# Fermilab

## Particle Physics Division
## Mechanical Department Engineering Note

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Project: MINOS / NuMI

Title: Alternative solutions to the ground water cooling system fouling problem

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Applicable Codes: none



Abstract Summary:

The ground water collected in the MINOS sump (at the base of the MINOS shaft) is used to provide cooling to the MINOS LCW system (this cools the MINOS detector magnet, power supply, and electronics racks) and the NuMI absorber intermediate skid. Refer to FESS drawing 6-7-6 PP-2 from Project 6-7-9 (The NuMI Outfitting contract) for the schematic representation of the system as originally built.

Since project completion, the ground water inflow has slowly reduced from a high of about 300 gallons per minute to the present value of about 150 gallons per minute. This measurement was made by Lee Hammond in FESS Engineering.

In addition, the sump water appears to have an increasing concentration of a slimy, rust colored material which fouls the MINOS LCW to ground water welded plate and frame heat exchanger. The presence of this material initially led to monthly heat exchanger flushing, then to the installation of a filter, and finally to the installation of a second plate and frame heat exchanger and a shell and tube heat exchanger to compensate for the fouling of the heat exchanger.

The fouling material appears to be sufficiently small that some passes thru a 50 micron filter media. Ten micron filter media appears to capture all of the material based on a visual inspection of the inner diameter of the filter cartridge.

It does not appear that the fouling has caused significant corrosion to the piping or heat exchanger. A short section of carbon steel pipe shows a complete coating of rust colored material on the inside, but no obvious corrosion evidence. See Photograph 1.

Photograph 1: Interior of carbon steel pipe formally used in the groundwater loop for MINOS.

The NuMI Absorber intermediate skid uses a large shell and tube heat exchanger between the ground water and the intermediate water loop (the intermediate water loop receives its heat from a plate and frame heat exchange with radioactive water (from the absorber core) on the hot side.

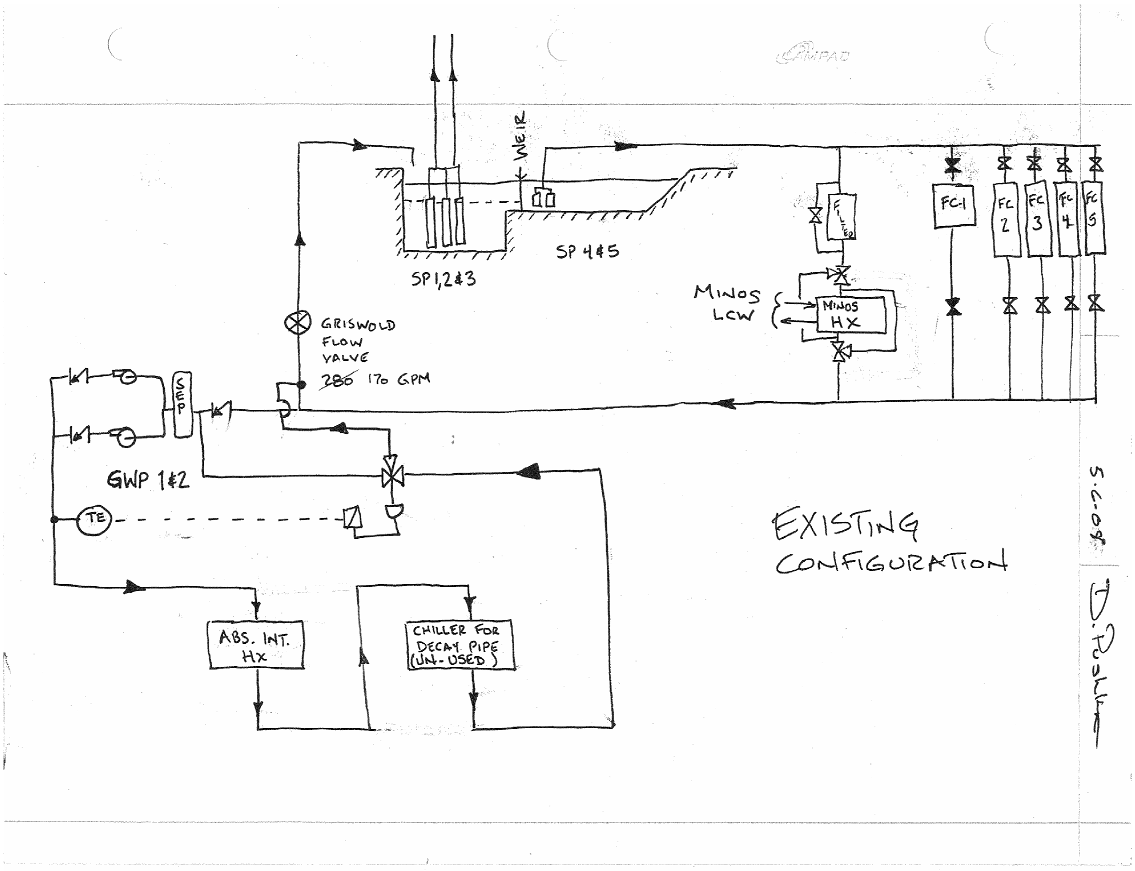



Figure 0: Present Schematic of the Ground Water System

The intermediate skid does not appear to have suffered significantly reduced performance as a result of fouling. This is likely due to the much larger flow passages in the shell and tube heat exchanger as compared to the plate and frame used on the MINOS LCW system.

In addition to the decreasing water inflow, and the decreased efficiency due to fouling, the heat loads to the MINOS hall are expected to increase as MINERVA, T-962, COUPP and other experiments use the facility.

To help others understand the current configuration, a simplified sketch of the system as it exists today, is shown in Figure 0. This is largely the same as the referenced drawing 6-7-6 PP-2 from Project 6-7-9 (The NuMI Outfitting contract) but with many instruments and valves omitted for simplicity.

Several possible system changes are possible to address the thermal load increases, the ground water flow decreases, and the fouling of the ground water side of the heat exchangers. Two alternate configurations are presented here.

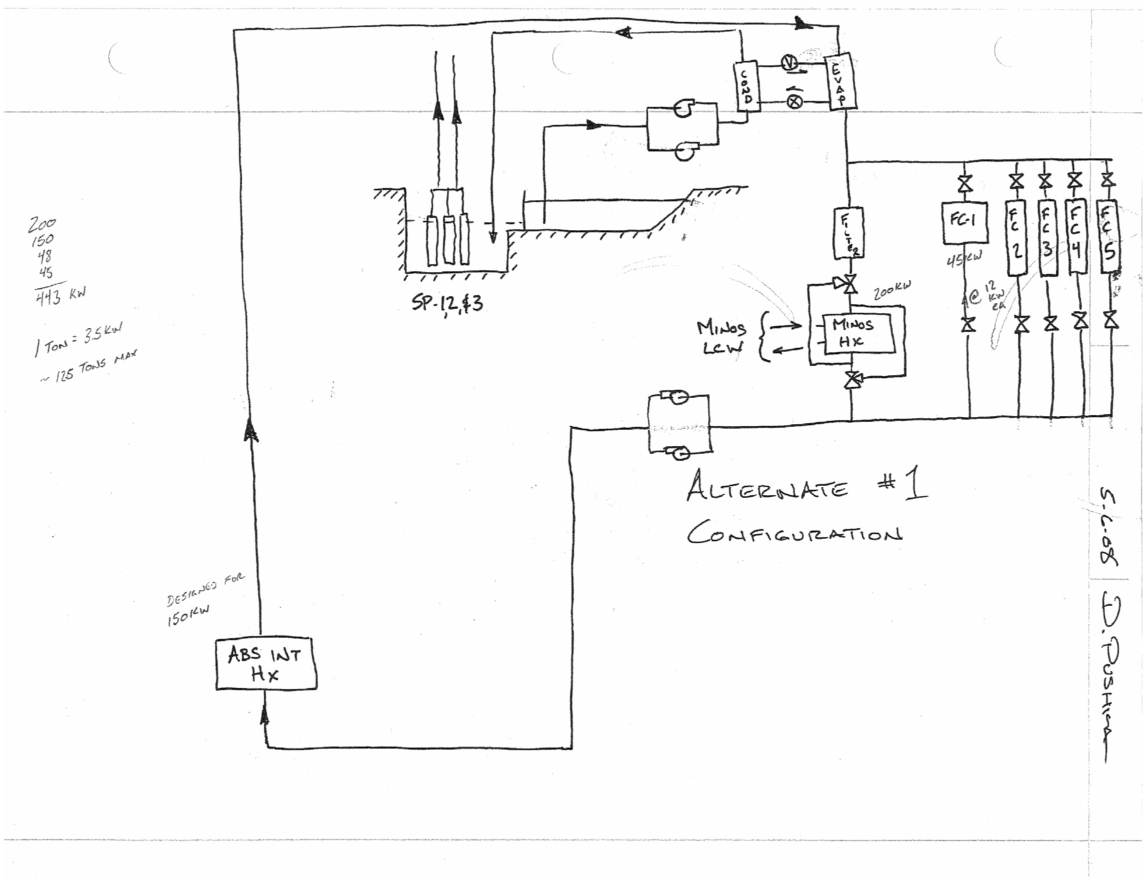



Figure 1: Schematic of Alternate Configuration #1

Alternate configuration #1 uses a packaged refrigerant chiller operated between two refrigerant to water heat exchangers. The cold side (the evaporator) cools a closed loop water system which in turn cools the LCW system and the fan coil (FC-1, FC2, etc.) air coolers in the MINOS hall. Once the closed loop water is warmed by the FC units and the LCW system, the same water is used to cool the absorber intermediate chiller.

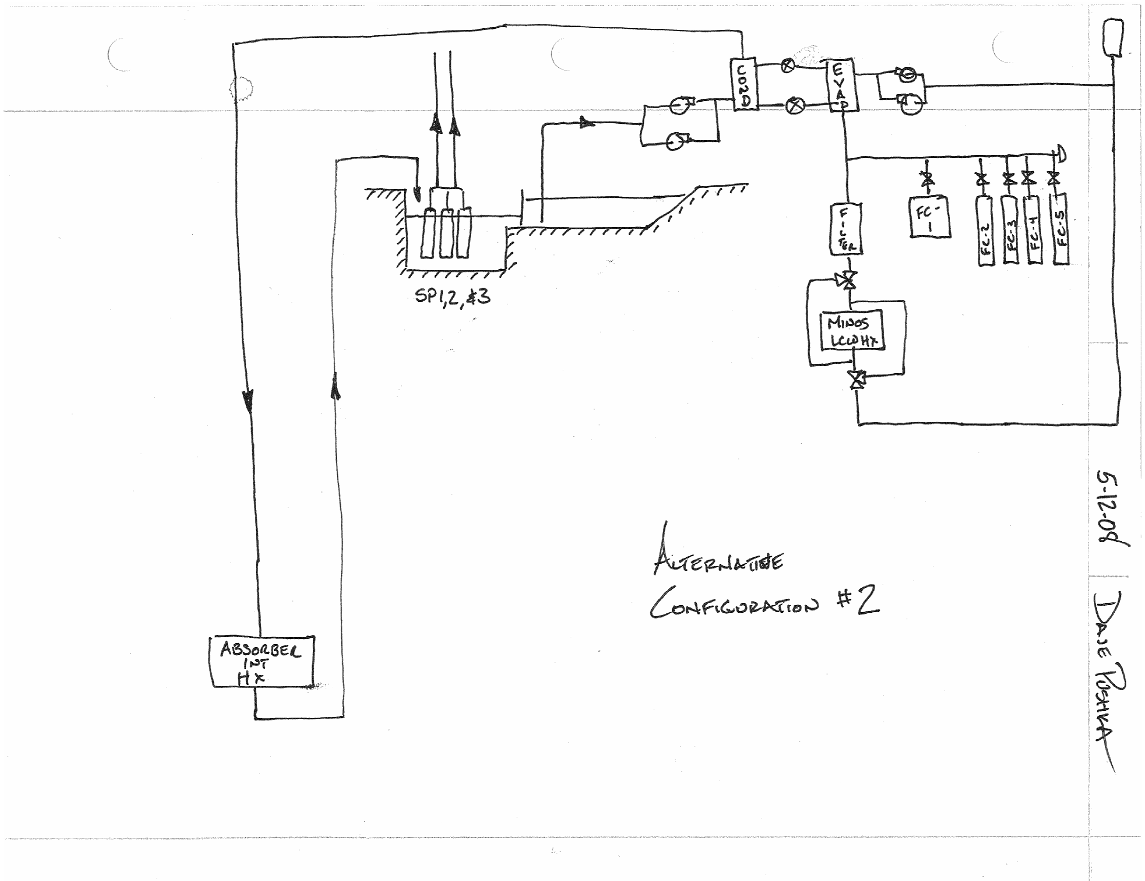



Figure 2: Schematic of Alternate Configuration #2



Alternate configuration #2 is the same as alternate #1 except that rather than using the closed loop water to cool the absorber intermediate skid, ground water is used instead.

The primary difference favoring configuration # 1 is that the closed loop water system can be treated to reduce corrosion and eliminate fouling in the absorber intermediate heat exchanger. The sole disadvantage is that the absorber cooling would be dependant on the ground water system, the refrigerant system, and the closed loop system all operating. Presently, absorber cooling only relies on the ground water system to operate (in addition to the intermediate and absorber RAW system) to cool the absorber.

<u>Water Quality Issues with either of the Alternate Configurations:</u>

In any alternate configuration using a packaged chiller, water quality issues will need to be considered. The packaged chiller units use plate and frame heat exchangers on both the evaporator and condenser sides. A condenser cooled with ground water will potentially experience the same fouling experienced with the MINOS LCW to Ground water heat exchanger. Therefore, it will be essential to include some water treatment or water filtering in the ground water side. Potential water treatment methods include:

1) Installing a pair of fine mesh strainers piped as in Figure 3 so that one is 'backwashed' while the other is filtering.
2) Installing a self cleaning filter as shown in Photograph 2.

Photograph 2: Self-Cleaning ICW strainer installed in Lab B. R.P Adams is the brand name.

A similar, but un-automated, unit is installed at MI-62 in pond water service in front of a shell and tube heat exchanger. The MI-62 unit is a Hellan brand.

A single self cleaning filter is the simplest installation, but cooling water flow is decreased when the filter goes thru the cleaning cycle. Two filters as shown in Figure 3 requires four (4) three way valves to be operated at the same time when switching between filters. Clearly this would be desired to be automated with a timing circuit and motorized (or pneumatic) valve operators.

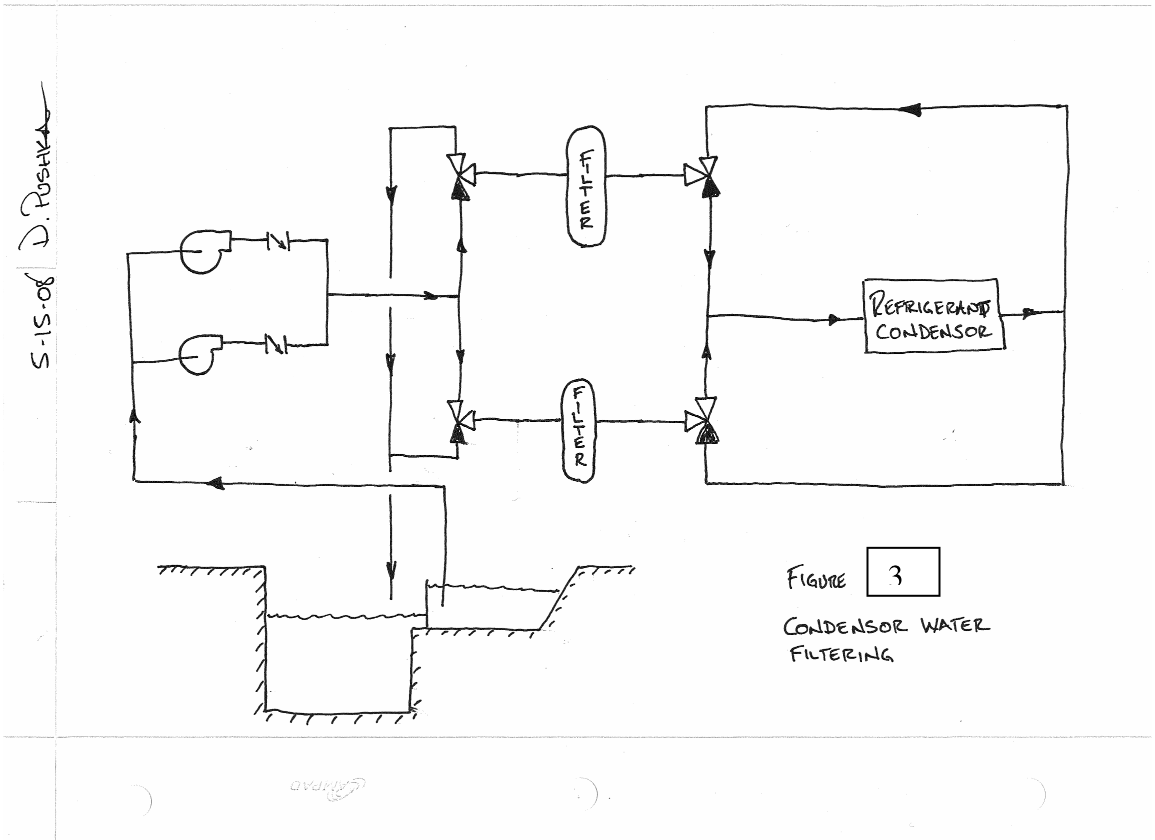



Figure 3; Water treatment with Refrigerant Chiller

<u>Operational Issues – SP-4 and SP-5:</u>

A few general issues should be addressed with any substantive changes to the ground water cooling system. First, the ground water pumps (SP4 and SP5) are Flygt Model BS-2151-011, 30 horsepower, submersible pumps. These are advertised as portable dewatering pumps for the construction and mining industry. Performance data is shown below in Figure 3, curve 10 (shown on the lower plot) for 60 Hertz operations at 3500 rpm (upper curve labeled "10").

Photograph 3: SP-4 unit which failed in May, 2008 after about 4 years of service.

Note location of intake screen at the bottom of the unit.

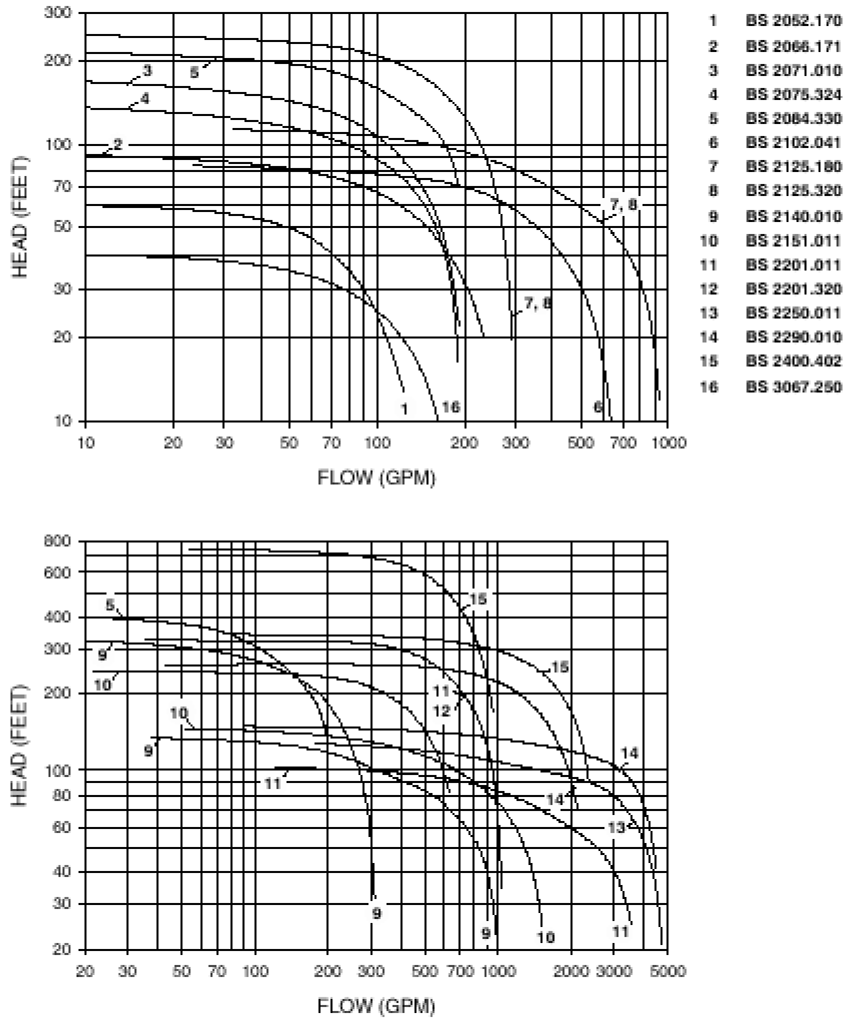



Figure 4: Performance Curves for the Existing SP-4 and SP-5.

The Flygt pumps operate at about 100 psi discharge pressure (232 feet of head) and about 180 gpm. This places the operating point on the flat portion of the curve.

Two of the Flygt pumps have had to be replaced due to internal failures. Contrast this with the replacement rate of the other pumps operating below ground (none of the pumps on the MINOS system or Absorber systems have had to be replaced) and it appears that the Flygt pumps do not live up to the advertisements.

Replacement of the submerged pumps requires the removal of the sump pit covers and the maintenance people to don fall protection harnesses. As a result, pump replacement requires a full day of crew labor.

Since SP-4 and SP-5 rest directly on the bottom of the sump pit and the intake is at the bottom of the unit, the sump pit does not act as a settling basin to allow the particulate to drop out of the water. Therefore, any debris that enters the sump pit gets pumped thru the ground water cooling system, leading to the fouling of the heat exchangers.

So, recommended changes to SP-4 and SP-5 are:

1) If the Flygt pumps remain in service, mount the pumps on a stand to position the intake several inches above the sump pit floor.
2) Consider replacing the Flygt pumps with units more closely matched to the design conditions. For example, a 6" submersible well pump (similar to SP-1, Sp-2 and SP-3) rated for 180 gpm at 220 feet of head would be 15 horsepower, six stage units. These could be installed in a six inch pipe, eliminating the need to open the sump pit covers for replacement. Energy savings would be measurable.
3) Coupled ANSI style pumps are preferred by the maintenance staff because the wet end and the motor can be repaired or replaced independently. Consider using a pair of self-priming units, mounted at floor level to replace SP-4 and 5.



General Items – Floor Gutter Cleaning Procedure

Accelerator division has used laborers to remove silt from the floor drains. This work has been accomplished using hand tools and results in some settled material being washed down stream. This may be related to the sudden plugging of the ground water filter in MINOS.

Floor gutters in MINOS have not been cleaned. Silt and other material is clearly visible in these gutters, especially where the water is stagnant. It is likely that when the strainers in front of the school house style fan coil units are flushed, a significant amount of particulate is washed down the gutter and into the sump. Since this particulate is not allowed to settle out, the particulate may be contributing to the plugging of the ground water filter in MINOS.

Floor Gutter Service Recommendations:

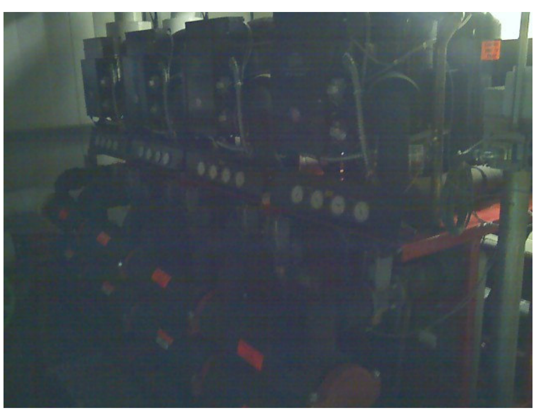
1) Change the floor gutter cleaning procedures to include the cleaning of the gutters in the MINOS near detector hall and access tunnel.
2) Develop a cleaning procedure that uses a small pump (perhaps similar to the pumps used to vacuum the bottom of commercial swimming pools) to vacuum the debris out of the gutter and into settling tank to minimize the amount of debris washed down stream. Allow the particulate to settle out, decant the clean water off (and back to the sump) and dispose (after performing a radiation survey) the collected particulate.

<ins>Refrigerant Based Chillers used for the Alternate Configurations:</ins>

Lee Hammond of FESS has suggested using packaged refrigeration systems similar to the units that replaced the target chase chiller in NuMI. Multistack is the brand name of the unit used at MI-65. See: http://www.multistack.com/ . A photograph of the Multistack unit is shown in photograph 4 below.

One advantage of the Multistack units is that they use multiple small compressors (similar in size to the units used in large home central air conditioners). It is sensible to size the unit for the anticipated MINERVA and COUPP loads today, and plan on not operating one or two of the compressors until those heat loads appear.

Perhaps an additional unit could be added if the Absorber heat loads increase due to the NuMI beam intensity increases.



Photograph 4: Multistack brand refrigerant chiller installed in MI-65

## HEAT LOADS:

Heat Load Summary – Original Design Values:

| | |
|---|---|
| MINOS LCW System | 200 kW |
| MINOS FC-1 | 45 kW |
| MINOS FC-2 | 12 kW |
| MINOS FC-3 | 12 kW |
| MINOS FC-4 | 12 kW |
| MINOS FC-5 | 12 kW |
| NuMI Absorber | 150 kW |
| Total: | 443 kW |
| Total: | 126 tons |

One ton of refrigeration is equal to 3.5 kW. So, the refrigeration equipment needed to service the above load needs to be sized for about 170 tons.

Actual Heat Load Measurements:

The MINOS LCW system has inlet and outlet temperature differences of about 10 degrees F. At 130 gpm, this represents a heat load of 150 kW

The Absorber RAW system has (per a lumberjack plot of E:ABRT10 and E:ABRT11) inlet and outlet temperature differences of about 3 degrees F. At a flow rate of 100 gpm, the heat load is only about 43 kW. This is substantially less than the original design specification of 150 kW which was based on the energy deposition calculations from the MARS analysis of the absorber.

Actual Heat Load Summary based on Measurements:

| | |
|---|---|
| MINOS LCW System | 150 kW |
| MINOS FC-1 | 45 kW |
| MINOS FC-2 | 12 kW |
| MINOS FC-3 | 12 kW |
| MINOS FC-4 | 12 kW |
| MINOS FC-5 | 12 kW |
| NuMI Absorber | 50 kW |
| Total: | 293 kW |
| Total: | 83 tons |

Future Anticipated Heat Load Increases:

| | |
|---|---|
| MINERVA Electronics § | 75 kW |
| MINERVA Magnet and Power supply § | 60 kW |
| COUPP §§ | 20 kW |
| Total: | 155 kW |
| Total: | 44 tons |

§ per MINERVA the Impact Statement dated March 12, 2004
§§ Guessed based on knowledge about the COUPP Detector

With the actual operation experience taken into account, an 85 ton refrigeration system appears to meet the present system needs. Considering the future MINERVA, COUPP, and T962 loads totaling 155 kW, an additional 44 tons of refrigeration is needed.