# 4.7 WATER, VACUUM AND GAS SYSTEMS (WBS 1.1.7)

## 4.7.1 Introduction

In this section are grouped together details of the various utilities required for the NuMI beams. Water and gas would normally be expected to fall under the heading of utilities, and for NuMI it has been decided to include vacuum as well.

## 4.7.2 System Description: Water systems

Cooling water at Fermilab falls into three categories - **Industrial Cooling Water (ICW**), **Low Conductivity Water (LCW**) and **RadioActive Water (RAW**). These systems are needed to remove, directly or indirectly, the heat generated by the operation of electrical devices and to dispose of the energy deposited in various components by high energy beams. Without functional cooling systems, many beamline components would be damaged and fail due to excessive thermal buildup. There are seven NuMI water systems.

**4.7.2.1 The MI-62 (Upstream) LCW system**. This system provides cooling water to all of the extraction and pre-target magnets. The MI-62 LCW system rejects its heat to the pond G pond water system. There are two installed pumps, one pump runs, one in hot stand-by. Controls for the MI-62 water system will also include controls and instrumentation for the pond water (PW) system. The MI-62 (Upstream) LCW system is not anticipated to become activated. See Drawing 8875.117-ME-406228, NuMI Extraction & Pre-Target (Upstream) LCW System P&ID

| | |
|---|---|
| Approximate System Volume: | 4200 gallons |
| Approximate Pump Specifications: | 600 gallons per minute<br>440 feet total developed head<br>125 horsepower |
| Heat Load | 760 kW |
| Nominal Heat Exchanger Capacity | 1200 kW |

**4.7.2.2 The MINOS LCW system**. This system provides cooling water to the MINOS Near Detector Coil, its power supply and the electronics racks located in the MINOS Near Detector Hall. The MINOS LCW system rejects its heat to a FESS provided chilled water system in the MINOS Service Building and MINOS Cavern. There are two installed pumps, one pump runs, one in hot stand-by. Control of the FESS provided chilled water system is outside of the scope of the NuMI Water Systems Controls. The MINOS (Downstream) LCW system is not anticipated to become activated. See Drawing 8875.117-ME-406230, NuMI Downstream P&ID.

| | |
|---|---|
| Approximate System Volume: | 310 gallons |
| Approximate Pump Specifications: | 145 gallons per minute<br>110 feet total developed head<br>3 horsepower |
| Heat Load | 109 kW |
| Nominal Heat Exchanger Capacity | 150 kW |

**4.7.2.3 The Decay Pipe Cooling RAW system**. This system provides cooling to the 2300 feet long vacuum decay pipe located in the tunnel between the NuMI Target Hall and the NuMI Absorber Caverns. The Decay Pipe Cooling RAW System rejects its heat to a FESS provided chilled water system at the upstream end of the decay pipe and also rejects its heat at the downstream end to the same FESS provided chilled water system that accepts heat from the MINOS LCW System. There are two installed pumps, one pump runs, one in hot stand-by. Control of these systems is outside of the scope of the NuMI Water Systems Controls.

The water in this system will become activated. Kamran Vasiri has calculated the activation of the Decay Pipe Cooling System. After one year of operation and one hour of cool down, the total activity in the decay pipe cooling system should be approximately 87 mCi/year. Dose rate to a person standing next to the pump suction tank should be approximately 1 mrem per hour. See Drawing 8875.117-ME-406231,NuMI Decay Pipe Cooling P&ID

| | |
|---|---|
| Approximate System Volume: | 725 gallons |
| Approximate Pump Specifications: | 24 gallons per minute<br>270 feet total developed head<br>7.5 horsepower |
| Heat Load | 140 kW |
| Nominal Heat Exchanger Capacity | 150 kW |

**4.7.2..4 The Absorber Cooling RAW System**. This system provides cooling to the NuMI Absorber (Beam Dump), which is located in the NuMI Absorber Cavern at the downstream end of the decay pipe. The Absorber Cooling RAW system rejects its heat to an Intermediate Water System, which in turn rejects its heat to a pond water system at the MINOS service building. There are two installed pumps, one pump runs, one in hot stand-by. Control of the intermediate system is within the scope of the NuMI Water Systems Controls but the pond water system is not.

The water in this system will become activated. Kamran Vasiri has calculated the affect of a complete failure of the water containment systems for the absorber RAW system. Based on the concentration of tritium in the absorber cooling water of 16,000 pCi/ml (represents one year of running) and a water inflow rate of 150 gpm (conservative) the concentration of tritium in the sump discharge water would be less then 1500 pCi/ml. This is less than the allowable limit of 2000 pCi/ml. See Drawing 8875.117-ME-406229, NuMI Absorber RAW System P&ID

Absorber Core Cooling System

| | |
|---|---|
| Approximate System Volume: | 90 gallons |
| Approximate Pump Specifications: | 506 gallons per minute<br>65 feet total developed head<br>3 horsepower |
| Heat Load | 150 kW |
| Nominal Heat Exchanger Capacity | 150 kW |

Absorber Intermediate Cooling System:

| | |
|---|---|
| Approximate System Volume: | 880 gallons |
| Approximate Pump Specifications: | 50 gallons per minute<br>52 feet total developed head<br>3 horsepower |
| Heat Load | 150 kW |
| Nominal Heat Exchanger Capacity | 150 kW |

**4.7.2..5 The Target & Baffle RAW System**. This system provides cooling to the NuMI Target and Beam Baffles located in the NuMI Target Hall. There are two installed pumps, one pump

runs, one in hot stand-by. This system rejects its heat to the MI-62 LCW system. See Drawing 8875.117-ME-406232, NuMI Target & Baffle P&ID. The water in this system will become activated. Kamran Vaziri has calculated the amount of radioactivity as a function of time in the target RAW system to be about 3.5 curies after one year of operation. Of this, approximately 0.8 Curies is the relatively long-lived isotope tritium. Dose rate at one foot from the piping for this system will be about 14.3 rads per hour. Only 0.2 rads per hour is from $^{7}$Be, the rest is from short-lived isotopes. Approximately 1 $cm^3$ of hydrogen gas will be produced each day for this system.

| | |
|---|---|
| Approximate System Volume: | 85 gallons |
| Approximate Pump Specifications: | 10gallons per minute<br>42 feet total developed head<br>1/2 horsepower |
| Heat Load | ~5 kW |
| Nominal Heat Exchanger Capacity | 20 kW |

**4.7.2..6 The Horn 1 RAW System**. This system provides cooling to Horn 1 located in the NuMI Target Hall. The Horn 1 RAW System rejects its heat to a FESS provided chilled water system. There are two installed pumps, one pump runs, one in hot stand-by. Control of this FESS provided chilled water system is outside of the scope of the NuMI Water Systems Controls. See Drawing 8875.117-ME-406477,NuMI Horn #1 and Horn #2 RAW Water P&ID The water in this system will become activated. Kamran Vaziri has calculated the amount of radioactivity as a function of time in the horn1 cooling water. He has also calculated the amount of shielding needed around the DI bottles necessary to keep the dose to about 1 mrem per hour for people in close proximity to the DI bottles. Approximately 3 inches of lead are sufficient.

| | |
|---|---|
| Approximate System Volume: | 105gallons |
| Approximate Pump Specifications: | 110 gallons per minute<br>106 feet total developed head<br>5 horsepower |
| Heat Load | 43.5 kW |
| Nominal Heat Exchanger Capacity | 90 kW |

**4.7.2..7 The Horn 2 RAW System**. This system provides cooling to Horn 2 located in the NuMI Target Hall. There are two installed pumps, one pump runs, one in hot stand-by. The Horn 2 RAW System rejects its heat to a FESS provided chilled water system. Control of this FESS provided chilled water system is outside of the scope of the NuMI Water Systems Controls. The water in this system will become activated.

| | |
|---|---|
| Approximate System Volume: | 95 gallons |
| Approximate Pump Specifications: | 110 gallons per minute<br>103 feet total developed head<br>5 horsepower |
| Heat Load | 40 kW |
| Nominal Heat Exchanger Capacity | 50 kW |

## 4.7.3 System Description: Vacuum Systems

Transport of the NuMI proton and hadron beams requires that various levels of vacuum be established in the MI tunnel, extraction stub, carrier pipe, pretarget area and decay pipe. Since the NuMI beamlines are single pass, requirements are not so stringent as they are in a circular machine. The novel feature is the 675 m long decay pipe, which has a very large evacuated volume. There are two vacuum systems:

**4.7.3.1 The primary beam transport system**. This vacuum system starts in the extraction area at the Lambertson magnets and continues through magnet bends 1 and 2, through the carrier pipe, to the pre-target area, through the final bend, bend 3, and just into the target pile. This vacuum system ends just before the second horn protection baffle. The vacuum in the primary beam transport system needs to operate at $1 \times 10^{-6}$ torr in the vicinity of the beam instrumentation but can rise to a higher level of $1 \times 10^{-5}$ torr in the middle of the carrier pipe. See Drawing 8875.117-MC-406XXX, NuMI Proton Beam-line Vacuum P&ID.

**4.7.3..2 The decay pipe vacuum system**. This system starts just downstream of the target pile and extends 2214 feet (675 meters) to just upstream of the beam absorber. This system needs to operate at a pressure of approximately 1 torr. See Drawing 8875.117-ME-406092,NuMI-Vacuum Decay Pipe Vacuum P&ID.

## 4.7.4 System Description: Utility System Controls

For each of the seven water systems and the two vacuum systems listed above, the following summary lists the interlocks, alarms, permits, analog variables, ON-OFF signals to and from ACNET, and finally the local instrumentation.

**Interlocks**: Each water system has one or more pumps, which are protected by a series of interlocks. These pump interlocks may be implemented in hard wired relay logic (ladder logic) or implemented in a Programmable Logic Controller (PLC). The decision as to which method to use has not yet been.

**Analog Variables:** Each system will have a number of instruments, which output analog variables to be displayed on an ACNET parameter page and/or a customized application program. Typically, these variables include water system pressures, temperatures, flow rates, expansion tank liquid levels, and resistivity. These signals may be chosen to be 4-20 ma signals or 0 to 10 VDC signals. The decision as to whether these analog signals are fed directly into a MADC or are fed into a PLC has not yet been made

**Alarms**: From the set of analog variables, there will be alarms for conditions where the analog variable either exceeds or is less than a given value. The intent is that when the variable exceeds or falls under a given value, an alarm will be displayed on the alarms display in the main control room. These alarms will be generated in ACNET in comparing the value of the analog variables to predetermined ‘limits’.

**ON-OFF signals to ACNET**: Each system will generate digital status for reading by ACNET. For example, the intent is to monitor current switches on the pump motors and to indicate on an ACNET console that a particular pump is drawing current (on) or not drawings current (off).

**ON-OFF signals from ACNET**: Each system will receive one or more digital commands from ACNET. These signals will be used to start or stop pumps based on an operator’s command at the ACNET console.

**Permits**. These permits will be for ‘beam permits’ or ‘power supply permits’ or both. The intent of these permits is to generate a signal that indicates satisfactory operation of the system.

Should the parameters of the system indicate that the system is not operating satisfactory, the permit signal will be removed.

**Local instrumentation**: This is instrumentation, which is non-interfaced to the control system. This instrumentation is typically comprised of pressure gauges, thermometers, flow meters and level gauges. This local instrumentation provides a visual indication and is intended to aid in system commissioning and to de-bug system problems in the event of a failure or poor performance.

#### 4.7.4.1 MI-62 (Up Stream) LCW System

**LCW Pump Motor Interlocks**

| | |
|---|---|
| Contactor – | 3phase rotation<br>Over-current<br>Motor Internal Over-temperature Switch<br>(Wired Normally Closed) |
| Expansion Tank Liquid Level | Low Low Low |
| LCW Supply Temperature | Low Low (permit if value > 60 degrees F) |
| LCW Supply Temperature | High High (permit if value < 110 degreesF) |

**Pond Water Pump Motor Interlocks**

| | |
|---|---|
| Contactor – | 3 phase rotation<br>Over-current<br>Motor Internal Over-temperature Switch<br>(Wired Normally Closed) |
| Differential Pressure Across Pump | Low (w/ 15 second time delay) |

**Analog Variables to ACNET**

- LCW Supply Pressure
- LCW Pump Suction Pressure
- LCW Supply Temperature
- LCW Return Temperature

- LCW Supply Resistivity (4-20 ma Signal)
- LCW Resistivity Out of the DI Bottles (4-20 ma Signal)
- LCW Resistivity at the NuMI TSB Power Supply Room (4-20 ma Signal)
- LCW Expansion Tank Liquid Level
- Differential Pressure Across Pond Water Strainer
- Pond Water Pump Suction Pressure
- Pond Water Pump Discharge (Supply) Pressure
- Pond Water Supply Temperature
- Pond Water Return Temperature

**Alarms to ACNET**

- Pond Water Supply Pressure Low for15 Seconds
- High Differential Pressure Across Pond Water Strainer
- Expansion Tank Pressure Low
- Expansion Tank Liquid Level Low
- Expansion Tank Liquid Level High
- LCW Supply Temperature High (alarm if value > 100 Degrees Fahrenheit.)
- LCW Supply Temperature Low (alarm if value < 70 Degrees Fahrenheit.)

**ON-OFF Signals to ACNET**

- LCW Pump Current Switches

**ON-OFF Signals from ACNET**

- LCW Pump Remote Start and Stop Switches

**Inputs to Beam Permit**

- Sum of Magnet Power Supply Permit Inputs

**Inputs to Beam Line Magnet Power Supply Permit**

- Either LCW Pump Drawing Current
- Expansion Tank Liquid Level Not Low Low
- LCW Supply Temperature Not High (permit if value < 110 degrees Fahrenheit.)

**Local Instrumentation (Gauges w/o wires)**

Pressure Gauges

- LCW Pump Suction (2) Range is 0 to 30 psig
- LCW Pump Discharge (2) Range is 0 to 300 psig

- Expansion Tank (1) Range is 0 to 60 psig
- Power Supply LCW Supply Headers (2) Range is 0 to 200 psig
- Power Supply LCW Return Headers (2) Range is 0 to 200 psig
- Power Supply LCW Supply Header in Tunnel (1) Range is 0 to 300 psig
- Power Supply LCW Return Header in Tunnel (1) Range is 0 to 300 psig
- Pond Water Basket Strainer Inlet and Outlet (2) Range is 0 to 200 psig
- DI-Bottle inlet header (1) Range is 0 to 60 psig
- DI-Bottle outlet header (1) Range is 0 to 60 psig
- LCW Supply Header in Tunnel at TSB (1) Range is 0 to 300 psig
- LCW Return Header in Tunnel at TSB (1) Range is 0 to 300 psig

Temperature Gauges

- Heat Exchanger (4) Range is approximately 0 to 200 degree Fahrenheit.

Flow Gauges

- Di-Bottle Flow (1) Range is 6 to 60 gpm
- LCW Make-Up (1) Range is 6 to 60 gpm

Level Gauges (Sight Glasses)

- Expansion Tank

### 4.7.4.2 MINOS (Down Stream) LCW System

**Pump Motor Interlocks**

| | |
|---|---|
| Contactor – | 3 phase rotation<br>Over-current<br>Motor Internal Over-temperature Switch<br>(Wired Normally Closed) |
| Expansion Tank Liquid Level | Low Low |
| LCW Supply Temperature | Low Low (permit if value > 60 degrees F)<br>w/ 5 minute time delay |

**Analog Variables to ACNET**

- LCW Supply Pressure
- LCW Pump Suction Pressure
- LCW Booster Pump Discharge Pressure
- LCW Supply Temperature
- LCW Supply Resistivity (4-20 ma Signal)
- LCW Resistivity Out of the DI Bottles (4-20 ma Signal)
- LCW Expansion Tank Liquid Level

**Alarms to ACNET**

- Expansion Tank Liquid Level Low
- Expansion Tank Liquid Level High
- LCW Supply Temperature High (alarm if value > 75 Degrees Fahrenheit.)
- LCW Supply Temperature Low (alarm if value < 65 Degrees Fahrenheit.)

**ON-OFF Signals to ACNET**

- LCW Pump Current Switches
- Booster Pump Current Switch

**ON-OFF Signals from ACNET**

- LCW Pump Remote Start and Stop Switches

**Inputs to Beam Permit**

None

**Inputs to Near Detector Magnet Power Supply Permit**

- Either LCW Pump Drawing Current
- Booster LCW Pump Drawing Current
- Expansion Tank Liquid Level Not Low Low
- LCW Supply Temperature Not High (allow permit if value < 80 degrees F)

**Local Instrumentation (Gauges w/o wires)**

Pressure Gauges

- LCW Pump Suction (2) Range is 0 to 30 psig
- LCW Pump Discharge (1) Range is 0 to 60 psig
- LCW Booster Pump Discharge (2) Range is 0 to 100 psig
- Expansion Tank (1) Range is 0 to 60 psig
- DI-Bottle inlet header (1) Range is 0 to 60 psig
- LCW Supply Header (1) Range is 0 to 60 psig
- LCW Return Header (1) Range is 0 to 60 psig

Temperature Gauges

- Heat Exchanger (4) Range is approximately 20 to 140 degree Fahrenheit.

Flow Gauges

- Di-Bottle Flow (1) Range is 2 to 20 gpm

Level Gauges (Sight Glasses)

- Expansion Tank

### 4.7.4.3 Decay Pipe Cooling RAW System

**Pump Motor Interlocks**

| | |
|---|---|
| Contactor | 3 phase rotation<br>Over-current<br>Motor Internal Over-temperature Switch<br>(Wired Normally Closed) |
| Expansion Tank Liquid Level | Low Low |

**Analog Variables to ACNET**

- Pump Discharge Pressure
- Pump Suction Pressure
- Water Supply Temperature (2 points)
- Water Return Temperature (2 points)
- Water Expansion Tank Liquid Level

**Alarms to ACNET**

- Expansion Tank Liquid Level Low
- Expansion Tank Liquid Level High
- Cooling Water Supply Temperature High (alarm if value > 75 Degrees Fahrenheit.)
  (This temperature will be measured at two locations)
- Cooling Water Return Temperature High (alarm if value > 95 Degrees Fahrenheit.)
  (This temperature will be measured at two locations)

**ON-OFF Signals to ACNET**

- RAW Pump Current Switches
- Flow Switch low.

**ON-OFF Signals from ACNET**

- RAW Pump Remote Start and Stop Switches

**Inputs to Beam Permit**

- Return Water Temperature Not High (measured at 2 points)
- Pump Differential Pressure Not Low (1 minute time delay)
- Pump Differential Pressure Not High (1 minute time delay)
- Either Pump Drawing Current

- Expansion Tank Level not Low Low

**Local Instrumentation (Gauges w/o wires)**

Pressure Gauges

- Pump Suction (2) Range is 0 to 60 psig
- Pump Discharge (1) Range is 0 to 200 psig
- Expansion Tank (1) Range is 0 to 60 psig
- DI-Bottle inlet header (1) Range is 0 to 60 psig
- Heat Exchanger Inlet in Tunnel at TSB (1) Range is 0 to 100 psig
- Heat Exchanger Outlet in Tunnel at TSB (1) Range is 0 to 100 psig
- Heat Exchanger Inlet in Tunnel at D.S. End (1) Range is 0 to 100 psig
- Heat Exchanger Outlet in Tunnel at D.S. End (1) Range is 0 to 100 psig
- Full Flow Filter Differential Pressure (1) Range is 0 to 10 psig

Temperature Gauges

- Heat Exchangers Inlets and Outlets (8) Range is approximately 20 to 140 degree F

Flow Gauges

- Di-Bottle Flow (1) Range is 2 to 20 gpm

Level Gauges (Sight Glasses)

- Expansion Tank

### 4.7.4.4 Absorber Cooling RAW System

**Pump Motor Interlocks**

Absorber RAW Pumps:

| | |
|---|---|
| Contactor | 3 phase rotation<br>Over-current<br>Motor Internal Over-temperature Switch (Wired Normally Closed) |
| Absorber RAW Expansion Tank Liquid Level | Low Low |

Absorber Intermediate Loop Pumps:

| | |
|---|---|
| Contactor | 3 phase rotation<br>Over-current<br>Motor Internal Over-temperature Switch (Wired Normally Closed) |
| Absorber Intermediate Loop Expansion Tank Liquid Level | Low Low |

**Analog Variables to ACNET**

- Absorber RAW Pump Discharge Pressure (Supply Pressure)
- Absorber RAW Return Pressure
- Absorber RAW Pump Suction Pressure
- Absorber RAW Water Supply Temperature
- Absorber RAW Water Return Temperature
- Absorber RAW Water Expansion Tank Liquid Level
- Absorber RAW Resistivity out of the DI Bottle (4-20 ma Signal)
- Absorber Intermediate Loop Supply Temperature

**Alarms to ACNET**

- Absorber RAW Expansion Tank Liquid Level Low
- Absorber RAW Expansion Tank Liquid Level High
- Absorber RAW Water Supply Temperature High (alarm if value > 105 Degrees F.)
- Absorber RAW Water Return Temperature High (alarm if value > 125 Degrees F.)
- Absorber Intermediate Expansion Tank Liquid Level Low

- Absorber Intermediate Expansion Tank Liquid Level High
- Absorber Intermediate Water Supply Temperature High (alarm if value > 95 Degrees F)

**ON-OFF Signals to ACNET**

- Absorber RAW Pump Current Switches (2)
- Absorber Intermediate Pump Current Switches (2)

**ON-OFF Signals from ACNET**

- Absorber RAW Pump Remote Start and Stop Switches

**Inputs to Beam Permit**

- Absorber RAW Return Water Temperature Not High (permit if value < 130 Degrees F)
- Absorber RAW Pump Differential Pressure Not Low
- Absorber RAW Pump Differential Pressure Not High
- Either Absorber RAW Pump Drawing Current
- Absorber RAW Expansion Tank Level not Low Low
- Either Absorber Intermediate Pump Drawing Current
- Absorber Intermediate Expansion Tank Level not Low Low

**Local Instrumentation (Gauges w/o wires)**

Pressure Gauges

- RAW Pump Suction (2) Range is 0 to 60 psig
- RAW Pump Discharge (2) Range is 0 to 100 psig
- Intermediate Pump Suction (2) Range is 0 to 60 psig
- Intermediate Pump Discharge (2) Range is 0 to 100 psig
- RAW Expansion Tank (1) Range is 0 to 60 psig
- Intermediate Expansion Tank (1) Range is 0 to 60 psig
- DI-Bottle inlet header (1) Range is 0 to 60 psig
- RAW Full Flow Filter Differential Pressure (1) Range is 0 to 10 psig
- Intermediate Full Flow Filter Differential Pressure (1) Range is 0 to 10 psig
- RAW Return Header (1) Range is 0 to 100 psig
- Intermediate Return Header (1) Range is 0 to 100 psig

Temperature Gauges

- Heat Exchangers Inlets and Outlets (8) Range is ≈ 20 to 140 degree Fahrenheit.

Flow Gauges

- Di-Bottle Flow (1) Range is 2 to 20 gpm

Level Gauges (Sight Glasses)

- RAW Expansion Tank
- Intermediate Expansion Tank

### 4.7.4.5 Target & Baffle RAW System

**Pump Motor Interlocks**

Target RAW Pumps:

| | |
|---|---|
| Contactor | 3 phase rotation<br>Over-current<br>Motor Internal Over-temperature Switch<br>(Wired Normally Closed) |
| Target RAW Expansion Tank Liquid Level | Low Low |

**Analog Variables to ACNET**

- Target RAW Pump Discharge Pressure (Supply Pressure)
- Target RAW Return Pressure
- Target RAW Pump Suction Pressure
- Target RAW Water Supply Temperature
- Target RAW Water Return Temperature
- Target RAW Water Expansion Tank Liquid Level
- Target RAW Resistivity out of the DI Bottle (4-20 ma Signal)

**Alarms to ACNET**

- Target RAW Expansion Tank Liquid Level Low
- Target RAW Expansion Tank Liquid Level High
- Target RAW Water Supply Temperature High (alarm if value > 105 Degrees F)
- Target RAW Water Return Temperature High (alarm if value > 125 Degrees F)

**ON-OFF Signals to ACNET**

- Target RAW Pump Current Switches (2)

**ON-OFF Signals from ACNET**

- Target RAW Pump Remote Start and Stop Switches

**Inputs to Beam Permit**

- Target RAW Return Water Temperature Not High (permit if value < 130 Degrees F)
- Target RAW Pump Differential Pressure Not Low
- Target RAW Pump Differential Pressure Not High

- Either Target RAW Pump Drawing Current
- Target RAW Expansion Tank Level not Low Low

**Local Instrumentation (Gauges w/o wires)**

Pressure Gauges

- Target RAW Pump Suction (2) Range is 0 to 30 psig
- Target RAW Pump Discharge (2) Range is 0 to 60 psig
- Target RAW Expansion Tank (1) Range is 0 to 60 psig
- DI-Bottle inlet header (1) Range is 0 to 60 psig
- Target RAW Full Flow Filter Differential Pressure (1) Range is 0 to 10 psig
- Target RAW Return Header (1) Range is 0 to 100 psig

Temperature Gauges

- Heat Exchangers Inlets and Outlets (4) Range is 40 to 180 degree Fahrenheit.

Flow Gauges

- Di-Bottle Flow (1) Range is 2 to 20 gpm

Level Gauges (Sight Glasses)

- RAW Expansion Tank

### 4.7.4.6 Horn 1 RAW System

**Pump Motor Interlocks**

Horn 1 RAW Pumps:

| | |
|---|---|
| Contactor | 3 phase rotation<br>Over-current<br>Motor Internal Over-temperature Switch<br>(Wired Normally Closed) |
| Horn 1 RAW Expansion Tank Liquid Level | Low Low |
| Horn 1 Pump Running Local Indicator Lights | On/Off |

**Analog Variables to ACNET**

- Horn 1 RAW Pump Discharge Pressure (Supply Pressure)
- Horn 1 RAW Expansion Tank Pressure
- Horn 1 RAW Pump Suction Pressure
- Horn 1 RAW Water Supply Temperature
- Horn 1 RAW Water Return Temperature
- Horn 1 RAW Water Expansion Tank Liquid Level
- Horn 1 RAW Resistivity out of the DI Bottle (4-20 ma Signal)

**Alarms to ACNET**

- Horn 1 RAW Expansion Tank Liquid Level Low
- Horn 1 RAW Expansion Tank Liquid Level High
- Horn 1 RAW Water Supply Temperature High (alarm if value > 75 Degrees F)
- Horn 1 RAW Water Return Temperature High (alarm if value > 85 Degrees F)

**ON-OFF Signals to ACNET**

- Horn 1 RAW Pump Current Switches (2)

**ON-OFF Signals from ACNET**

- Horn 1 RAW Pump Remote Start and Stop Switches

**Inputs to Power Supply Permit**

- Horn 1 RAW Return Water Temperature Not High (permit if value > 90 Degrees F)
- Horn 1 RAW Pump Differential Pressure Not Low
- Horn 1 RAW Pump Differential Pressure Not High

- Either Horn 1 RAW Pump Drawing Current
- Horn 1 RAW Expansion Tank Level not Low Low

**Local Instrumentation (Gauges w/o wires)**

Pressure Gauges

- Horn 1 RAW Pump Suction (2) Range is 0 to 60 psig
- Horn 1 RAW Pump Discharge (2) Range is 0 to 100 psig
- Horn 1 RAW Expansion Tank (1) Range is 0 to 60 psig
- DI-Bottle inlet header (1) Range is 0 to 60 psig
- Horn 1 RAW Full Flow Filter Differential Pressure (1) Range is 0 to 10 psig
- Horn 1 RAW Jet Pump Motive (1) Range is 0 to 60 psig
- Horn 1 RAW Supply Header (2) Range is 0 to 60 psig
- Horn 1 RAW Jet Pump Suction (1) Range is -30 inches Hg to 15 psig
- DI Bottle Outlet Filter Inlet Range is 0 to 30 psig.

Temperature Gauges

- Heat Exchangers Inlets and Outlets (4) Range is 20 to 120 degree Fahrenheit.
- Return Water Temperature Range is 20 to 120 degree Fahrenheit

Flow Gauges

- Di-Bottle Flow (1) Range is 2 to 20 gpm
- Horn 1 Inner Conductor A Flow, Range is 2 to 20 gpm
- Horn 1 Inner Conductor B Flow, Range is 2 to 20 gpm
- Horn 1 Outer Conductor Flow, Range is 2 to 20 gpm
- Horn 1 Clamp Flow, Range is 2 to 20 gpm

Level Gauges (Sight Glasses)

- RAW Expansion Tank

OtherInstrumentation:

- Pump Hour Meter (2)

### 4.7.4.7 Horn 2 RAW System

**Pump Motor Interlocks**

Horn 2 RAW Pumps:

| | |
|---|---|
| Contactor | 3 phase rotation<br>Over-current<br>Motor Internal Over-temperature Switch<br>(Wired Normally Closed) |
| Horn 2 RAW Expansion Tank Liquid Level | Low Low |
| Horn 2 Pump Running Local Indicator Lights | On/Off |

**Analog Variables to ACNET**

- Horn 2 RAW Pump Discharge Pressure (Supply Pressure)
- Horn 2 RAW Expansion Tank Pressure
- Horn 2 RAW Pump Suction Pressure
- Horn 2 RAW Water Supply Temperature
- Horn 2 RAW Water Return Temperature
- Horn 2 RAW Water Expansion Tank Liquid Level
- Horn 2 RAW Resistivity out of the DI Bottle (4-20 ma Signal)

**Alarms to ACNET**

- Horn 2 RAW Expansion Tank Liquid Level Low
- Horn 2 RAW Expansion Tank Liquid Level High
- Horn 2 RAW Water Supply Temperature High (alarm if value > 75 Degrees F)
- Horn 2 RAW Water Return Temperature High (alarm if value > 85 Degrees F)

**ON-OFF Signals to ACNET**

- Horn 2 RAW Pump Current Switches (2)

**ON-OFF Signals from ACNET**

- Horn 2 RAW Pump Remote Start and Stop Switches

**Inputs to Power Supply Permit**

- Horn 2 RAW Return Water Temperature Not High (permit if value < 90 Degrees F)
- Horn 2 RAW Pump Differential Pressure Not Low

- Horn 2 RAW Pump Differential Pressure Not High
- Either Horn 2 RAW Pump Drawing Current
- Horn 2 RAW Expansion Tank Level not Low Low

**Local Instrumentation (Gauges w/o wires)**

Pressure Gauges

- Horn 2 RAW Pump Suction (2) Range is 0 to 60 psig
- Horn 2 RAW Pump Discharge (2) Range is 0 to 100 psig
- Horn 2 RAW Expansion Tank (1) Range is 0 to 60 psig
- DI-Bottle inlet header (1) Range is 0 to 60 psig
- Horn 2 RAW Full Flow Filter Differential Pressure (1) Range is 0 to 10 psig
- Horn 2 RAW Jet Pump Motive (1) Range is 0 to 60 psig
- Horn 2 RAW Supply Header (1) Range is 0 to 100 psig
- Horn 2 RAW Jet Pump Suction (1) Range is 30 inches Hg to 15 psig
- DI Bottle Outlet Filter Inlet Range is 0 to 30 psig.

Temperature Gauges

- Heat Exchangers Inlets and Outlets (4) Range is ≈ 20 to 120 degree Fahrenheit.
- Return Water Temperature Range is ≈ 20 to 120 degree Fahrenheit

Flow Gauges

- Di-Bottle Flow (1) Range is 2 to 20 gpm
- Horn 2 Inner Conductor A Flow, Range is 2 to 20 gpm
- Horn 2 Inner Conductor B Flow, Range is 2 to 20 gpm
- Horn 2 Outer Conductor  Flow, Range is 2 to 20 gpm
- Horn 2 Clamp Flow, Range is 2 to 20 gpm

Level Gauges (Sight Glasses)

- RAW Expansion Tank

OtherInstrumentation:

- Pump Hour Meter (2)

### 4.7.4.8 Vacuum Decay Vacuum System

**Vacuum Pump Motor Interlocks**

Vacuum Decay Pipe Pumps:

| | |
|---|---|
| Contactor | 3 phase rotation<br>Over-current<br>Motor Internal Over-temperature Switch<br>(Wired Normally Closed) |

**Vacuum Pump Inlet Isolation Valve Interlocks**

Allow valve to open if:

Pump Inlet Pressure is less than the header pressure **and**
Hand switch is in the Auto Position **and**
Vacuum Pump is running.

**Analog Variables to ACNET**

- Vacuum Decay Pipe Vacuum Header Pressure (2)
- Vacuum Decay Pipe Pump Inlet Pressure (2)
- Vacuum Decay Pipe Pump Exhaust Line Pressure (1)
- Vacuum Decay Pipe Pump Oil Temperature (2)

**Alarms in ACNET**

- Vacuum Decay Pipe Vacuum Header Pressure High
- Vacuum Decay Pipe Vacuum Exhaust Header Pressure High

**ON-OFF Signals to ACNET**

- Vacuum Decay Pipe Pump Current Switches (2)
- Vacuum Decay Pipe Pump Inlet Isolation Valves Open Limit Switch (2)
- Vacuum Decay Pipe Pump Inlet Isolation Valves Close Limit Switch (2)

**ON-OFF Signals from ACNET**

- Vacuum Decay Pipe Pump Remote Start and Stop Switches
- Vacuum Decay Pipe Pump Inlet Isolation Valves Open and Close Hand Switch (2)

### Inputs to Beam Permit

- Vacuum Decay Pipe Pressure Satisfactory

### Local Instrumentation (Gauges w/o wires)

Temperature Gauges

- Vacuum Pump Oil Temperature Gauge, Range is ≈ 40 to 180 degree Fahrenheit.

Level Gauges (Sight Glasses)

- Vacuum Pump Oil Level Sight Glass

APPENDIX 1 – Piping Schematics

Drawing 8875.117-MC-406233
NuMI Water Systems Piping and Instrumentation Diagram (P&ID) Legend

Drawing 8875.117-ME-406228
NuMI Extraction & Pre-Target (Upstream) LCW System P&ID

Drawing 8875.117-ME-406230
NuMI Downstream P&ID

Drawing 8875.117-ME-406229
NuMI Absorber RAW System P&ID

Drawing 8875.117-ME-406231
NuMI Decay Pipe Cooling P&ID

Drawing 8875.117-ME-406232
NuMI Target & Baffle P&ID

Drawing 8875.117-ME-406477
NuMI Horn #1 and Horn #2 RAW Water P&ID

Drawing 8875.117-ME-406092
NuMI-Vacuum Decay Pipe Vacuum P&ID

Drawing 8875.117-MC-406XXX
NuMI Proton Beam-line Vacuum P&ID