PIP-II LCW 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

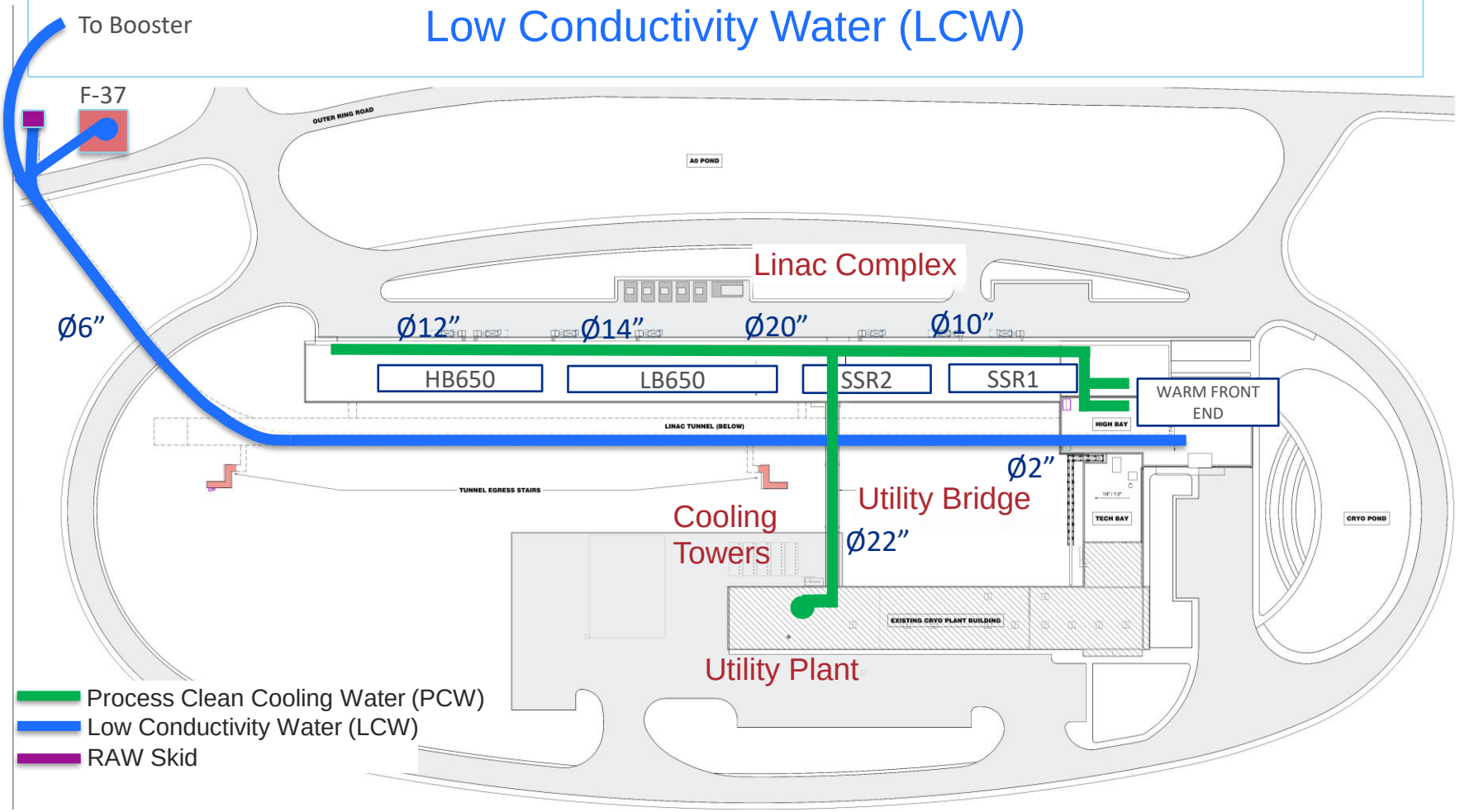
Table of Contents

Overall Cooling Water Design Configuration

Two main water-cooling systems:

Process Clean Water (PCW)

Low Conductivity Water (LCW)



System Highlights

- Category D Piping System
- 304 Stainless Steel Schedule 10 piping material and weld pipe fittings
- Centrifugal Pumps
- Electro-deionization Skid
- Dissolved Oxygen Removal Skid
- Tube and Shell Heat Exchanger
- Facility cooling media – Industrial Cooling Water
- Particulate filtration
- Expansion Reservoir Tank – 250 Gallon
- Make up water via – Deionized water from 50 Gallon portable drums

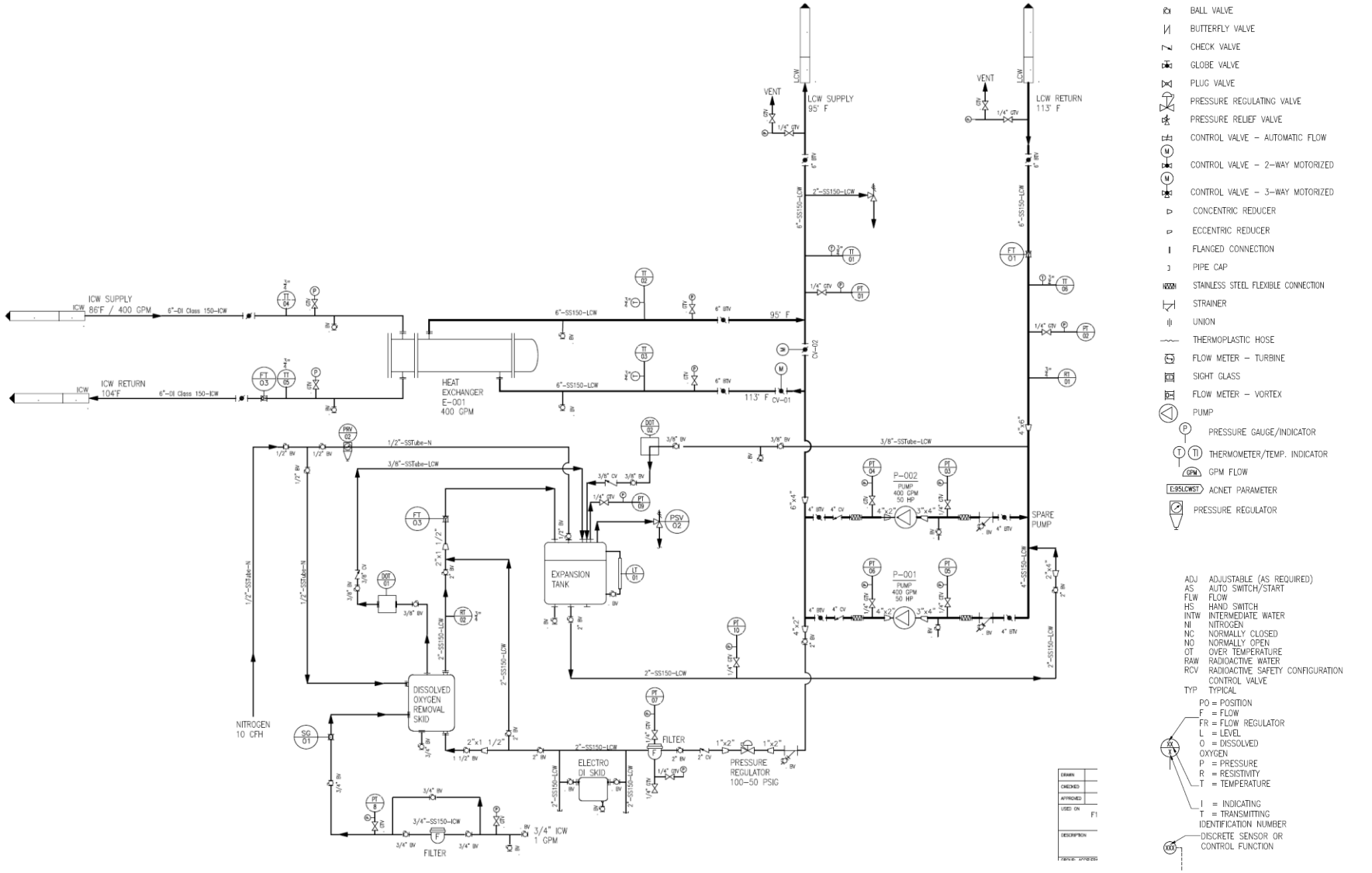
Functional Requirements for LCW System

- 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-A002 - Building Infrastructure shall design the LCW system, including piping, valves, and instrumentation of the WFE including the LEBT solenoids, MEBT bunching cavities.
- F-121.04.04-A003 - Building Infrastructure shall design the LCW system, including piping, valves, and instrumentation for the magnets of the LINAC enclosure region, BTL to the Booster accelerator, the main beam absorber, and power supplies in the F37 Service Building.
- F-121.04.04-A005 - Building Infrastructure shall design system level controls instrumentation for LCW flow, pressure, temperature, resistivity, and dissolved oxygen.

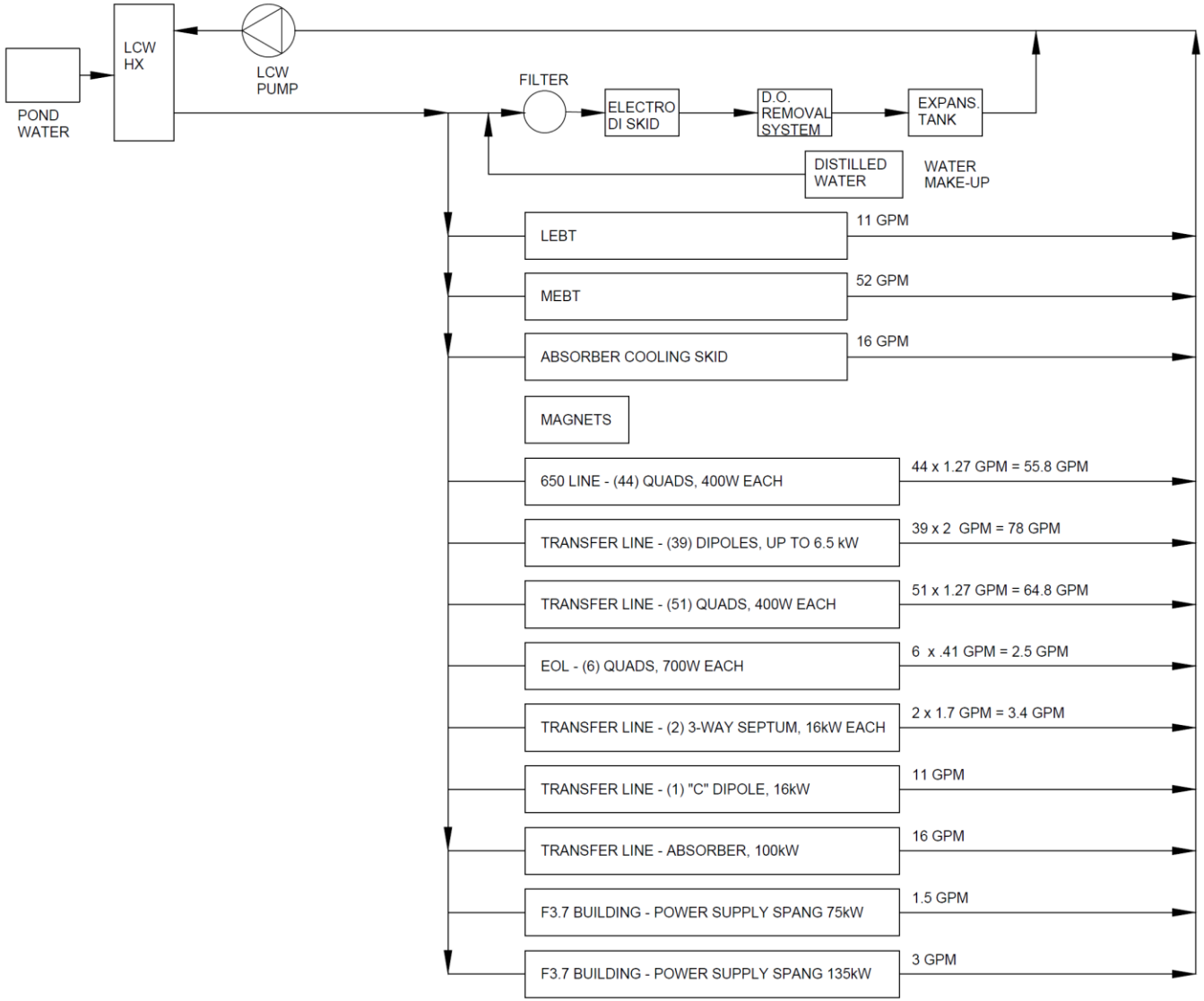
Technical Requirements for LCW System

- Building Infrastructure shall design the LCW System according to the following specifications:
- Discharge Pressure = 105 PSIG
- Suction Pressure = 15 PSIG
- Supply Temperature = 95°F+/- 1ºF
- Delta T (ΔT) = 17° F
- Total Heat Load @Δ17 Fº = 200 KW
- Total Flow Required = 315 GPM
- Oxygen removal levels >20 PPB
- Resistivity = 4 MOhm*cm
- Side stream Particulate filtration at 5 micron
- Cooling water flow requirement summary for individual components can be found in the Building Infrastructure Water Usage Document – Teamcenter Document #ED0012655 – (LCW Flow Block Diagram slide)

LCW Pump Room P&ID in F37 Service Building

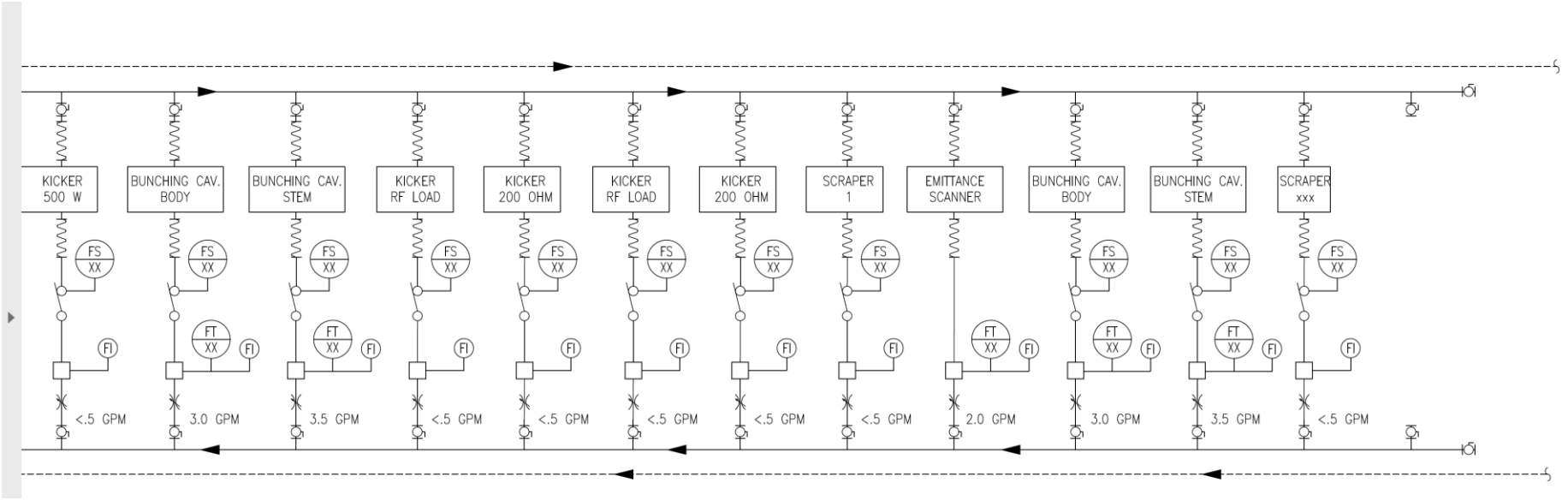


LCW Flow Block Diagram



TOTAL FLOW REQUIRED - 315 GPM
FLOW AVAILABLE - 400 GPM

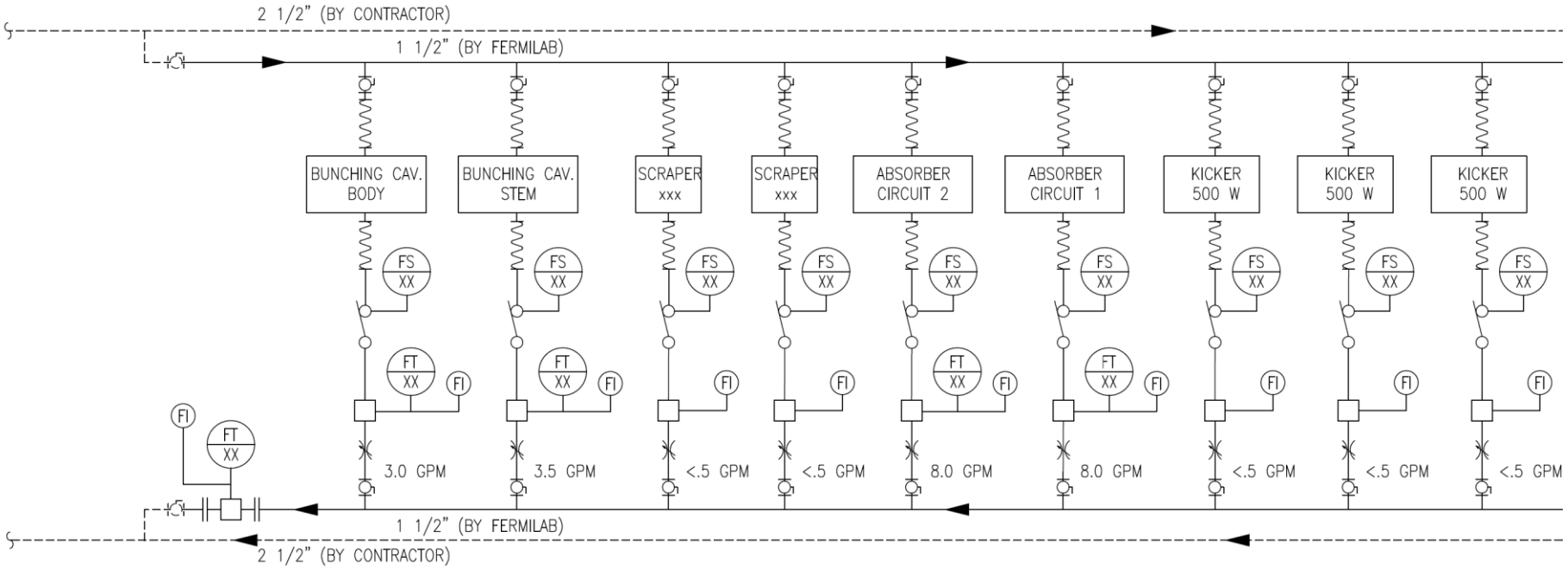
MEBT P&ID



LEGEND:

- BALL VALVE
- FLEX HOSE
- FLOW SWITCH
- FLOW AND TEMPERATURE TRANSMITTER
- (FI) FLOW INDICATOR
- FLOW RESTRICTOR

MEBT P&ID (continued)



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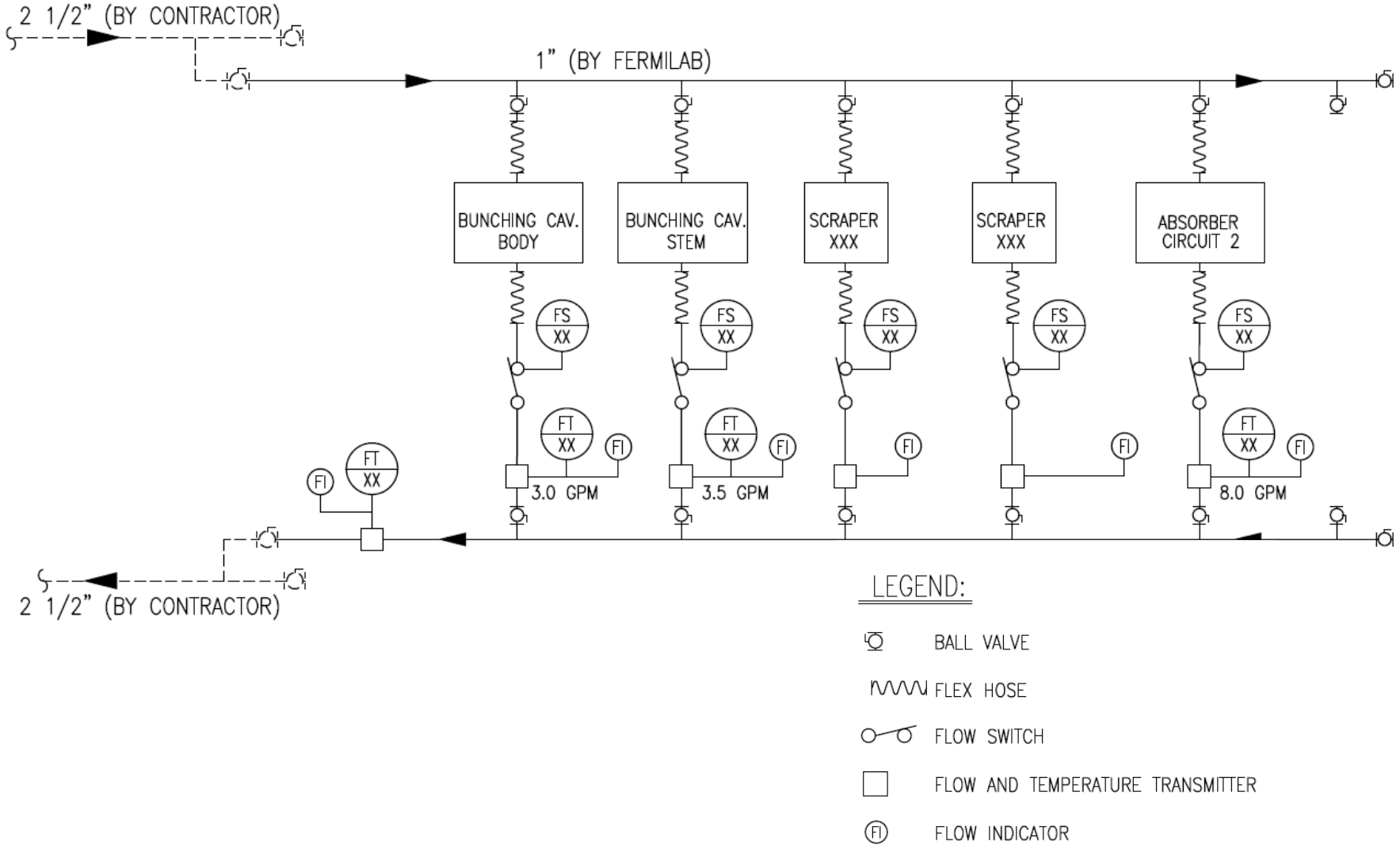
LEBT P&ID


2 1/2" (BY CONTRACTOR)
1" (BY FERMILAB)
BUNCHING CAV. BODY
BUNCHING CAV. STEM
SCRAPER XXX
SCRAPER XXX
ABSORBER CIRCUIT 2
FS XX
FT XX
FI
3.0 GPM
3.5 GPM
8.0 GPM
2 1/2" (BY CONTRACTOR)
LEGEND:
BALL VALVE
FLEX HOSE
FLOW SWITCH
FLOW AND TEMPERATURE TRANSMITTER
FLOW INDICATOR

Preliminary Analysis Of Designed Piping Loads

PIP-II 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 LCW Piping (continued)

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	
6	6.625	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
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

Preliminary Analysis Of Fluid Pressure Drop/Fluid Flow Distribution

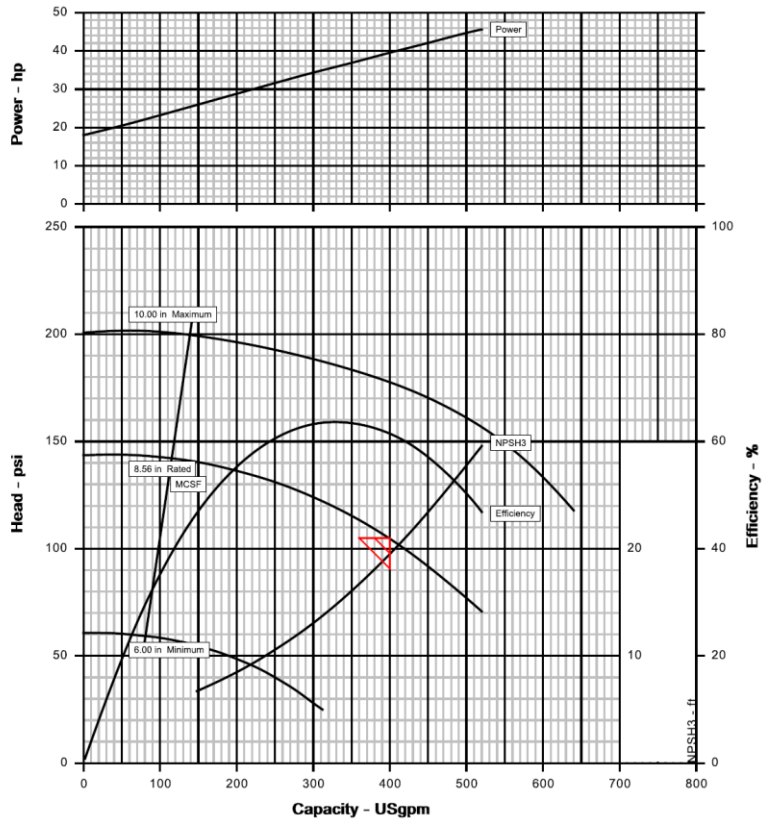
- Aft Fathom
- Fluid dynamic simulation software
- Calculates pressure drop and pipe flow distribution in liquid fluid systems
- Use of this software confirms centrifugal pump selection and size satisfies system requirements

LCW Pump Curve

FLOWSERVE

Pump size & type / Stages	: 2K3x2-10ARV M3 ST / 1		
Based on curve no.	: MIII7820V		
Impeller diameter	: 8.56 in		
Customer	: Superior Industrial Equipment	Capacity	: 400.0 USgpm
Item number	: P-1	Head	: 105.00 psi
Service	: -	Density / Specific gravity	: - / 1.000
Flowserve reference	: 2581899072	Pump speed	: 3550 rpm
Date	: June 8, 2020	Ns / Nss	: 849 / 7480 (US units)
		Test tolerance	: ANSI/HI 14.6 Grade 1B

CURVES ARE APPROXIMATE, PUMP IS GUARANTEED FOR ONE SET OF CONDITIONS; CAPACITY, HEAD, AND EFFICIENCY....

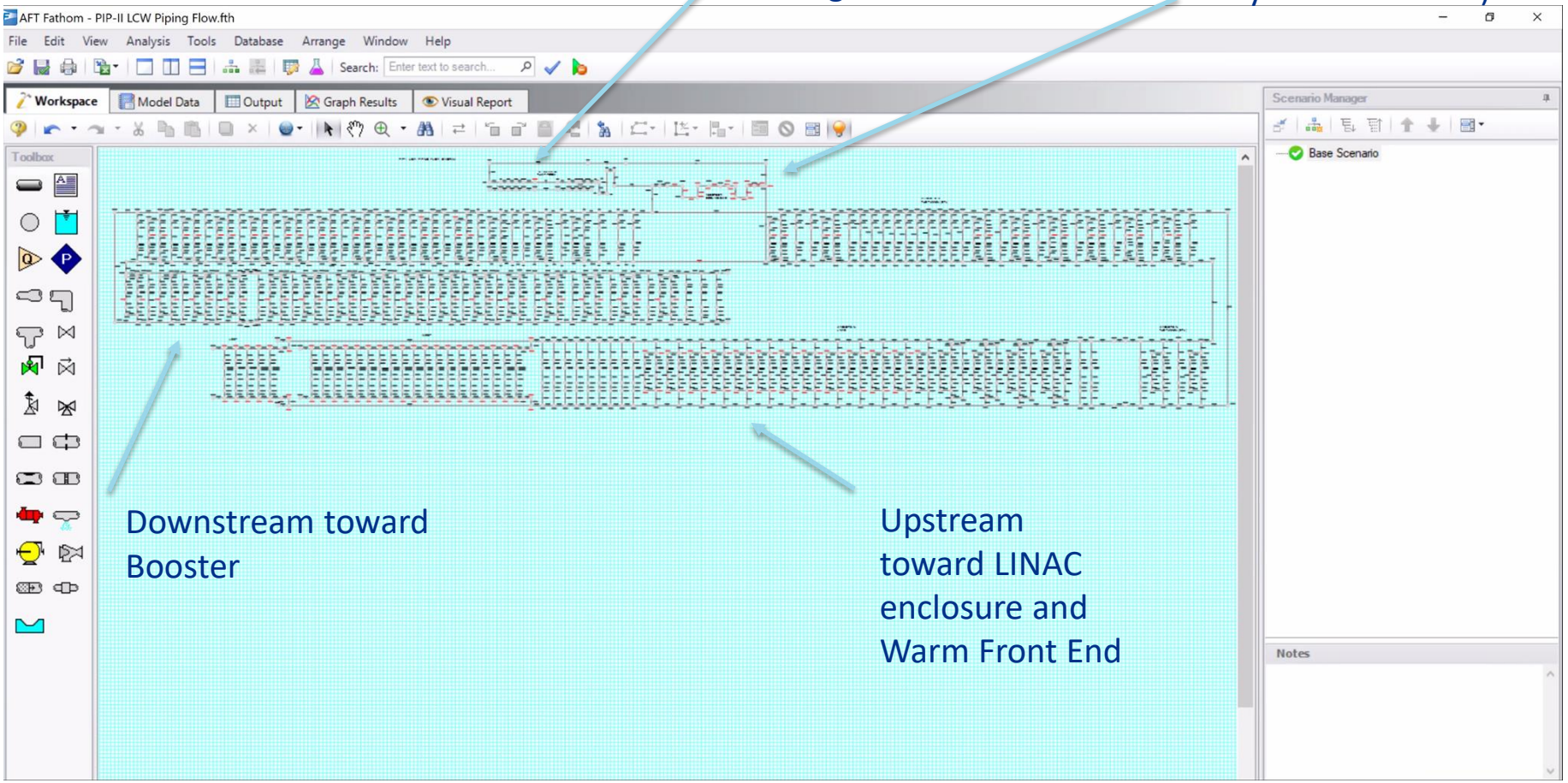


The customer must provide a minimum NPSHa of 19.4 ft.

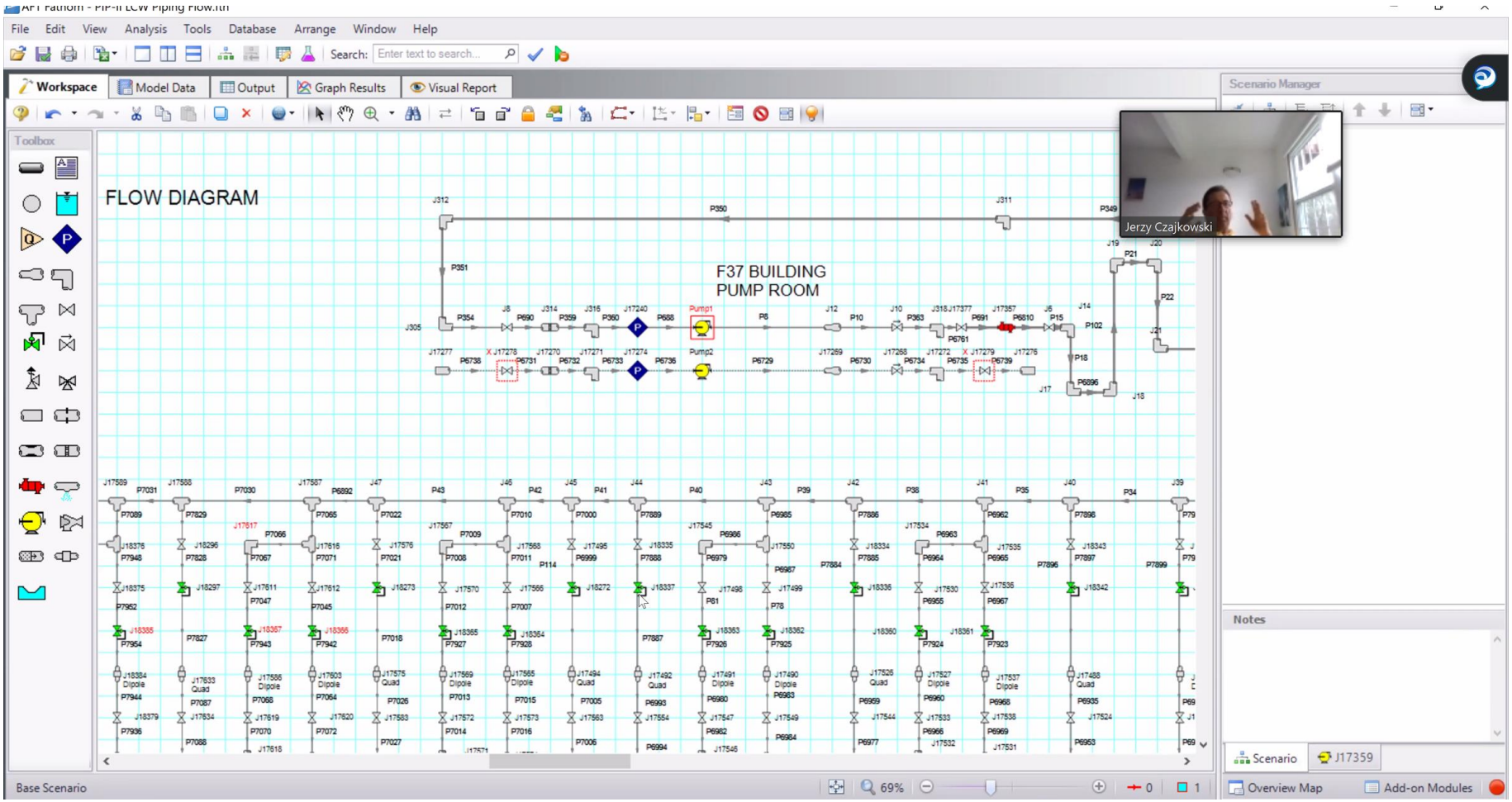
Aft Fathom Screenshots

Pump Room at F37 Service Building

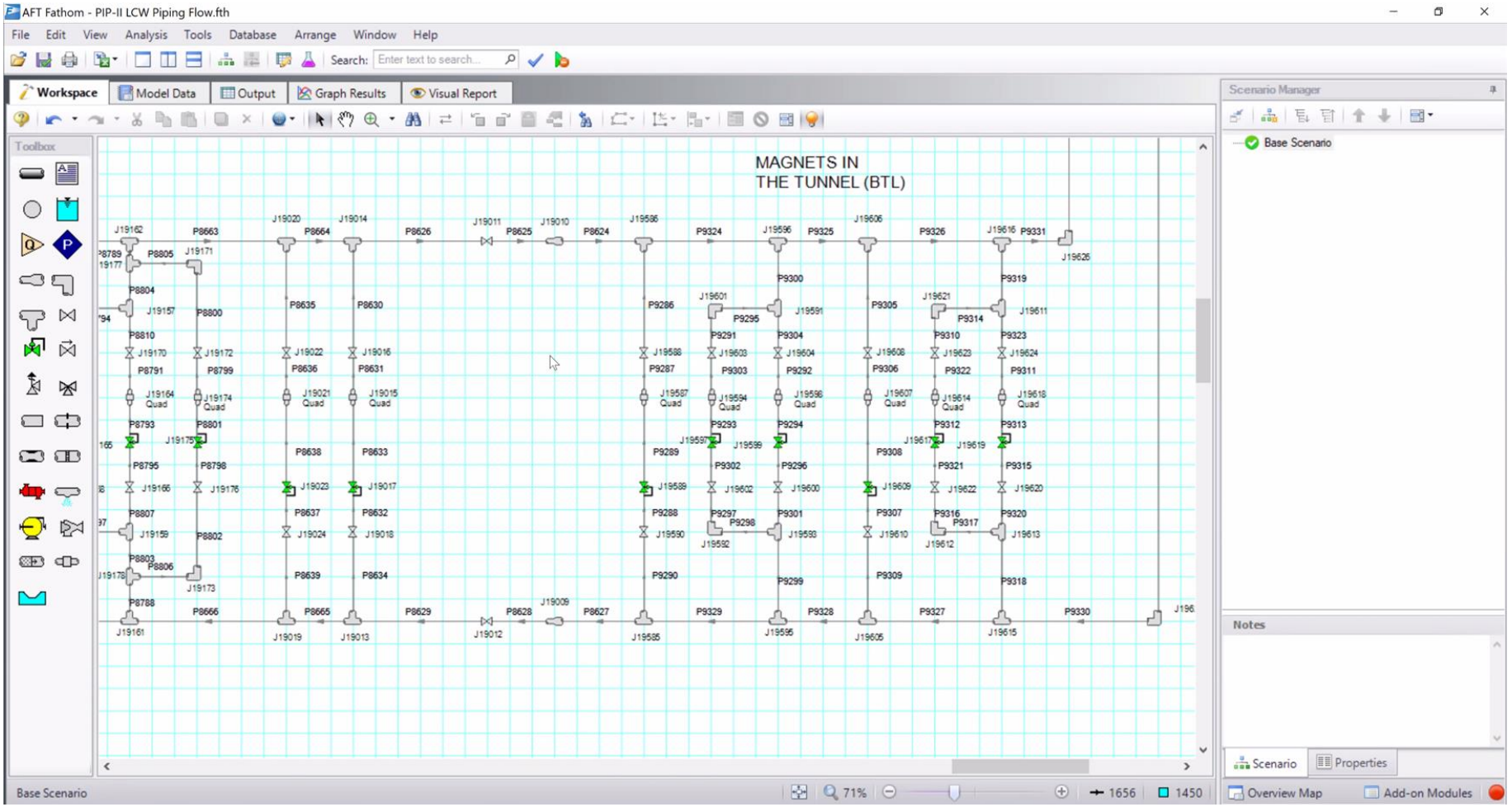
Absorber RAW (location shown in analysis not to scale)



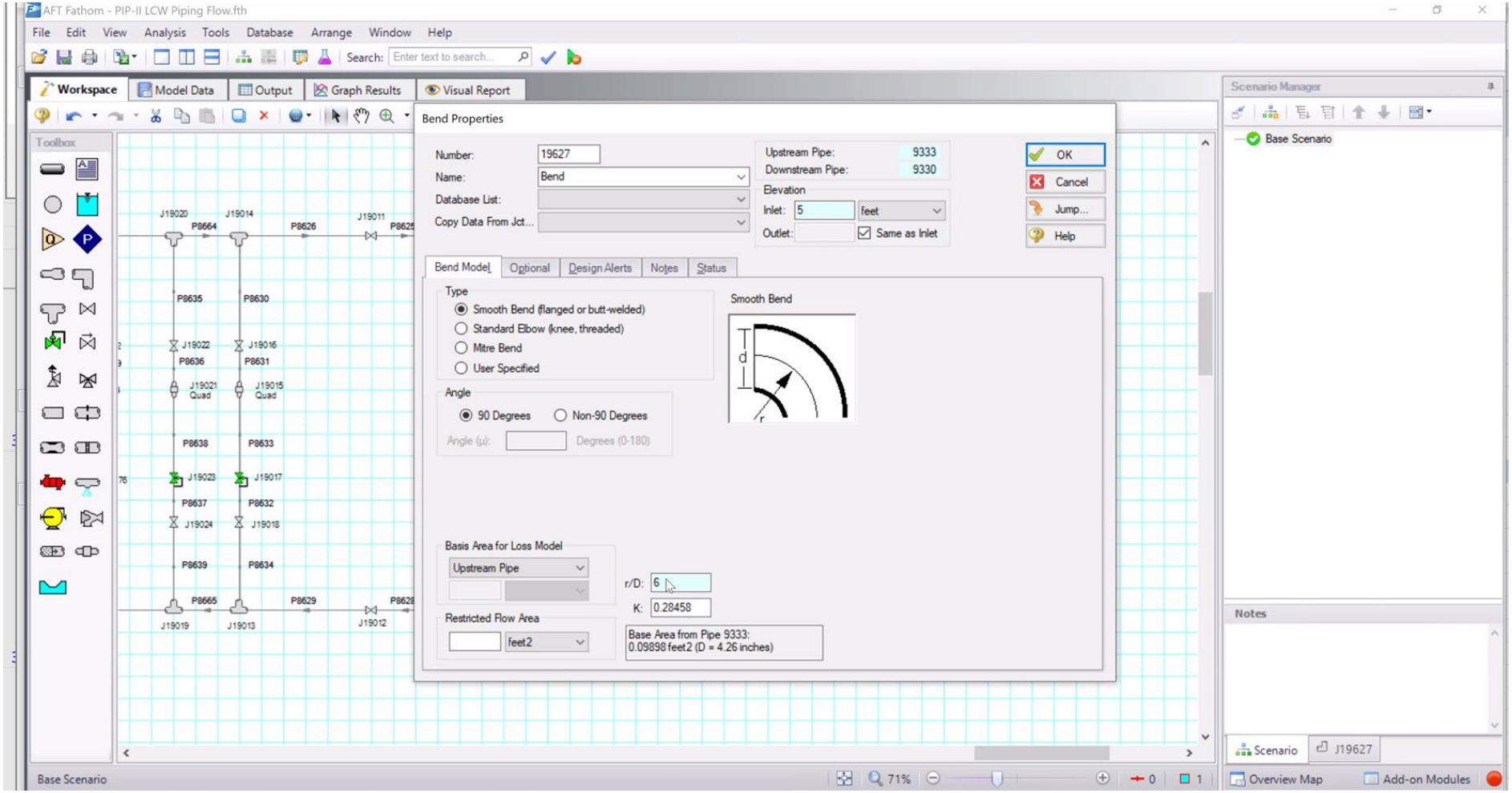
Aft Fathom Screenshots (Continued)



Aft Fathom Screenshots (Continued)



Aft Fathom Screenshots (Continued)



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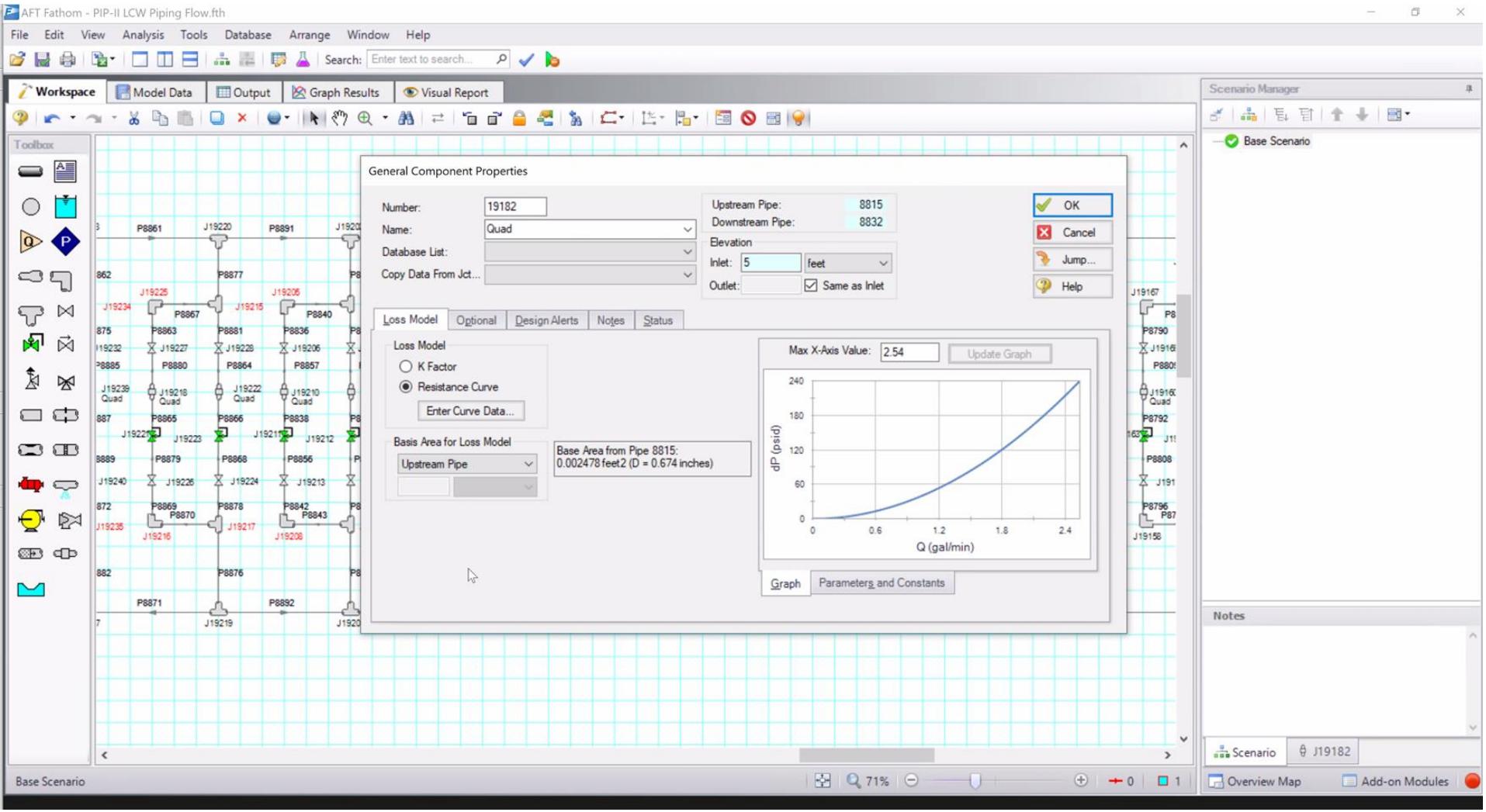
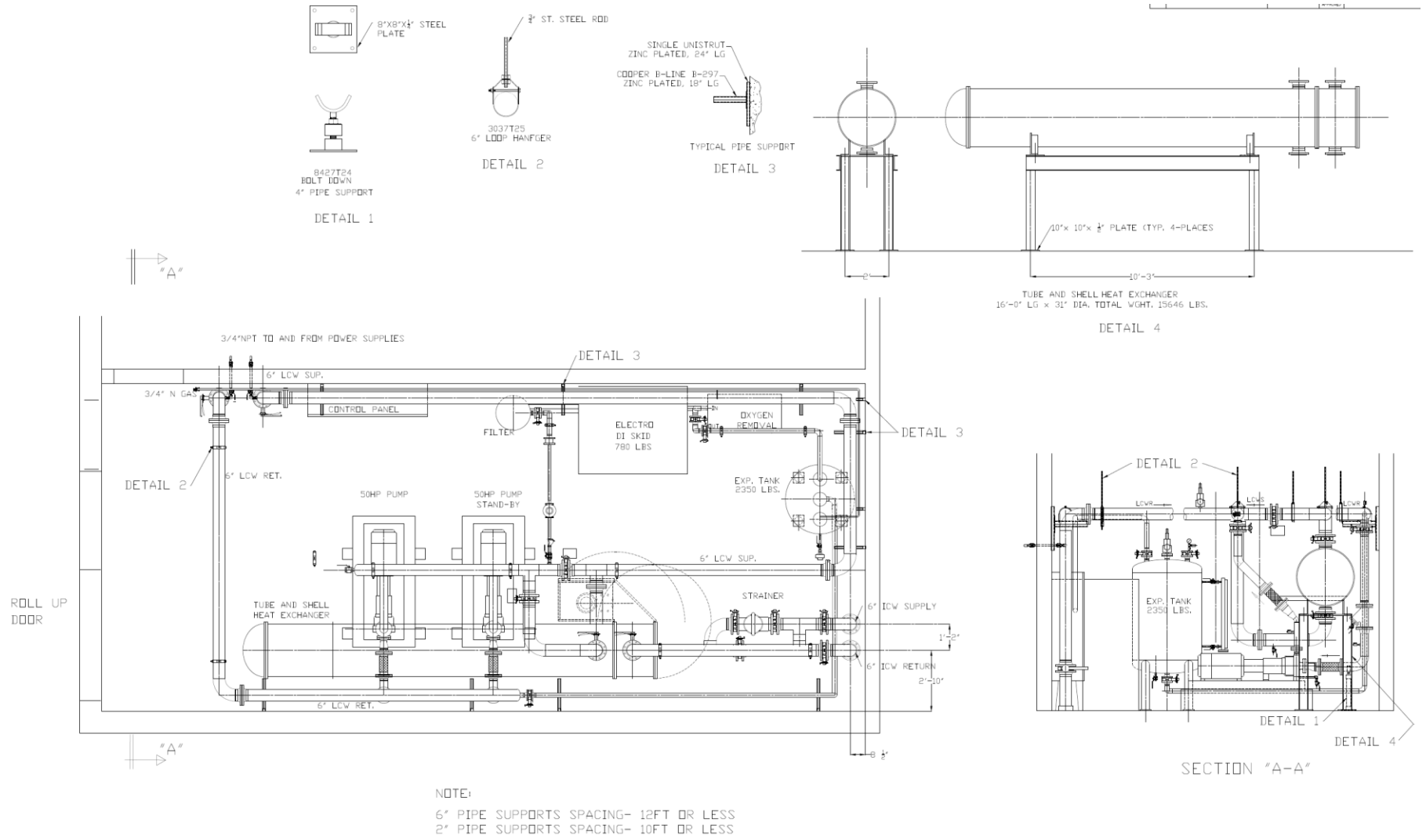


Preliminary Structural Support Analysis Of LCW Piping in F37 Service Building and Pump Room

- Working with Conventional Facilities
- Obtain firm fixed price proposal for professional A/E services
- Services will include review of:
  - The existing structural design of the F37 Service Building to determine if structural modifications are required to support the anticipated process loads.
- Our engineering team will design the LCW piping and pump room equipment supports and oversee installation.

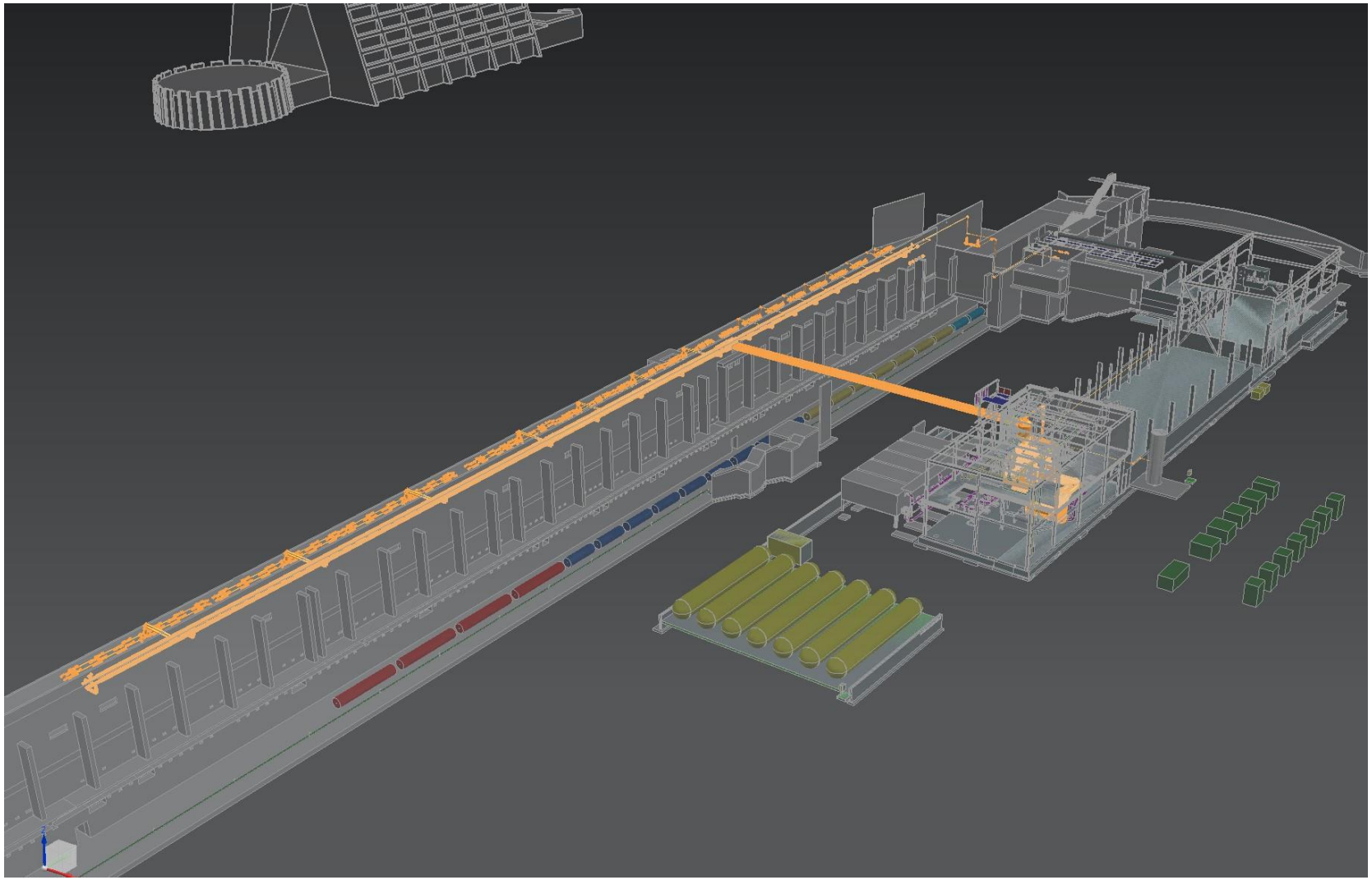
Preliminary Structural Support Analysis - LCW Pump Room in F37 Service Building (Continued)



Preliminary Structural Support Analysis - LCW Piping (Continued)

- Structural analysis of the LCW piping in the following areas not covered in this project scope:
  - BTL Enclosure
  - LINAC Enclosure
  - LINAC Warm Front End
- Structural analysis of LCW piping in these areas will be covered within the design scope of the Conventional Facilities

3D Screenshots – Site Complex (Southeast Elevated View)



3D Screenshots – LINAC Enclosure – Typical LB650 sector (West Elevated View)