# Primary Beamline
# Low Conductivity Water (LCW)
# Preliminary Design Review

Technical Design Aspects

131.01.03.03.02.04.02 Primary Water LCW System
131.01.03.03.02.04.03 Electrical Bus

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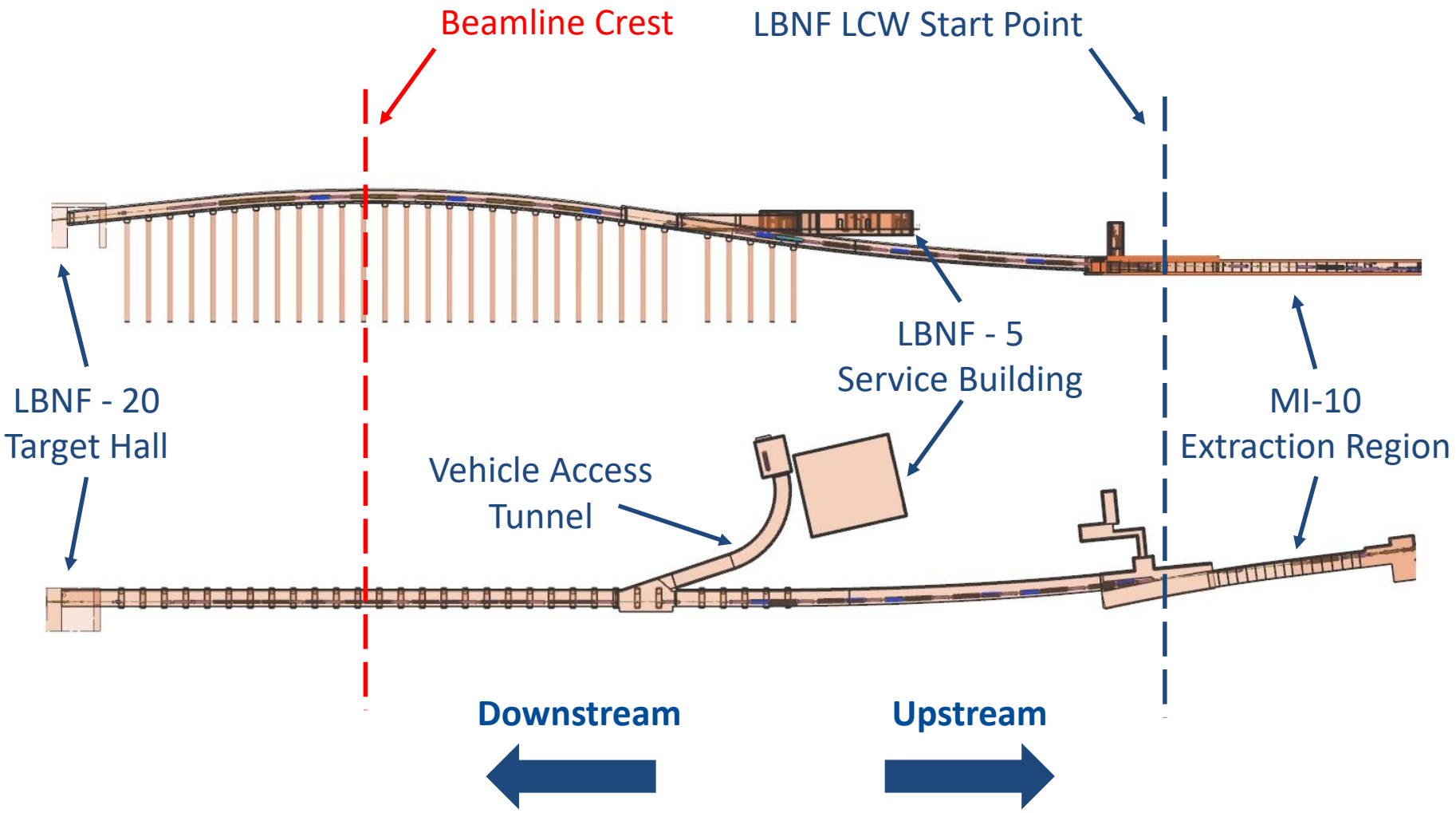
# System Operational Scope



# Summary of Major System Updates

- Re-arrangement of service building
  - MVA staging area merged with service building
  - Re-arrangement of dipole power supplies
    - Significant changes to pipe and bus routing
- Minor magnet lattice re-arrangements
- LBNF LCW fill system from MI added
- System now uses one primary pump with one hot spare

# System Operational Scope

- Provide LCW cooling
  - LBNF magnets downstream of Q203
  - LBNF magnet power supplies in LBNF – 5
  - Horn power supplies in LBNF – 20
  - Water cooled bus
- Manage dipole bus routing and hydraulics
  - System does not include cable-connected magnets
  - System does not include bus-to-magnet connections (flags)
  - Includes pump room bus shielding
- Provide LCW makeup for RAW room

# System Design Requirements

- Meet previously described operational goals
- Require minimal unscheduled interventions
- Meet established lab practices for flow and capacity
- Operate over a range of elevations determined by CF
- Use pond water for cooling and MI LCW for fill
- Conform to ASME B31.3 and FESHM 5031.1

| Fluid | Low Conductivity Water |
|---|---|
| Resistivity | 9MΩ·cm or better |
| Nominal Temperature | 95°F |
| Radioactivity | < 1900 pCi/ml |
| MAWP | 200 psig |

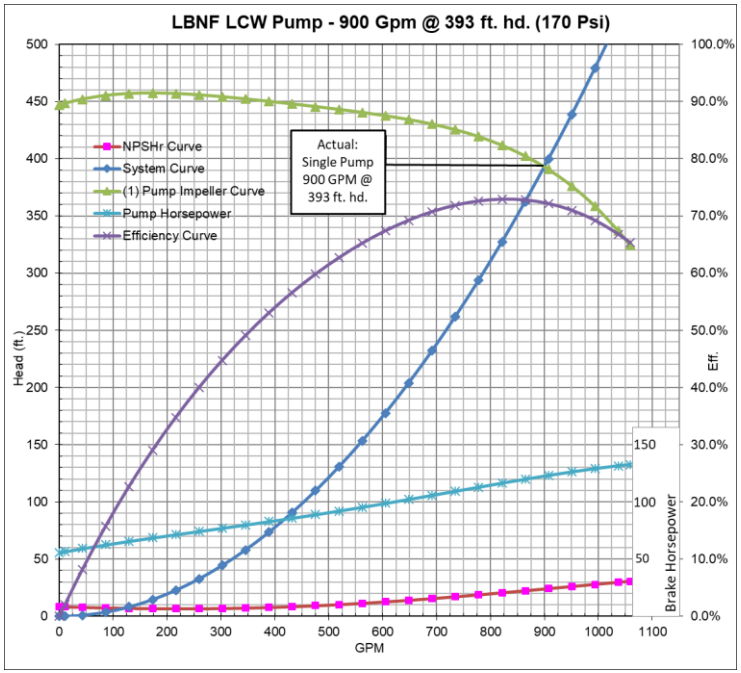
# Component Summary

- 41 water cooled magnets – 502 GPM, 477 kW
  - 2 QQU - Q60 Quadrupoles
  - 15 QQB - 3Q120 Quadrupoles
  - 12 IDA Dipoles
  - 12 IDD Dipoles
- 24 power supplies – 228 GPM, 178 kW
  - 15 quadrupole power supplies
  - 7 dipole power supplies
  - 2 horn power supplies
- 4,612 feet of 2”x2” dipole bus – 95 GPM, 193 kW
  - 5 pairs of bus

# Flow Requirements

- Sum of est. flows: 895 GPM
- With 5% contingency: 940 GPM
  - Horn PS flow may be over-estimated
- Fathom model: 124 BHP
  - 135 HP motor req. at 92% Efficiency
- 150 HP 900 GPM Flowserve Pump
  - 72% efficiency @ 908 GPM
  - 109.3% of BEP
  - 37.4 ft. NPSHA, 24.1 ft NPSHR

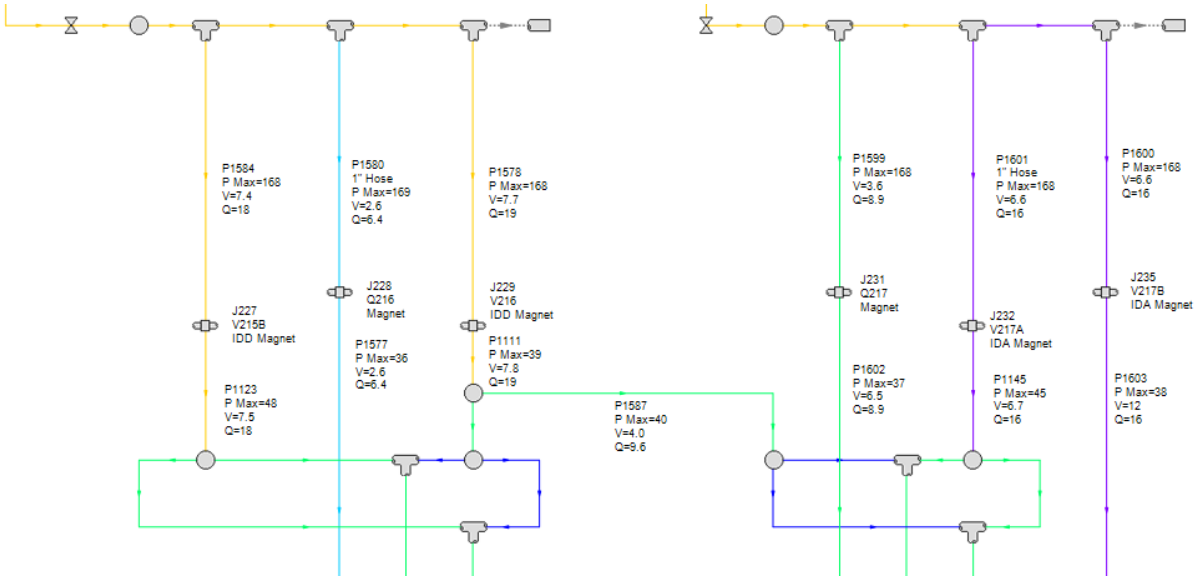
| | Flow Required |
|---|---|
| Magnets | 502 GPM |
| Magnet Power Supplies | 128 GPM |
| Dipole Bus | 95 GPM |
| Horn Power Supplies | 100 GPM |
| Filtration Allowance | 50 GPM |
| RAW Room Fill | 20 GPM |
| 5% Contingency | 45 GPM |
| **Estimated System Flow** | **940 GPM** |



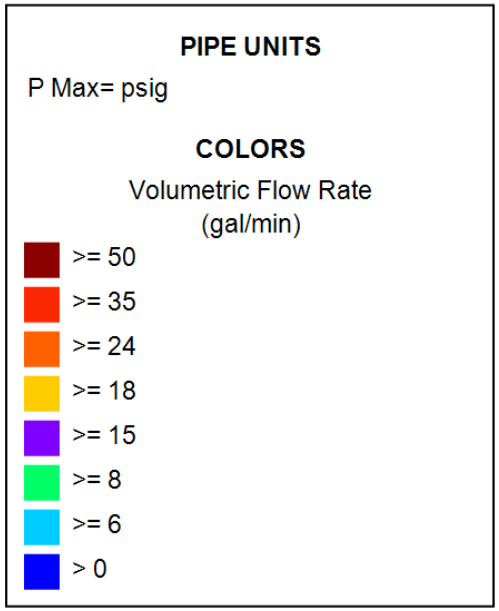
# Flow Requirements

- All magnets 100 psi dP or higher
- Using full dipole flows
  - Only 2/3 may be required

| Magnet Type | Required flow |
|---|---|
| QQB - 3Q120 Quad | 6 GPM |
| QQU - 3Q60 Quad | 8 GPM |
| IDA Dipole | 15 GPM |
| IDD Dipole | 18 GPM |

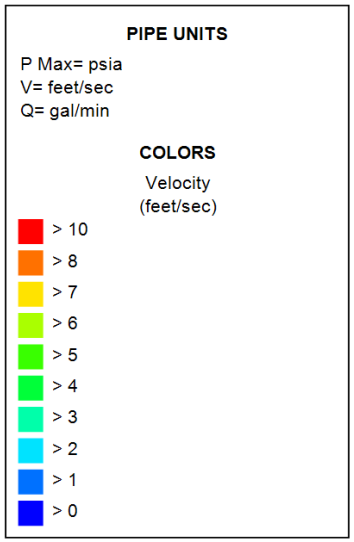


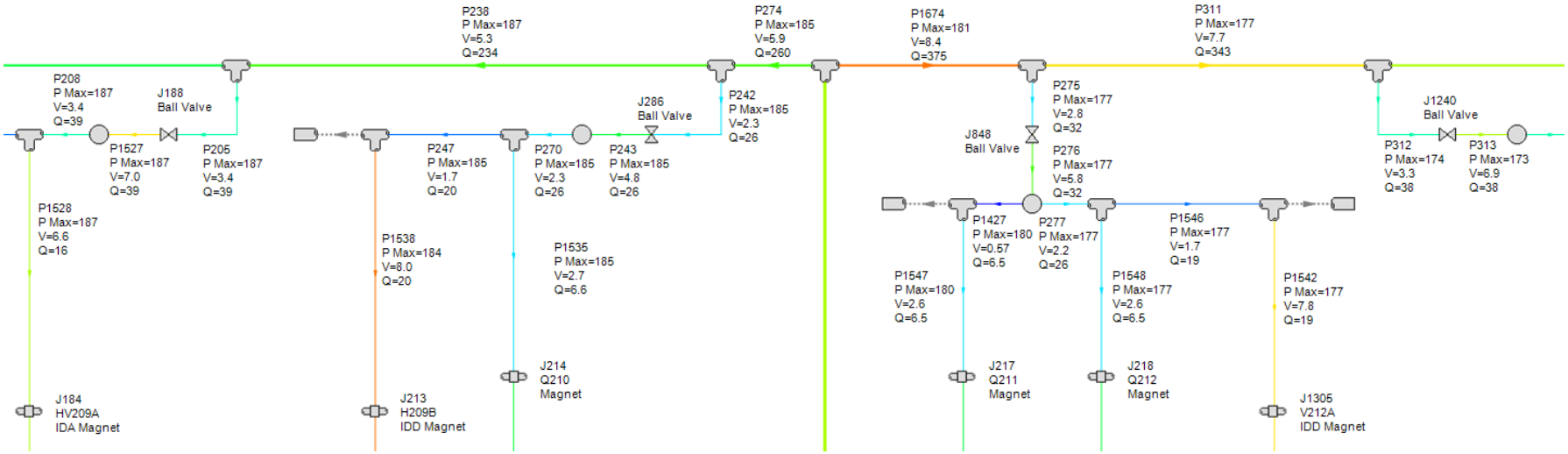

Detail view of magnets after beamline crest from "PDF of Fathom Model Indicating Fluid Flows" in DUNE DocDB Doc. #16706



# Fluid Velocity

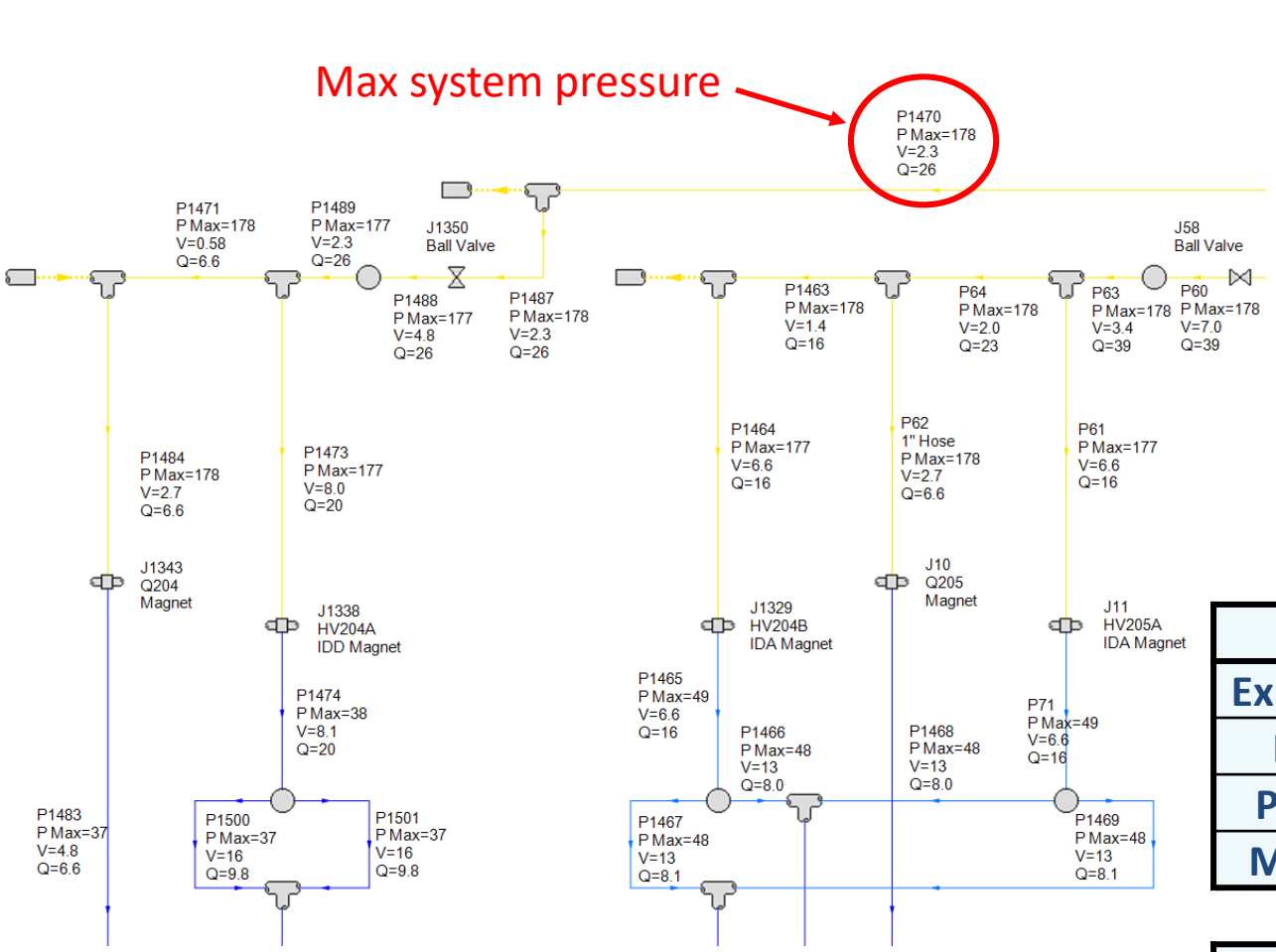
| | |
|---|---|
| **Pump Outlet** | 5.3 ft/s |
| **Vehicle Access Headers** | 6.4 ft/s |
| **Upstream Supply Header** | 8.4 - 3.8 ft/s |
| **Downstream Supply Header** | 5.9 - 2.3 ft/s |
| **Upstream RR Header** | 5.9 ft/s |
| **Downstream RR Header** | 8.4 ft/s |

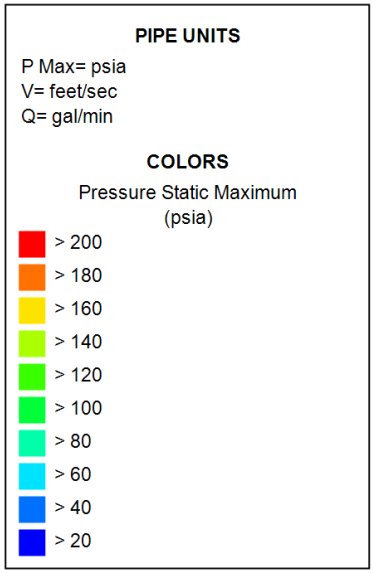



Detail view of LCW supply piping at tunnel alcove from “PDF of Fathom Model Indicating Fluid Velocities” in DUNE DocDB Doc. #16706

# System Pressures




| MAWP | 200 psig |
|---|---|
| Expansion Tank | 15 psig ($N_2$) |
| Pump Inlet | 2 psig |
| Pump Outlet | 170 psig |
| Max Pressure | 178 psig |

| Magnet dP | 109-140 psi |
|---|---|
| Magnet PS dP | 60 psi |
| Horn PS dP | 50 psi |

Detail view of LCW supply piping at upstream end of tunnel from “PDF of Fathom Model Indicating Fluid Pressures” in DUNE DocDB Doc. #16706

# Heat Dissipation

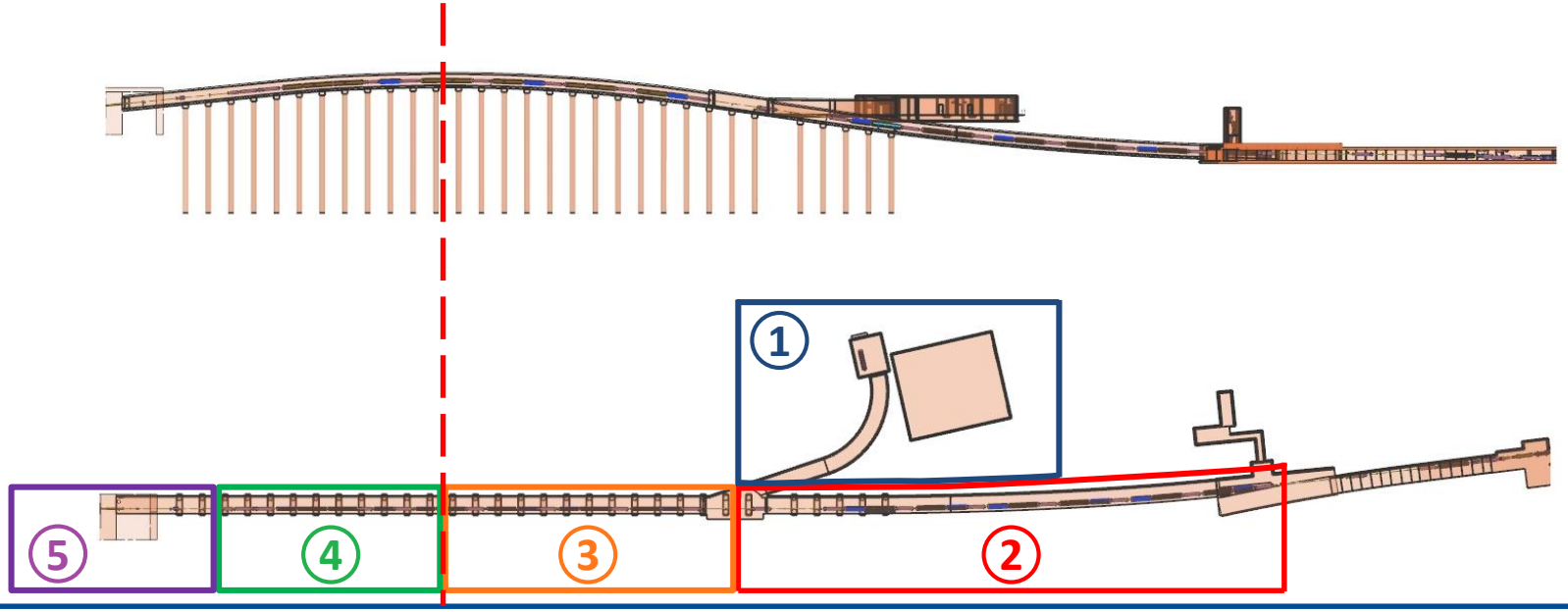
- **Nominal fluid temp: 95 °F**
- Heat exchanger ΔT: 9.1°F
- Magnets ΔT: 1.4°F – 11.5°F
- Power supplies ΔT: 0.9°F – 9.1°F
- Dipole bus ΔT:  7°F – 22.8°F
- **Max fluid temp: 118°F**
  - Occurs in longest bus run
  - Does not account for air cooling

| | Dissipated Power |
|---|---|
| Magnets | 477 kW |
| Magnet Power Supplies | 103 kW |
| Dipole Bus | 193 kW |
| Horn Power Supplies | 60 kW |
| 10% Contingency | 83 kW |
| Pump BkW to LCW | 97 kW |
| **Total kW Dissipated:** | **1,013 kW** |
| **Selected HX Size** | **1,200 kW** |

| Pump Motor Heat Dissipation | |
|---|---|
| Pump Motor Horsepower: | 150 |
| Pump Motor Power in kW: | 111.9 |
| Pump Motor Efficiency: | 90% |
| Heat Loss into Room (kW): | 11.2 |
| | |
| **VFD Heat Dissipation** | |
| Pump Motor VFD Horsepower: | 150 |
| Pump Motor VFD Power in kW: | 111.9 |
| Pump Motor VFD Efficiency: | 93% |
| Heat Loss into Room (kW): | 7.8 |
| | |
| **Total Heat Loss into Pump Room:** | **19 kW** |

# System Capacities

| | | Fluid Volume |
|---|---|---|
| 1 | Service Building & Pipes to Tunnel | 2,721 Gal. |
| 2 | Magnets Upstream of Service Building | 622 Gal. |
| 3 | Magnets Downstream of Service Building Before Crest | 538 Gal. |
| 4 | Magnets Downstream of Service Building After Crest | 266 Gal. |
| 5 | Target Hall and Piping Leading to Target Hall | 195 Gal. |
| **Total System Volume:** | | **4,342 Gal.** |



# ASME B31.3/FESHM 5031.1 Compliance

- 8” straight pipe @ 200 psig $t_{required}$ = 0.054”
- 6” curved access corridor pipes @ 200 psig $t_{required}$ = 0.041”

- 8” sch. 10 304/304L pipe $t_{actual}$ = 0.138”, 2.5x thicker than required
- 6” sch. 10 304/304L pipe $t_{actual}$ = 0.134”, 3.2x thicker than required

- Only listed tees, junctions, valves, etc. will be used
  - Class 150 Flanges are sufficient

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