



PIP-II PCW System Design

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PIP-II LINAC Complex Mechanical Fluid
Systems PDR
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A Partnership of:

US/DOE

India/DAE

Italy/INFN

UK/UKRI-STFC

France/CEA, CNRS/IN2P3

Poland/WUST



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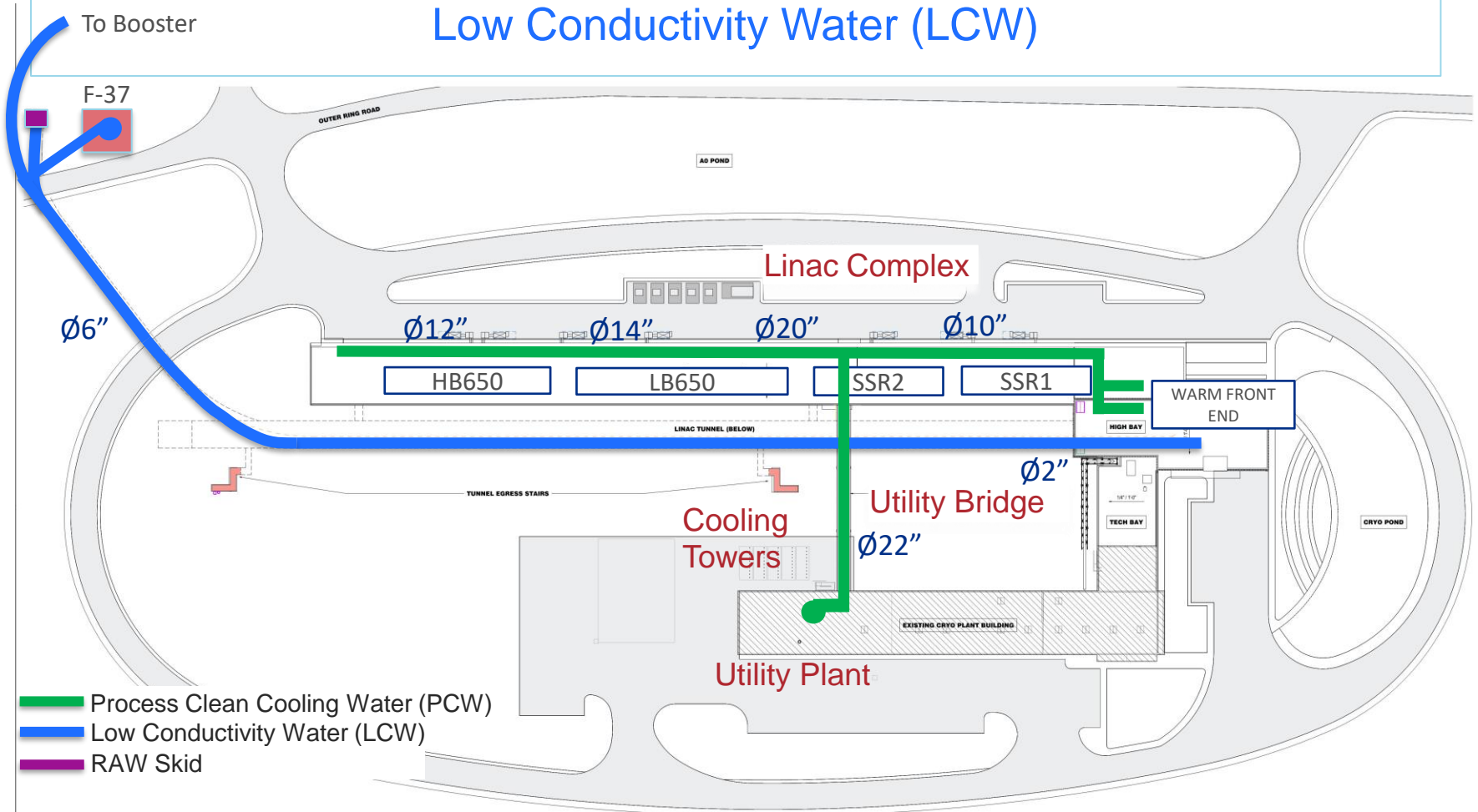
- Scope Cartoon
- System Highlights
- Requirements (FRS/TRS)
- Screen shots
- P&ID/Block Diagram/2D Pump Room
- System Analysis
 - Piping Analysis
 - Flow Analysis
 - Structure/Support Analysis

Overall Cooling Water Design Configuration

Two main water-cooling systems:

Process Clean Water (PCW)

Low Conductivity Water (LCW)



Functional Requirements for PCW System

- What is needed by the end user as well as the requirements and requested properties of inputs and outputs. Specifies the functions that a system or component must perform and establishes consensus among stakeholders on what the system is expected to provide.
- F-121.04.04-A001 - Building Infrastructure shall design the PCW system, including piping, valves, and instrumentation for cooling of the solid-state power amplifiers, circulators and loads for the SSR1, SSR2, LB650 and HB650 cryomodules in the LINAC Gallery and the HWR, MEBT, and LEBT in the HBB.
- F-121.04.04-A004 - Building Infrastructure shall design system level controls instrumentation for PCW flow, pressure, temperature, and dissolved oxygen.

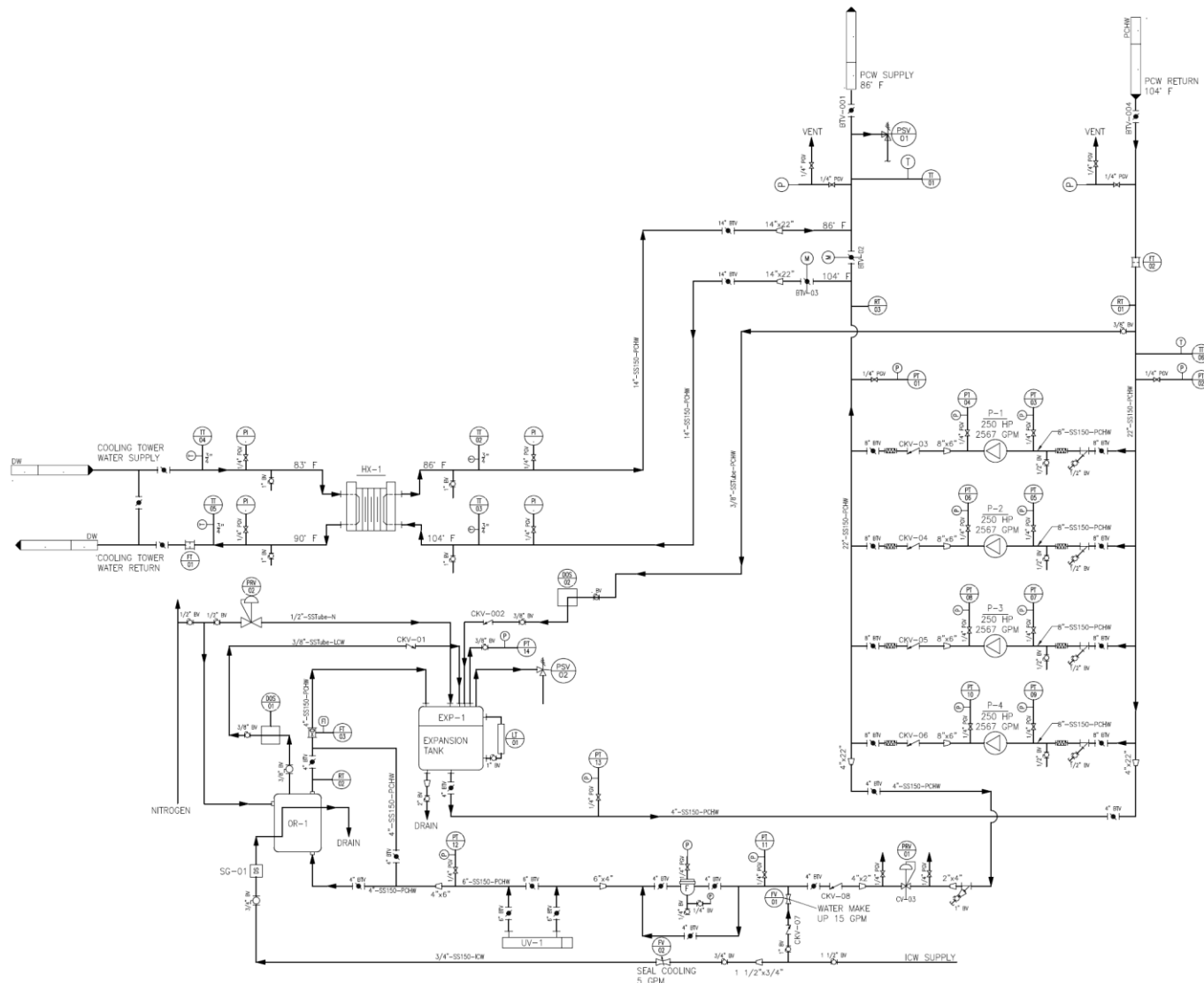
System Highlights

- Category D Piping System
- 304 Stainless Steel Schedule 10 piping material and weld pipe fittings
- Centrifugal Pumps
- No Low Conductivity Requirement, No deionization equipment
- Dissolved Oxygen Removal Skid
- Plate and Frame Heat Exchanger
- Facility cooling media – Cooling Tower Water
- Particulate filtration
- Ultraviolet (UV) sanitizing unit
- Expansion Reservoir Tank – 250 Gallon
- Make up water from Central Utility Building domestic water line

Technical Requirements for PCW System

- Building Infrastructure shall design the PCW system according to the following specifications:
- Discharge Pressure = 105 PSIG
- Suction Pressure = 15 PSIG
- Supply Temperature = 86°F +/- 1°F
- Delta T (ΔT) = 7.2 F°
- Total Heat Load = 8,146 KW
- Total Flow Required = 7723 GPM
- Side stream Particulate filtration at 5 micron
- Oxygen removal levels = >20 PPB
- Cooling water flow requirement summary for individual components can be found in the Building Infrastructure Water Usage Document – Teamcenter Document #ED0012655 - (PCW Flow Block Diagram slide)

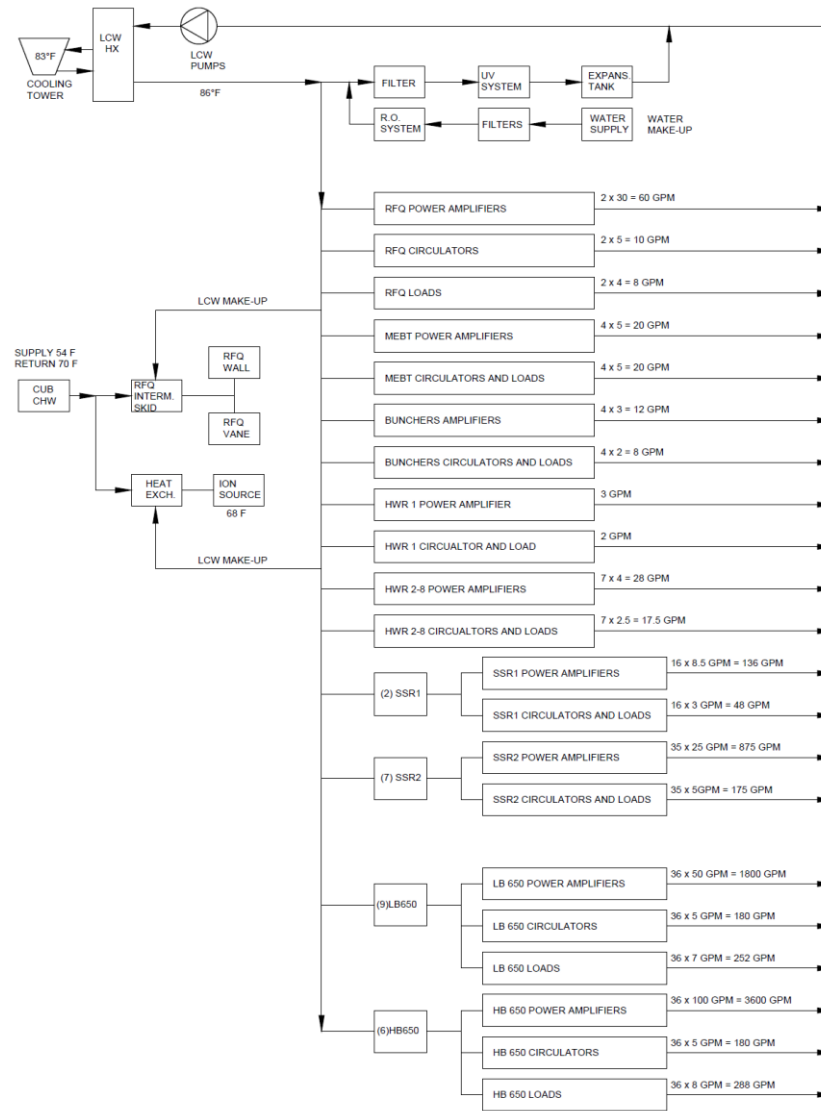
PCW Pump Room P&ID in Utility Plant



PIPING SYMBOL LIST

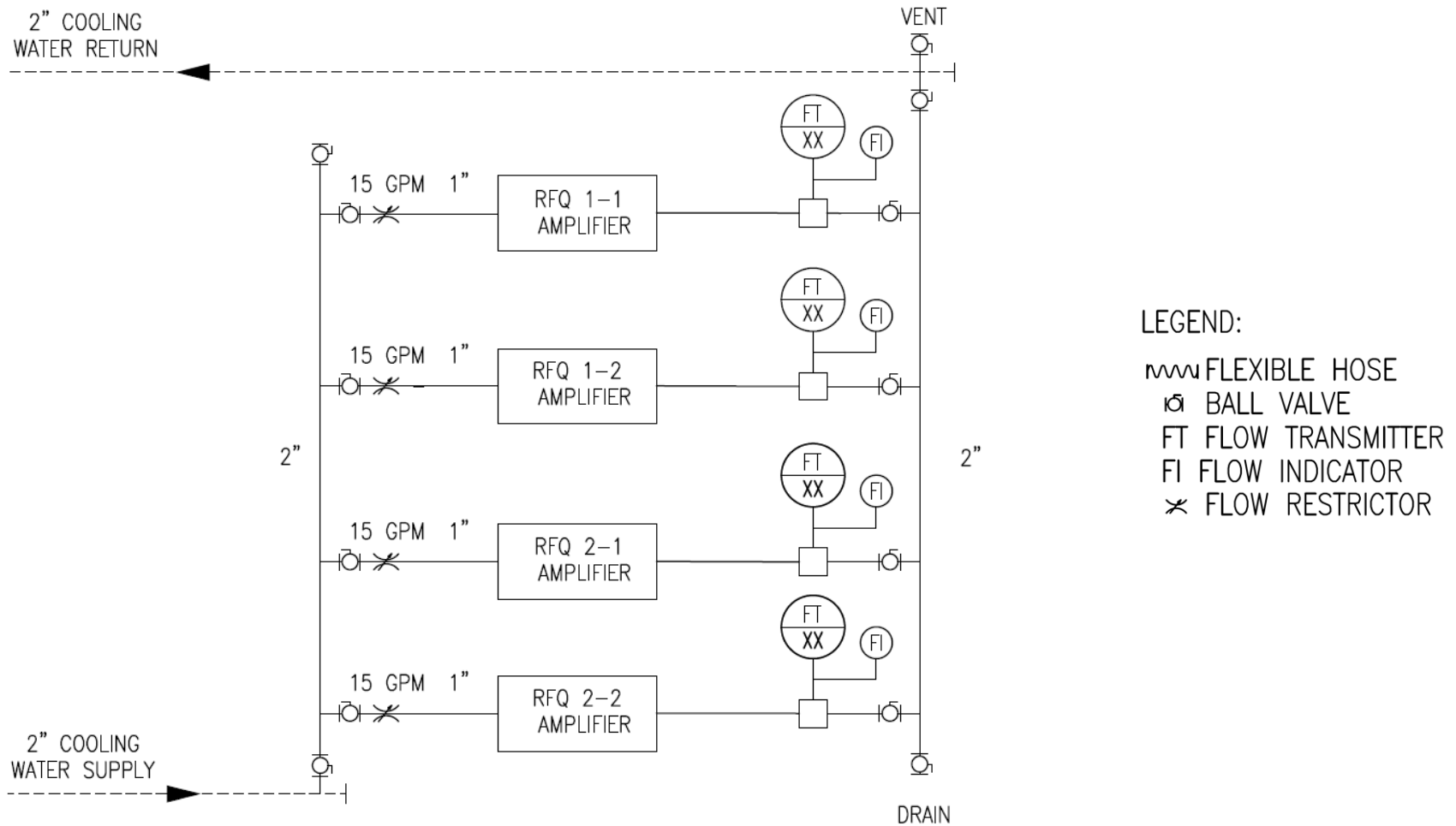
	BV - BALL VALVE
	BTV - BUTTERFLY VALVE
	CKV - CHECK VALVE
	GLV - GLOBE VALVE
	PGV - PLUG VALVE
	PRV - PRESSURE REGULATING VALVE
	PSV - PRESSURE RELIEF VALVE
	CV - CONTROL VALVE - AUTOMATIC FLOW
	CV - CONTROL VALVE - 2-WAY MOTORIZED
	CV - CONTROL VALVE - 3-WAY MOTORIZED
	CONCENTRIC REDUCER
	ECCENTRIC REDUCER
	FLANGED CONNECTION
	PIPE CAP
	STAINLESS STEEL FLEXIBLE CONNECTION
	STRAINER
	UNION
	THERMOPLASTIC HOSE
	FLOW METER - TURBINE
	SIGHT GLASS
	FLOW METER - VORTEX
	PUMP
	PRESSURE GAUGE/INDICATOR
	THERMOMETER/TEMP. INDICATOR
	GPM FLOW
	ACNET PARAMETER
	ADJ - ADJUSTABLE (AS REQUIRED)
	AS - AUTO SWITCH/START
	FLW - FLOW
	HS - HAND SWITCH
	INTW - INTERMEDIATE WATER
	NI - NITROGEN
	NC - NORMALLY CLOSED
	NO - NORMALLY OPEN
	OT - OVER TEMPERATURE
	RAW - RADIOACTIVE WATER
	RCV - RADIOACTIVE SAFETY
	CCV - CONFIGURATION CONTROL VALVE
	TYP - TYPICAL
	PO = POSITION
	F = FLOW
	FR = FLOW REGULATOR
	L = LEVEL
	O = DISSOLVED OXYGEN
	P = PRESSURE
	R = RESISTIVITY
	T = TEMPERATURE
	I = INDICATING
	T = TRANSMITTING
	IDENTIFICATION NUMBER
	DISCRETE SENSOR OR CONTROL FUNCTION

PCW Flow Block Diagram

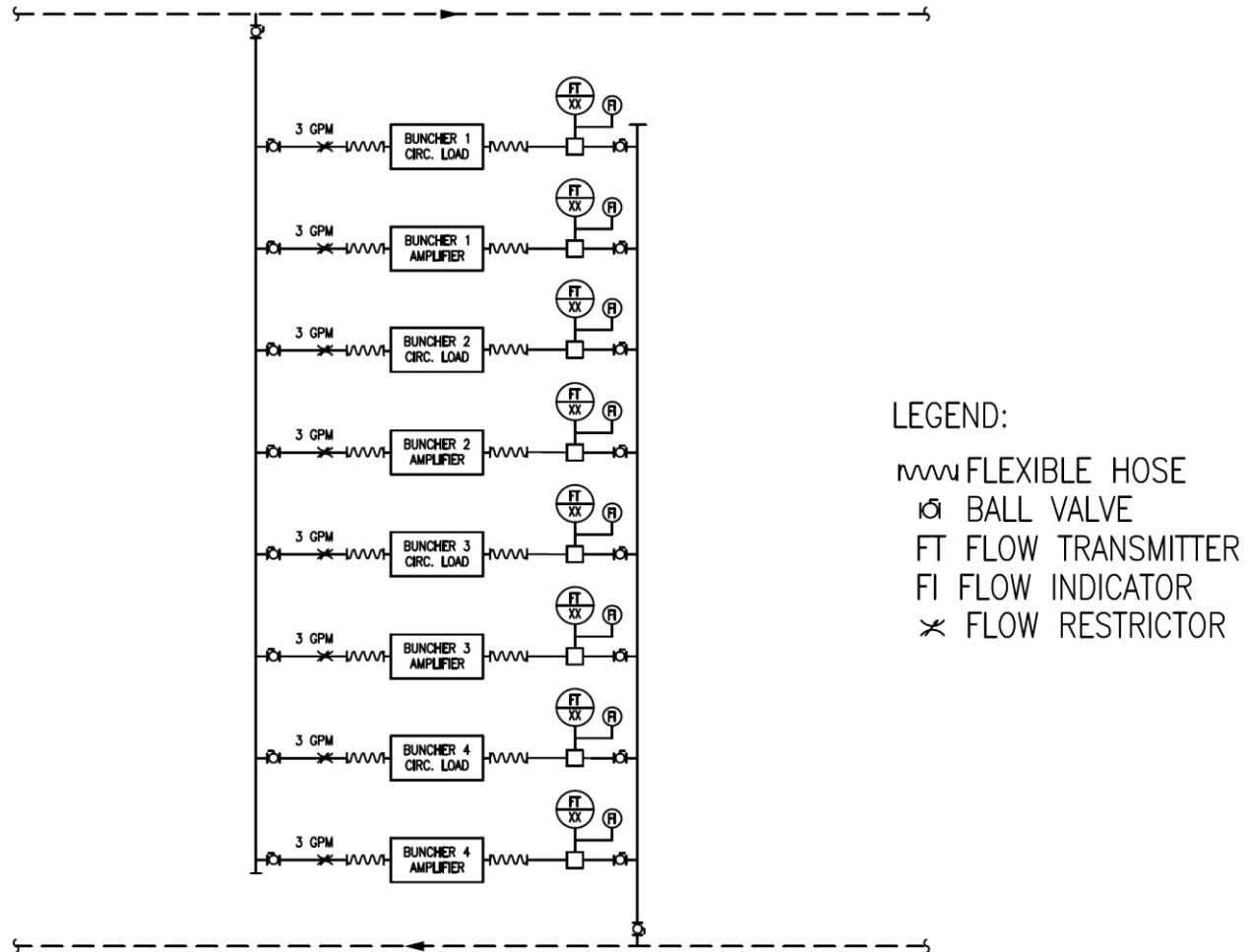


TOTAL LOAD @7.2 DEG ΔF - 8,146 kW
TOTAL FLOW REQUIRED - 7723 GPM

RFQ amplifier P&ID



MEBT Amplifiers P&ID



Preliminary Analysis Of Designed PCW Piping

PIP-II PROCESS CLEAN WATER (PCW) MATERIAL TYPE AND SIZES

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

Minimum Pipe Thickness is given by,

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

Where,

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

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 PCW Piping (continued)

CALCULATIONS:

Pipe:

Material Specification: 304/304L SS

Design Pressure (P): 100 psig

Design Temperature: 118 °F

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

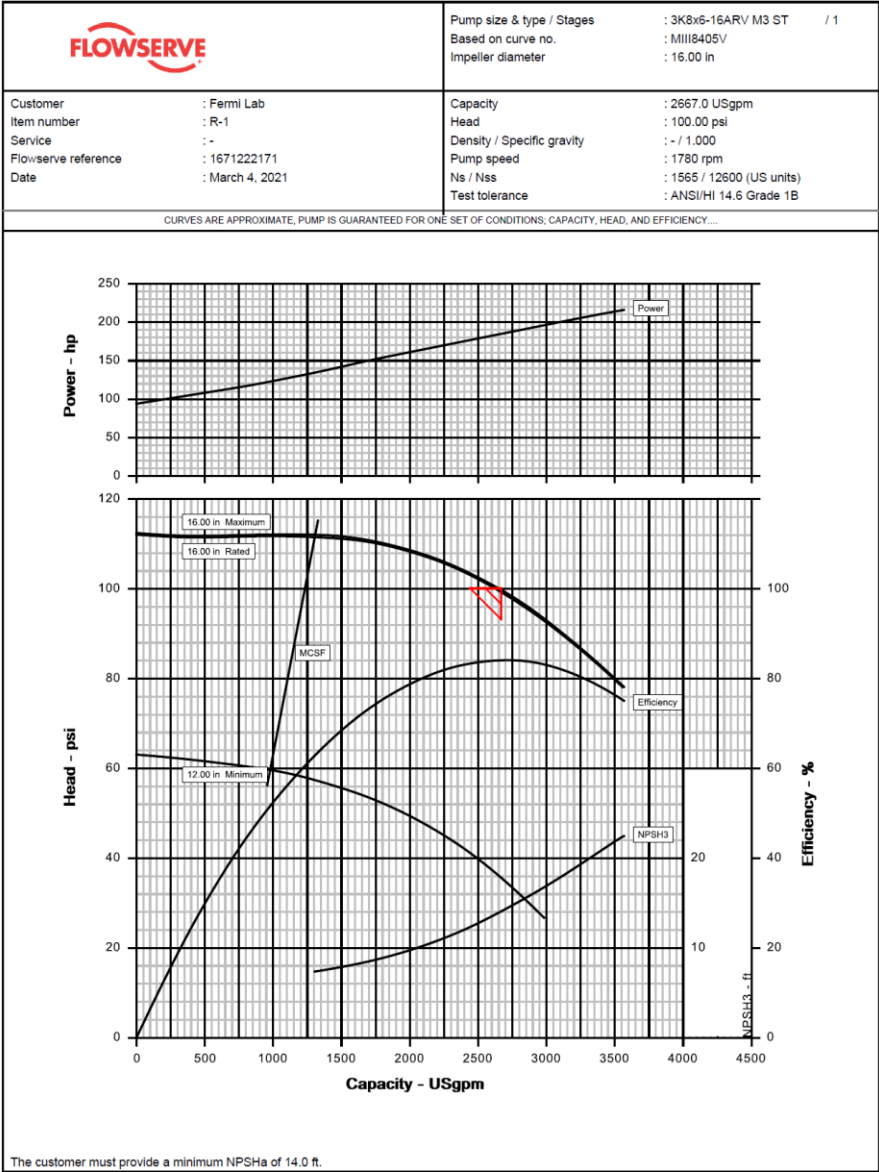
Primary piping wall thickness (T)
exceeds minimum wall thickness
(t_m) requirements

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	
22	22.000	10S	0.218	21.564	N/A	0.005	0.08209	Yes	0.08709	Yes
20	20.000	10S	0.218	19.564	N/A	0.005	0.07463	Yes	0.07963	Yes
18	18.000	10S	0.188	17.624	N/A	0.005	0.06716	Yes	0.07216	Yes
12	12.750	10S	0.180	12.39	N/A	0.005	0.04757	Yes	0.05257	Yes
10	10.750	10S	0.165	10.42	N/A	0.005	0.04011	Yes	0.04511	Yes
8	8.625	10S	0.148	8.329	N/A	0.005	0.03218	Yes	0.03718	Yes
6	6.635	10S	0.134	6.367	N/A	0.00500	0.02476	Yes	0.02976	Yes
4	4.500	10S	0.120	4.260	N/A	0.00500	0.01679	Yes	0.02179	Yes
3 1/2	4.000	10S	0.120	3.760	N/A	0.00500	0.01493	Yes	0.01993	Yes
3	3.500	10S	0.120	3.260	N/A	0.00500	0.01306	Yes	0.01806	Yes
2 1/2	2.875	10S	0.120	2.635	N/A	0.00500	0.01073	Yes	0.01573	Yes
2	2.375	10S	0.109	2.157	N/A	0.00500	0.00886	Yes	0.01386	Yes
1 1/2	1.900	10S	0.109	1.682	N/A	0.00500	0.00709	Yes	0.01209	Yes
1	1.315	40S	0.133	1.049	0.06957	0.07457	0.00491	Yes	0.07948	Yes
1	1.315	10S	0.109	1.097	N/A	0.00500	0.00491	Yes	0.00991	Yes
3/4	1.050	40S	0.113	0.824	0.05714	0.06214	0.00392	Yes	0.06606	Yes
3/4	1.050	10S	0.083	0.884	N/A	0.00500	0.00392	Yes	0.00892	Yes
1/2	0.840	40S	0.109	0.622	0.05714	0.06214	0.00313	Yes	0.06527	Yes

Preliminary Analysis Of Fluid Pressure Drop/Fluid Flow Distribution

- Aft Fathom
- Fluid dynamic simulation software
- Calculates pressure drop and pipe flow distribution in liquid fluid systems
- Use of this software confirms centrifugal pump selection and size satisfies system requirements

PCW Pump Curve (Single Pump)



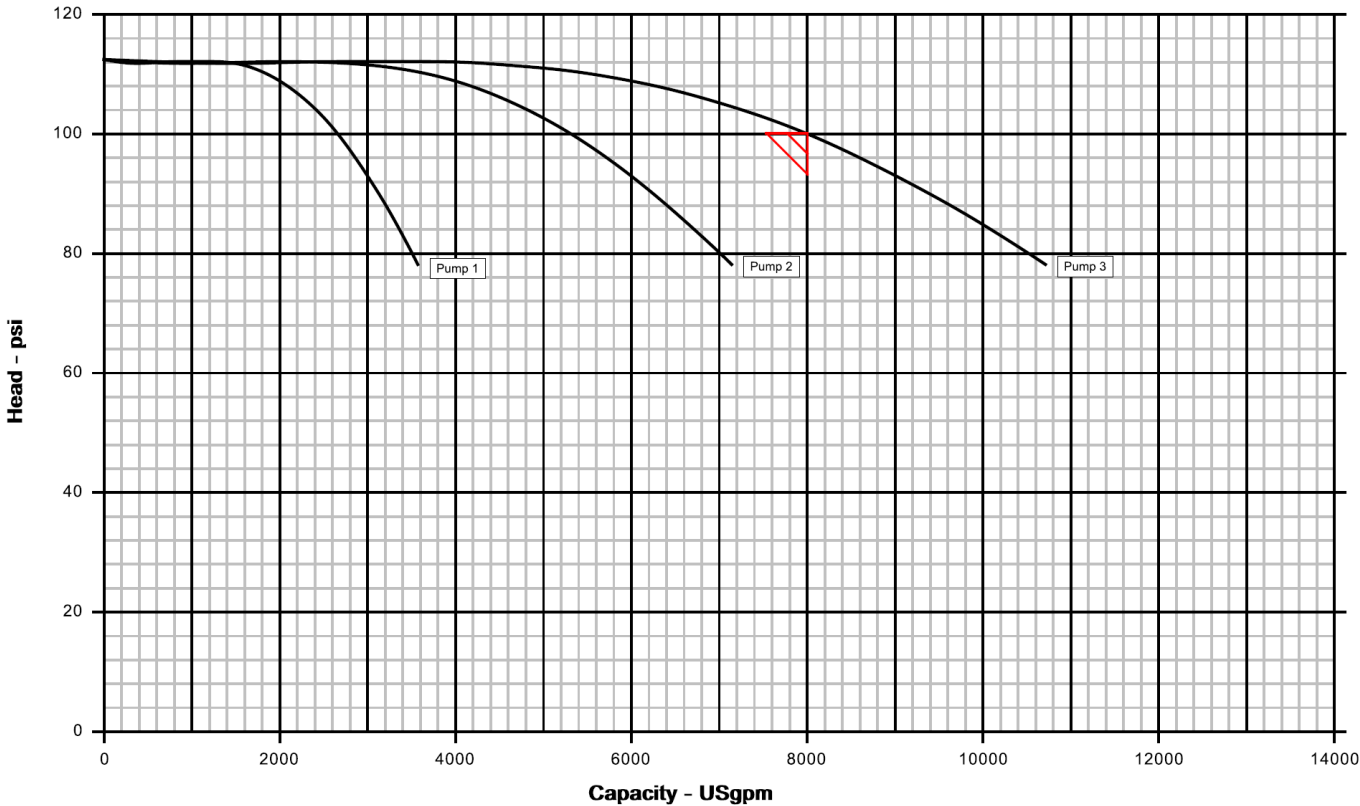
PCW Pump Curve (Multiple Pump in Parallel)

Customer : Fermi Lab
Item number : R-1
Service : -
Flowserve reference : 1671222171
Pump size & type / Stages : 3K8x6-16ARV M3 ST / 1
Based on curve no. : MIII8405V
Impeller diameter : 16.00 in



Capacity : 2667.0 USgpm
Head : 100.00 psi
Density / Specific gravity : - / 1.000
Pump speed : 1780 rpm
Ns / Nss : 1565 / 12600 (US units)
Date : March 4, 2021

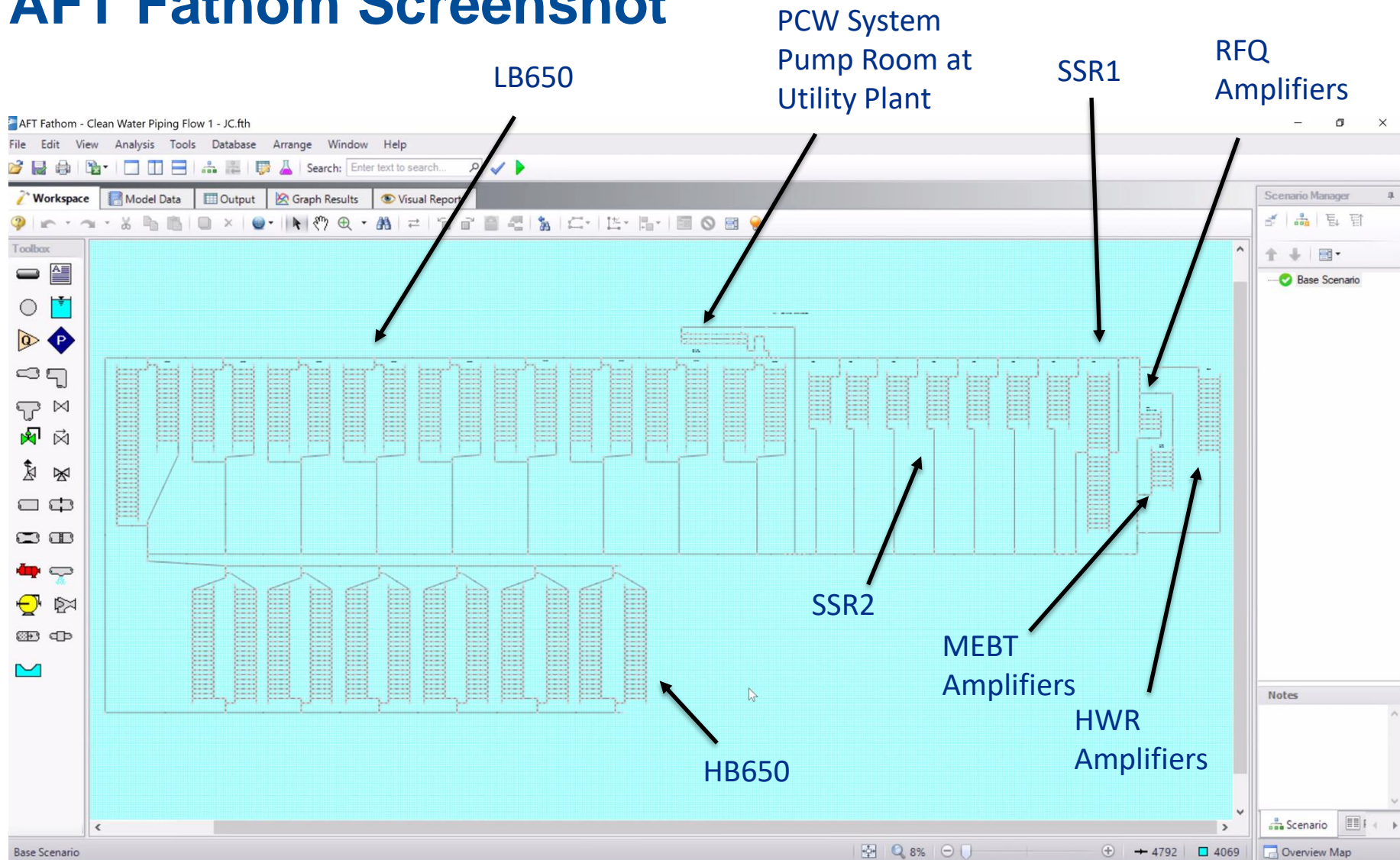
CURVES ARE APPROXIMATE. PUMP IS GUARANTEED FOR ONE SET OF CONDITIONS; CAPACITY, HEAD, AND EFFICIENCY.
MCSF PROVIDES MECHANICAL PROTECTION ONLY. MINIMUM THERMAL FLOW MUST BE CALCULATED FOR THE SPECIFIC FLUID AND OPERATING CONDITIONS.



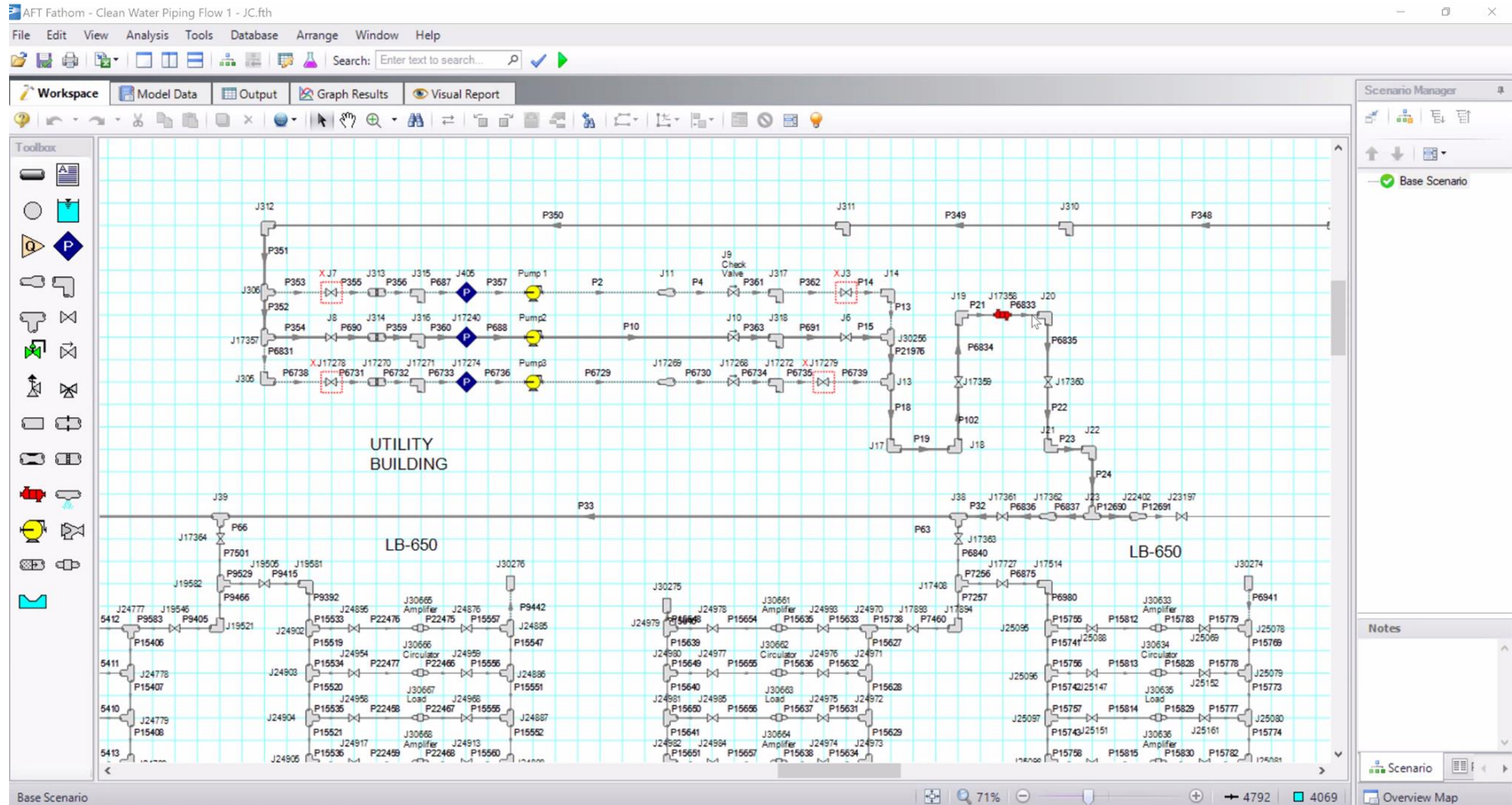
The customer must provide a minimum NPSHa of 14.0 ft.



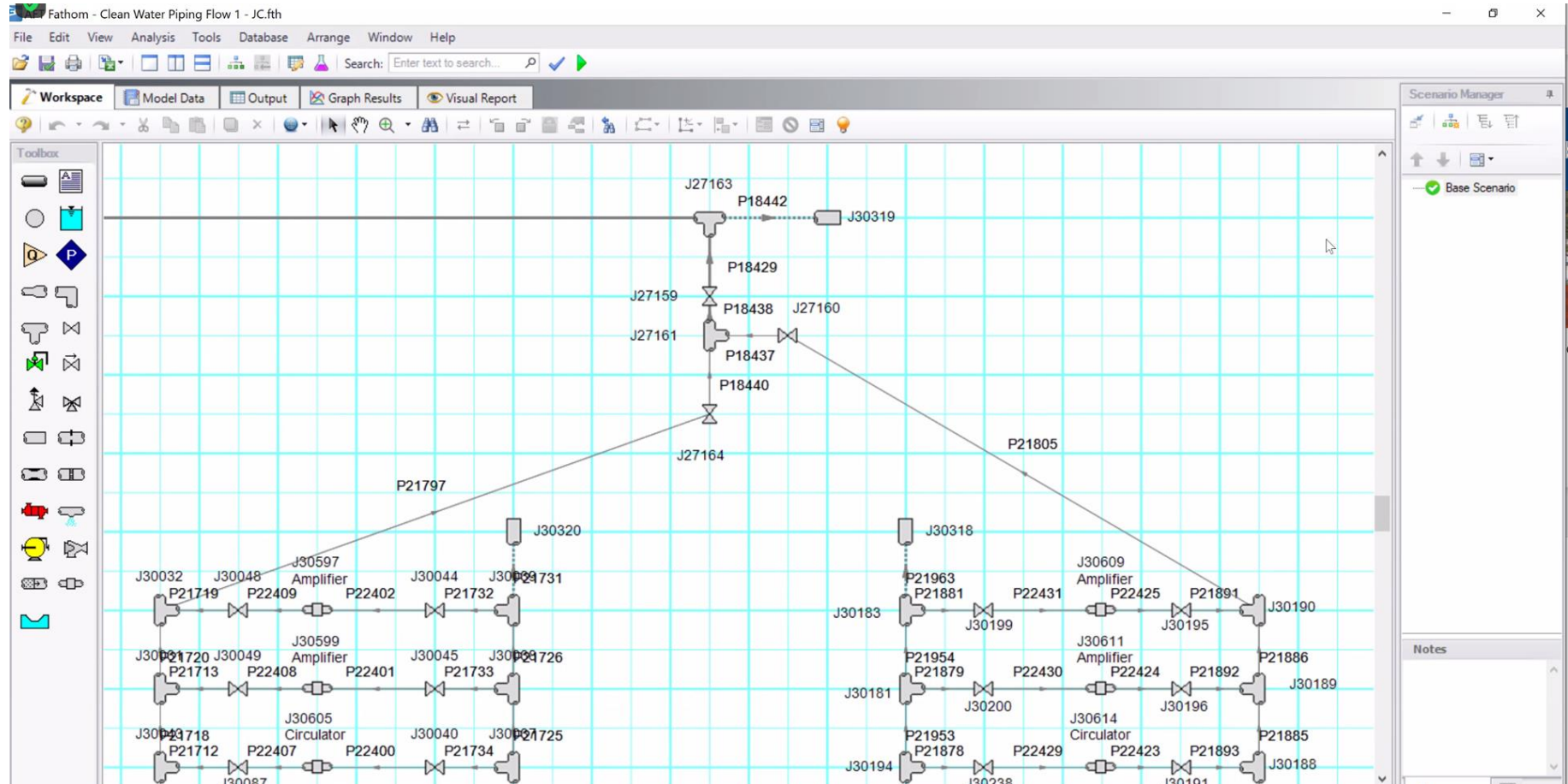
AFT Fathom Screenshot



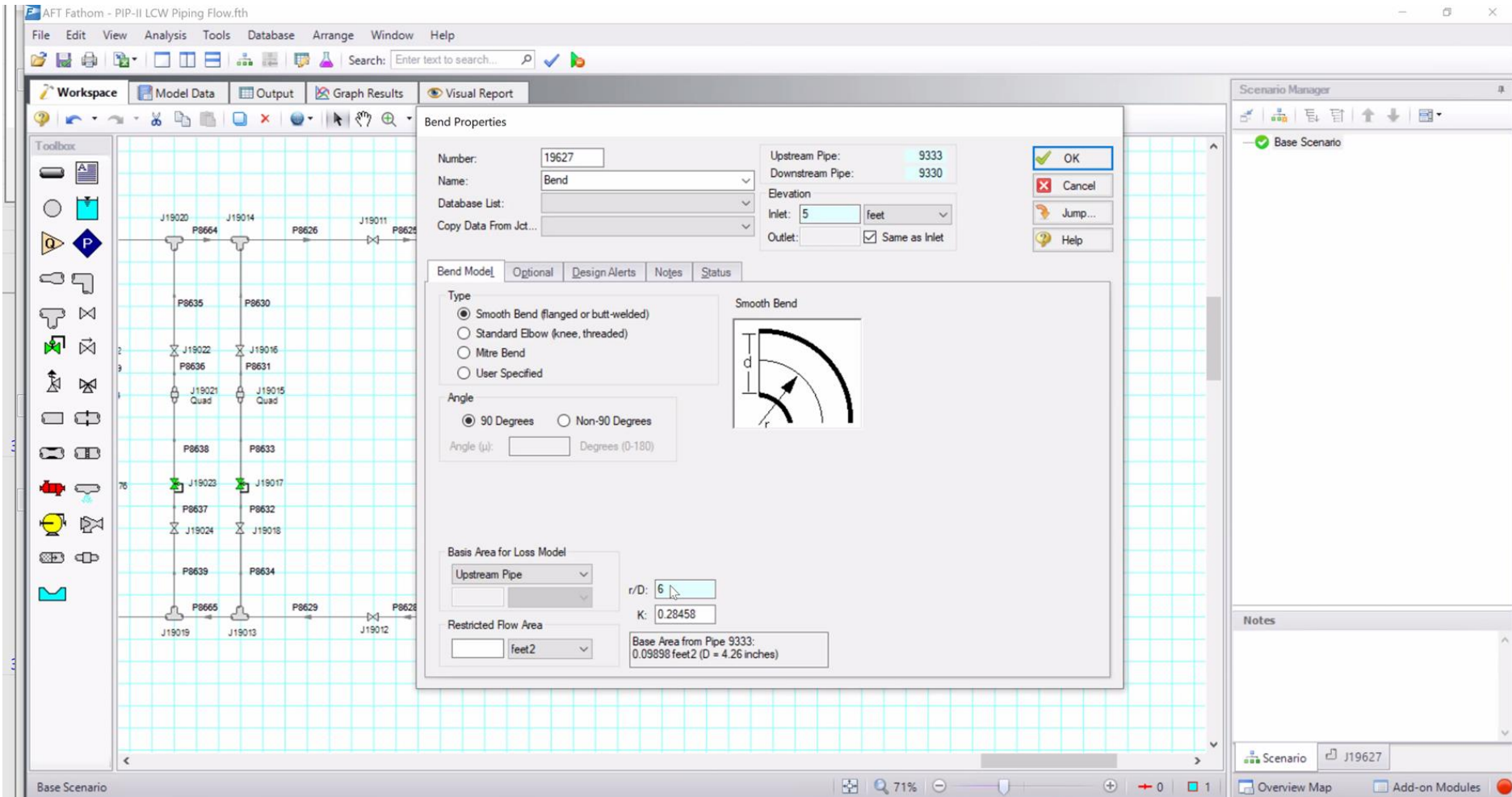
AFT Fathom Screenshot (Continued)



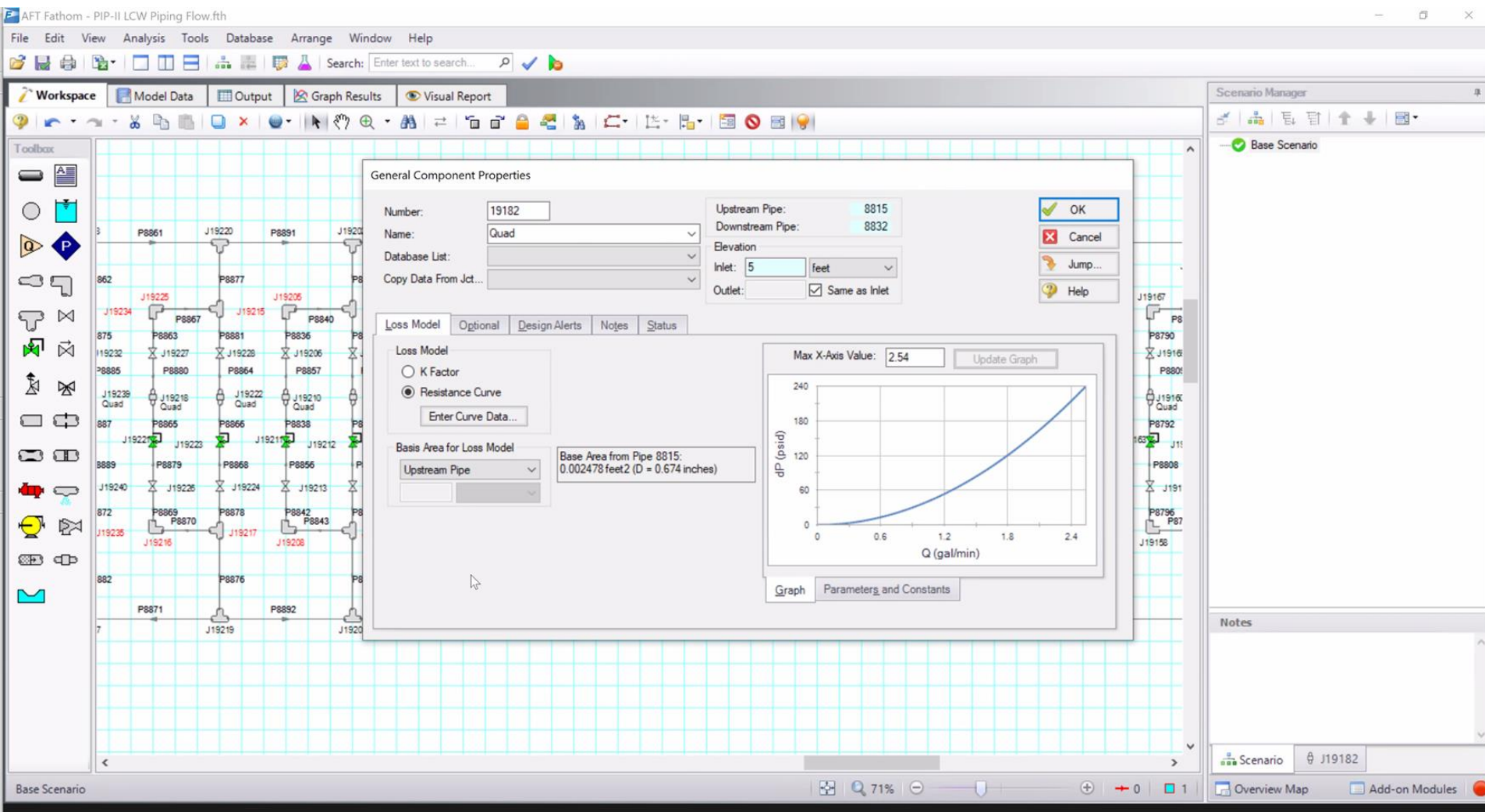
AFT Fathom Screenshot (Continued)



AFT Fathom Screenshot (Continued)



AFT Fathom Screenshot (Continued)



Preliminary Structural Support Analysis - PCW Piping

- Working with Conventional Facilities
- Obtain firm fixed price proposal for professional A/E services
- Services will include review of:
 - The configuration of the designed PCW piping system and the existing structural design of the mechanical bays of the PIP-II Utility Plant as part of the Cryogenic Plant Building
 - The dynamic loading on the existing building structure from the installation and operation of the PCW System equipment.

Preliminary Structural Support Analysis - PCW Piping (Continued)

- Services will also include:
 - Development of design documents suitable for procurement of the pipe supports needed to support the PCW System piping and equipment.
- Our engineering team will arrange and oversee the contract to include installation of both AE recommended piping supports and PCW piping and pump room equipment

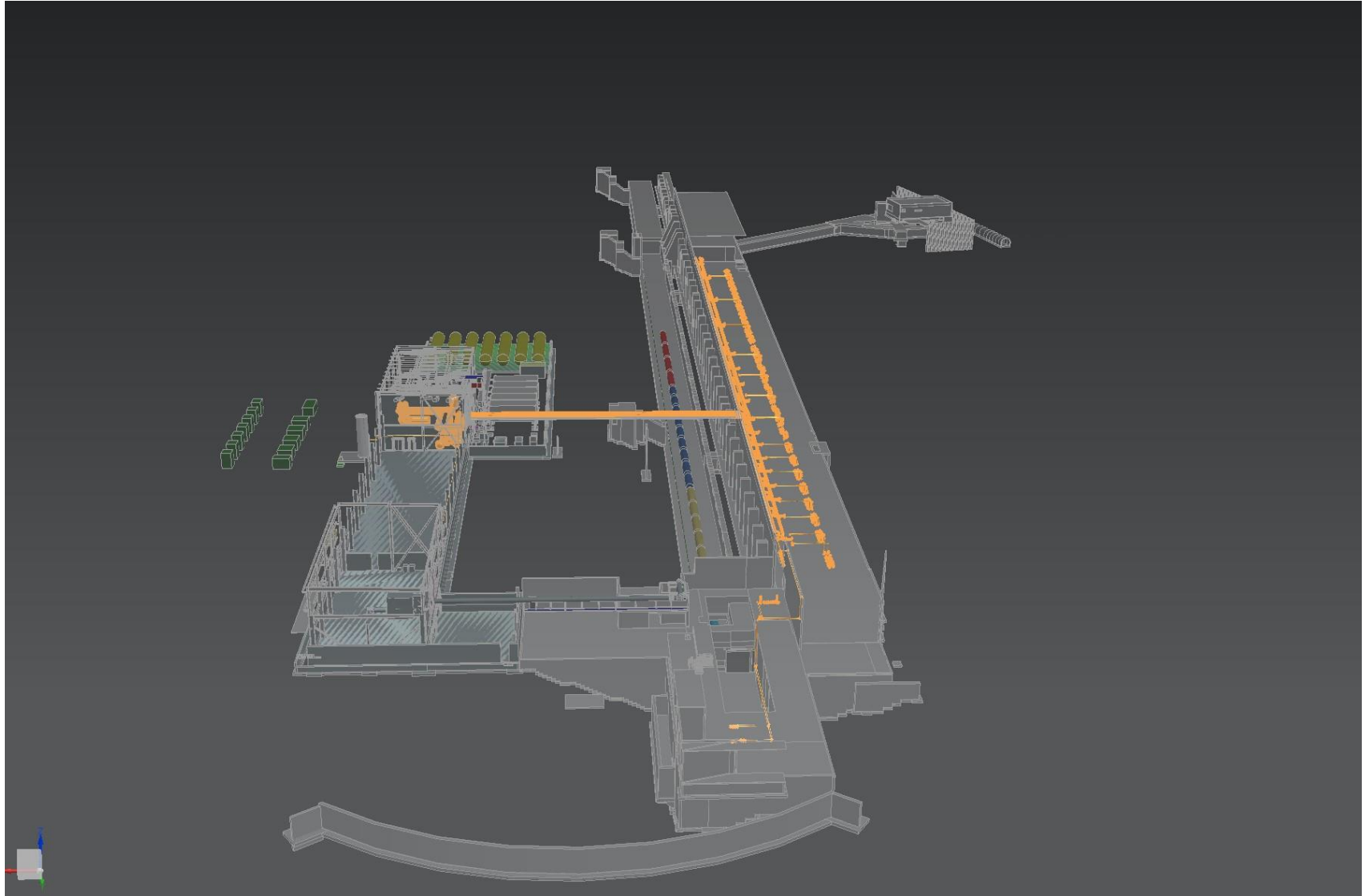
Preliminary Structural Support Analysis - PCW Piping (Continued)

- Structural analysis of PCW piping in the following areas are not included in this project scope:
 - LINAC Utilities Bridge
 - LINAC Gallery
 - LINAC High Bay Building
- Structural analysis of PCW piping in these areas will be covered within the design scope of the Conventional Facilities

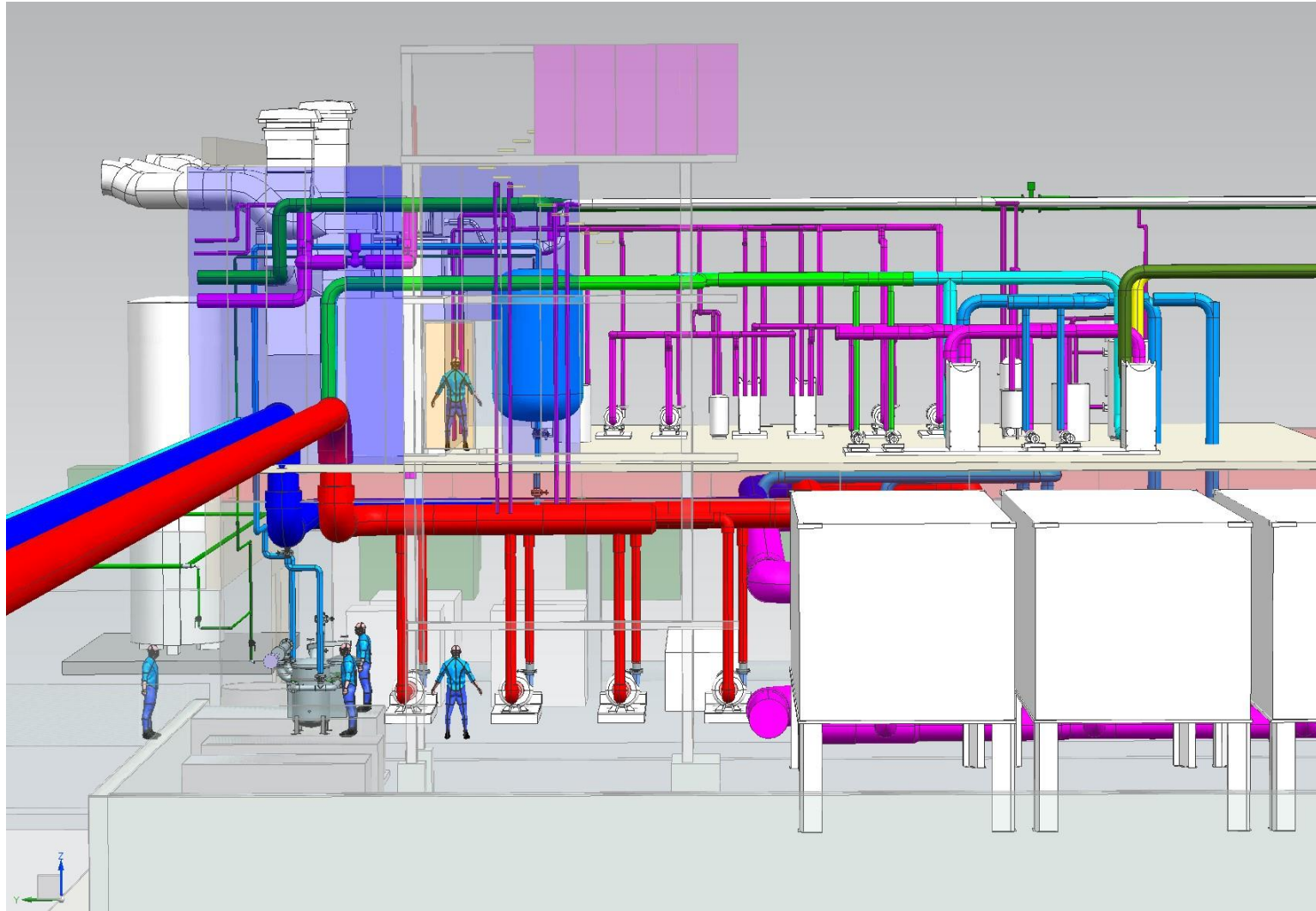
Preliminary Structural Support Analysis - PCW Piping (Continued)

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3D Screenshots – PCW System Distribution (North Elevated View)



3D Screenshots - PCW System Pump Room - Utility Plant (West Elevated View)



3D Screenshots – PCW System - HB650 SRF Amplifier Distribution (Southwest Elevated View)

