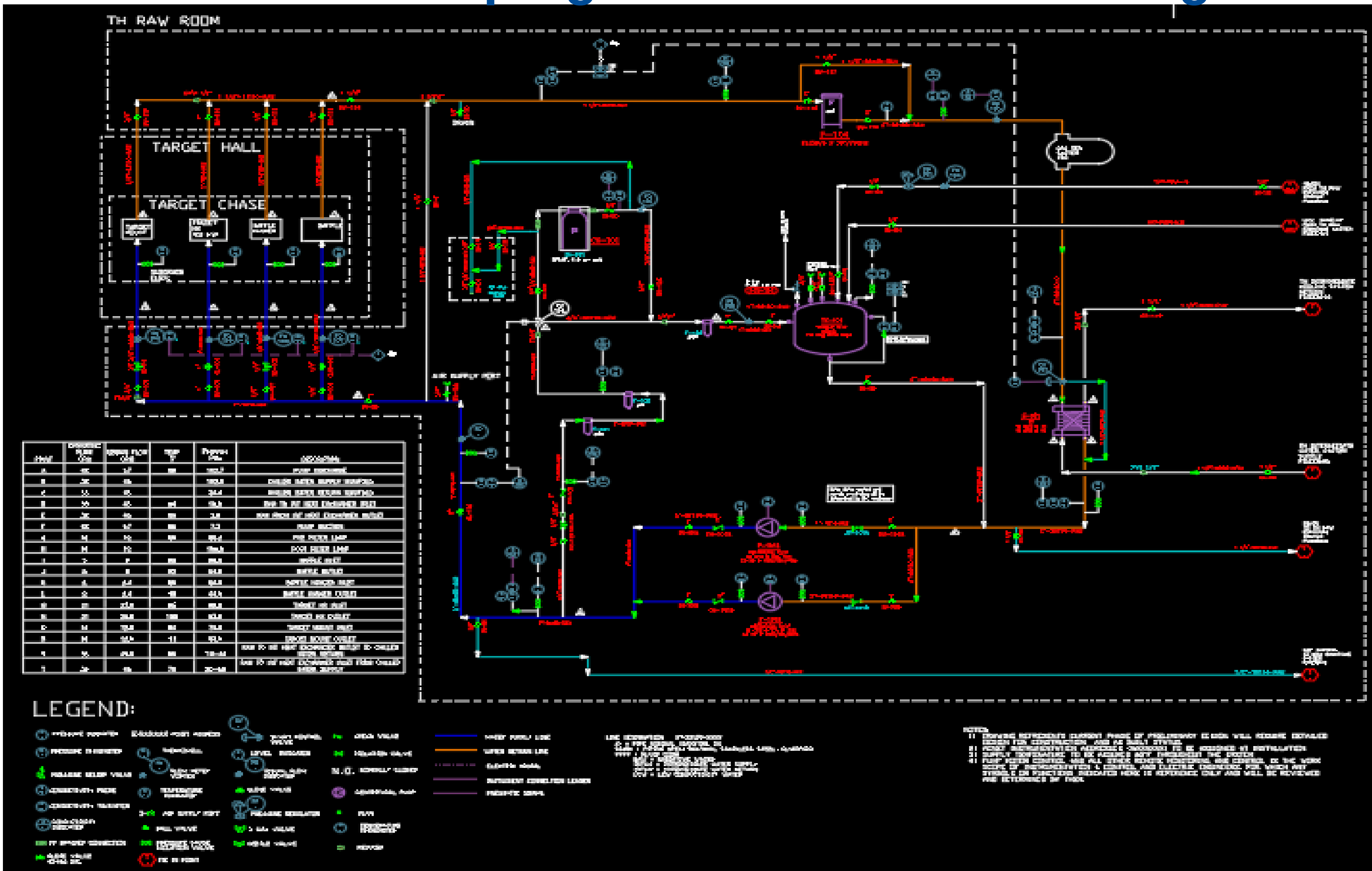
Process Flow – Piping & Instrumentation Diagram



Water Quality Control

- Initial fill: LCW – from TH 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
    - Inline Multi-Cartradge filter: 20µm
  - Maintaining Water resistivity: 4 – 8 $M\Omega \times cm$

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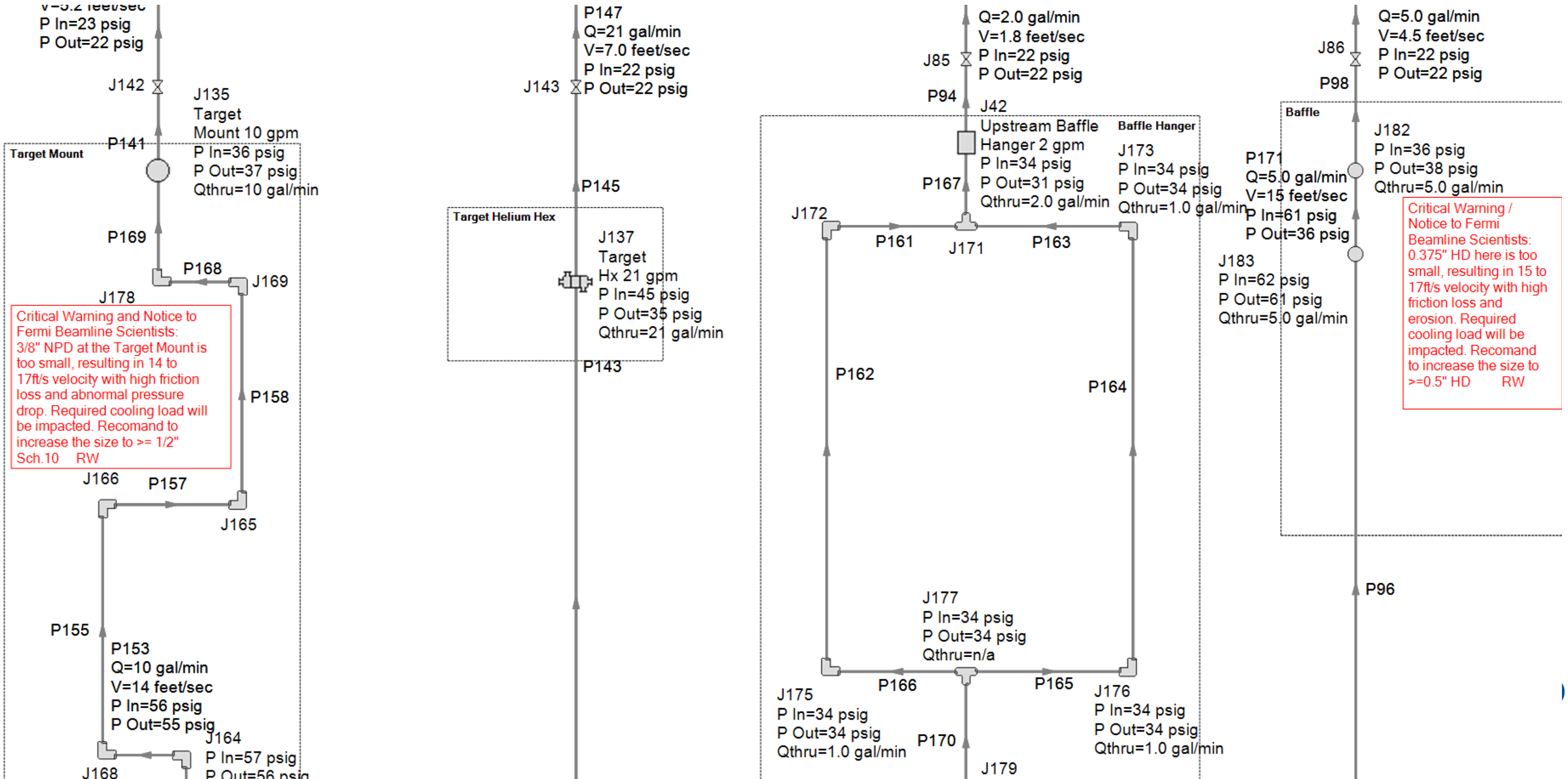
ESH – Radiation Risk Control

- Risks:
  - Initial LCW - to be radioactiviated after short running - 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

Concerns

- The pre-determined current tubing size of Target Mount and baffle are found too small resulting in abnormal static pressure at its inlet and outlet.
- Recommendation: increase size to ≥ 0.5”



Questions?

Thank You!

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