Fermi National Accelerator Laboratory

TM-1633
[SSC-N-678]

# Cooling Water for SSC Experiments - Supplemental Conceptual Design Report (SCDR)

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October 20, 1989

Operated by Universities Research Association, Inc., under contract with the United States Department of Energy

# SSC

# Supplemental Conceptual Design Report ( SCDR )

## 5.4.5 Cooling Water

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|---|---|---|
| **To :** | **Ray Stefanski** | **10/20/89** |
| **From :** | **Ross E. Doyle** | |
| **Section:** | **( SCDR ) 5.4.5 Cooling Water** | |

Fermilab has been requested by the SSC to help prepare this Supplemental Conceptual Design Report (SCDR). This effort is being coordinated by Ray Stefanski from Fermilab. A SSC Task Force of Eight Fermilab personal has been formed to provide information on the following Subjects;

| | | |
|---|---|---|
| 5.4.2. | Power | John Stoffel, Joseph Pathiyil |
| 5.4.3. | Cryogenics | Ron Fast |
| 5.4.4. | Gas Systems & Warm Liquids | Harry Carter |
| 5.4.5. | Cooling Water | Ross Doyle |
| 5.4.8. | Control Rooms | Rick Vidal, Romesh Sood |
| 5.4.2.&3. | Spectrometer Magnets | Alan Wehmann |

This report involves assistance to design and write sections of the SCDR and to provide cost estimates. Information contained in Section 5.4.5 Cooling Water has been obtained from the following sources;

SSC Task Force Personal

LCW Systems Fiction and Facts
By Ross Doyle Fermilab

Technical Manual For Calculating Cooling Pond Performance
By S. F. Krstulovich Fermilab

Energy Conservation Study of Heat Exchangers
in the Fermilab Experimental Areas
By A. M. Jonckheere Fermilab

Planing Study Report Casey's Pond Expansion
By Harza Engineering Company

Industrial Cooling Water ( ICW ) System Review
By Ross Doyle, Jack Mills Fermilab

Costs Of LCW Systems Obtained From Purchase Orders
Systems installed in the Expermental Areas
By Ross Doyle Fermilab

# SSC Supplemental Conceptual Design Report ( SCDR )

# 5.4.5.1

## 5.4.5.1.1 Description of an LCW Cooling System

Low Conductivity Water Systems ( LCW ) are used to remove heat from the elements as a result of the electrical resistance when DC power is applied to create or provide a magnet field. These systems also remove heat from the power supplies and secondary Radioactive Water Systems ( RAW ). These systems are closed-loop, constantly recycling the same water within the system, through a heat exchanger to remove the heat from the water. Approximately 1/2 percent of the water systems volume is passed through a anion/cantion mixture that removes the minerals present in the water, providing Deionized Water to prevent deterioration and erosion of the elements due to electrolysis. Elements are not energized unless the conductivity of the system is above 4 megohm/cm.

The supply pressure of an LCW system is normally 220 pounds per square inch, return pressure 40 pounds per square inch. **Note: Static pressure at the elements in the SSC hall would be 92 pounds per square inch.** The supply temperature of an LCW system is normally 95-105 Degrees fahrenheit, return temperature 125-135 Degrees fahrenheit.

## 5.4.5.1.2 Components of an LCW Cooling System

A. LCW Pumps
B. Heat Exchangers
C. Piping and Valves
D. Expansion Tank
E. Deionizer Loop
F. Control System

A. The LCW pump or pumps in a water cooling system are a crucial part of the design. These pumps should be Stainless Steel and have an oil slinger type of lubrication system. If at all possible a flat curve pump should be specified. Top suction pumps allow for a neater insulation. These pumps should be mounted on a spring base, this allows the piping and pumps to move during system start-ups. At no time should the floor or a raised section of the floor be considered the absorption mass for the pump. The spring base is the energy absorption mass for the pump. Normally made with structural "C" channel and intersecting reinforcement bars. Support angles for the springs are welded to the "C" frame. Pre-located threaded studs to mount the pump are connected to the reinforcement rods. The base is then filled with concrete and finished with a rough surface. The pump base is then installed and grouted in place. ( 100 HP. 7" x 39" x 82" - 150 HP. 10" x 60" x 96" ) Specifications for the pumps should not include the term "non-overloading". Pumps with this specification cannot be properly protected by the motors electrical contactor overload circut. All LCW pumps should have a strainer and disk valve on the suction side piping and a check valve and ball valve on the discharge piping.

B. Types of Heat Exchangers available for removing heat from the LCW systems.

a. Air Towers
b. Evaporative Air Towers
c. Water to Water ( Shell and Tube)
d. Water to Water ( Plate and Frame)

a. Air Towers

The standard outlet water temperature of an air tower is 10 to 15 degrees above ambient air temperature. **( Average daily mean air temperature during the summer at the SSC site is 84.9 Degrees, Chicago Temperature 71.9 Degrees )** Therefore standard air towers at the SSC for the LCW systems would not be suitable.

b. Evaporative Air Towers

The standard outlet water temperature for this type of an air tower is very close to the outside ambient air temperature. The recycled spray water must be treated with chemicals and on some units only demineralized water may be used.

c. Water to Water / Shell and Tube

This type of heat exchanger is the most reliable in the day to day operation of a LCW system and requires Industrial Cooling Water ( ICW ). Although not as efficient as a "Plate and Frame" type, cleaning is very easy and fast. Two gaskets must be properly aligned after cleaning. Normal 'down time' to clean an 'average' heat exchanger of this type 4 hours. The ICW is always in the tubes with this type of exchanger, and the LCW surrounds the tubes.

d. Water to Water / Plate and Frame

This type of heat exchanger is very efficient and requires ICW. These exchangers require less room than a shell and tube exchanger. Additional plates may be installed to increase the capacity of the exchanger. The major problems with this type of exchanger are; cleaning the plates, and the gaskets must be properly aligned on each plate after cleaning. This type of unit may have an average of 100 to 300 plates that require cleaning. Normal 'down time' to clean an 'average' heat exchanger of this type 12 hours.

C. The water mains in all LCW system should be Stainless Steel, especially if they are larger than 4 inches. Aluminum pipe should not be used, the insulation cost to install is twice as much as copper, three times as much as Stainless Steel. Aluminum pipe also contaminates the LCW system as the temperature fluctuates. **Note: Large copper pipe will not withstand a pressure check of 1 1/2 times above operating pressure for the SSC ( 468 PSI ).** LCW piping should be supported with roller type supports, at no time should the piping be wrapped with teflon at these supports. The LCW piping does not require a pitch in the piping for the removal of air. The venting of air from the system is normally done in the main LCW pump room. The elements in the halls will require an air vent at the highest point on the manifold. Piping should not be mechanically anchored to a wall or ceiling to prevent movement. **( SSC exception the ~ 200 LCW or ICW vertical mains in the utility duct to the halls should be mechanically anchored at the bottom only ).**

Flexible bellows should not be used on any LCW main except for the suction and discharge side of the main LCW pumps. To compensate for the expansion and contraction of the LCW piping expansion loops should be installed. The expansion loops should be the same schedule of as the rest of the piping in the system. This expansion loop should not be mechanically anchored. All LCW main supply flanges and valves should be 300lb. ASME rated ( 700 PSI @ 180 Deg. F. ). All LCW main return flanges and valves should be 150lb. ASME rated ( 260 PSI @ 180 Deg. F. ).

Ball valves are normally used on the high pressure side of the LCW system, and disk valves on the low pressure side. **( SSC exception all valving at the ~ 200 foot level should be ball valves, due to the high static pressure ).** Full bodied ball valves or flangeless ball valves can be used. Stainless Steel or bronze body valves with 316 Stainless Steel balls.

"Weld-o-lets" are used when elements only require a small amount of LCW < 60 Gallons per Minute. When elements require a large amount of LCW, run tees are normally used. All secondary piping and elements should be valved or connected in such a way that they may be isolated from the main piping. "Weld-o-lets" are also used for mounting pressure gauges, drain valves, flow monitors, temperature probes and temperature gauges in the LCW system. "Weld-o-lets" and "Braze-o-lets" are commercially available but are very expensive when obtained this way. Fermilab has these items made by small machine shops in the area, the cost is approximately 150% less. Drawing number ( 2831-MB-95953 ). There are several different types available with different materials and sizes.

**D.** The expansion tank compensates for the expansion and contraction of the LCW due to temperature changes in the system. The expansion tank with an air head provides the Net Positive Suction Head ( NPSH ) required for the pumps. The expansion tank is sized at 5% of the volume of LCW in a system. Note: only 50% of the systems volume changes in temperature when operating. The expansion tanks are normally Stainless Steel ASME rated at 150 pounds per square inch at a temperature of 150 degrees fahrenheit. Expansion tanks have the following; a sight glass that visually shows the level in the tank, two 4" 150lb. flanges so that levels or floats may be installed and several other openings for relief valves, air head pressure, connections to the system and drain valves. The expansion tank is connected to the suction side piping of the LCW pumps. LCW flow through the expansion tank is not required. House air at 90 pounds per square inch is reduced by a Pressure Regulating/Relieving Valve ( PRRV ). This special PRRV valve maintains the proper pressure NPSH on the expansion tank when the LCW expands and contracts with temperature fluctuation. The expansion tank must have a pressure relief valve set at 50 pounds per square inch, liquid rated.

E. The deionizer loop removes minerals present in the LCW system and also provides clean make-up ICW water for the system. It also filters the LCW and ICW to remove the particulates 10 microns or larger that are suspended in the water. Approximately one half percent of the water in a system is circulated through this deionizer loop. Normal flow rate is 15 to 20 gallons per minute. At Fermilab we use commercially available bottles that contain a mixture of anion/cantion. These bottles are regenerated on site and have a normal output of 18 megohm/cm after regeneration. The conductivity of the system is measure at the input to the deionizer loop and at the output of the loop. When the output of the deionizer bottles drop below 5 megohm/cm the bottles are replaced with recharged ones.

The piping of the deionizer loop is normally 2 inch copper pipe, dielectric unions are not required. All valves interconnecting the deionizer loop such as supply, return before and after the filters should be 2 inch ball valves. The deionizer loop is a branch of the LCW system. The LCW supply pressure is reduced to 40 pounds per square inch by a Pressure Regulating Valve ( PRV ). Note: A by-pass should not be installed around any pressure regulation device and drain valves are not required on either side of a PRV. Upstream of the PRV a strainer is installed to remove any large particles that may be in the LCW. After the PRV valve the piping is connected to a three-way valve, the deionizer loop is connected to the common side of this valve. After the three-way valve the system conductivity probe is installed. The piping is then connected to a canister filter rated at 10 microns, 30 gallons per minute, normally Stainless Steel ASME rated at 150 pounds per square inch at a temperature of 150 degrees fahrenheit. These filters have removable cartridges for easy replacement and air vents on the top. In all cases there should be single pressure gauges on the upstream and downstream sides of these filters.

After the filters a visual flow meter is installed normal flow range 0 to 40 gallons per minute. After the flow meter, a 2 inch copper manifold with " Braze-o-Lets " and 3/4 inch ball valves supplies LCW to the deionizer bottles. After the deionizer bottles another 2 inch copper return manifold with " Braze-o-Lets " and 3/4 inch ball valves routes the LCW to the final canister filter. At no time should the deionizer bottles be connected in series. Maximum flow rate through each deionizer bottle is 5 gallons per minute. The return deionizer loop manifold must have a pressure relief valve set at 50 pounds per square inch, liquid rated. Before the last filter the bottle a conductivity probe is installed. After the last filter and the conductivity probe a strainer and check valve is installed to prevent deionizer resion from entering the main LCW system. The return from the deionizer loop is then connected to the same line as the expansion tank and returned to the suction side of the pumps.

To make-up water in the LCW system, ICW water is used. The ICW supply pressure is reduced to 40 pounds per square inch by a PRV. Upstream of the PRV a strainer is installed. After the PRV a check valve is installed to prevent backflow. To add ICW to the system a three-way valve is turned so that the LCW flow to the deionizer loop is turned off and the ICW flow is opened to the deionizer loop. This method removes the minerals and dirt from the ICW water so as not to contaminate the LCW in the main system. One pass of ICW through a deionizer loop with good bottles ( 12 megohm/cm or greater ) is considered to be LCW at the outlet of the loop.

F. Proper control of the LCW systems is very important and must accomplish the following; Protection of the elements connected to the system. Protection of the main LCW pumps and, total system reliability. The power supplies for the elements are interlocked with the main LCW pumps. The LCW main pumps require several interlocks to be energized. Water in the expansion tank above the low level, and air pressure above 70 pounds per square inch. Interlocks activated after the LCW pumps have been energized are, system pressure, system total flow and the motor holding contacts. All critical interlocks and temperature readings are monitored by a computer system. Fermilab designed LCW system control boxes have replaced all of the commercially built controls that were originally installed.

**5.4.5.1.3 1988 - 89 Costs of an LCW Cooling System**

| | | |
|---|---|---|
| 1. | LCW Pump 4 x 6 x 12AT 650 GPM-600 Foothead | 20 K |
| 2. | 2 MW Shell and Tube heat exchanger | 23.5K |
| 3. | 6" 300 lb. Flangeless ball valve | 2 K |
| 4. | 6" Disk valve with operator | .2K |
| 5. | 6" Stainless Steel 300 lb. Weld neck flange | .3K |
| 6. | 3" Temperature control valve w/controller 150 lb. | 3.4K |
| 7. | 6" 304 Stainless Steel Bellows x 12" 300 lb. | 1.2K |
| 8. | 6" 150 lb. Stainless Steel Strainer 1/8" mesh | 2.3K |
| 9. | 20 Foot length 6" Stainless Steel 304 Sch. 10 | .4K |
| 10. | 6" Stainless Steel 90 deg. Elbow 304 Sch. 10 | .2K |
| 11. | 250 Gallon Expansion Tank Stainless Steel EST. ~ | 3.5K |

A. 1987 - Fitter cost of installing three LCW pumps (100 H.P. - 350 GPM-600 Foothead ) with a 2 MW Shell and Tube Heat Exchanger with 6" copper pipe. 35 K

B. 1987 - Fitter cost of installing three LCW pumps (100 H.P. - 350 GPM-600 Foothead ) with a 2 MW Shell and Tube Heat Exchanger with 6" aluminum pipe. 50 K

C 1988 - 89 Fitter cost of installing 1,250 Ft of two 6 inch Stainless Steel 304 pipes in a 5' deep trench with 3 expansion loops, interconnecting pipes, modifications to existing systems, installing a new heat exchanger, installing (1) new LCW pump and pressure checking every 500 Foot. 55 K

**5.4.5.1.3.1**

**LSD IR2 ( 4 MW ) Estimated Costs**
**Pump Room Only ( 1988/89 )**

| Quainty | Item | | Cost |
|---|---|---|---|
| 3 | 125 HP. Pumps (1 Stand-by) | 18 K each | 54 K |
| 3 | Pump Bases | 1 K each | 3 K |
| 1 | 4MW Water to Water Heat Exchanger | | 47 K |
| 1 | 3" Pressure Control Valve | | ~3 K |
| 4 | 6" S.S. Ball Valves | 2 K each | 8 K |
| 4 | 6" Disk Valves | .2K each | .8K |
| 3 | 6" S.S. Strainers | 2.3K each | 6.9K |
| 2 | 3" Temperature Controllers | 3.4K each | 6.8K |
| 6 | 6" S.S. Bellows | 1.2K each | 7.2K |
| 3 | 6" Check Valves | 1.3K each | 3.9K |
| ~200 ft. | 6" S.S. Pipe | | 4 K |
| 16 | 6" S.S. 90 Deg Ells | | 3.2K |
| 14 | 6" S.S. Flanges | .3K each | 4.2K |
| 6 | 6" S.S. Tees | | 1.8K |
| 2 | 6" x 4" S.S. Tees | | .7K |
| 3 | 6" x 3" Reducers S.S. | .1K each | .3K |
| 1 | Expansion Tank S.S. 250 Gallon | | 3.5K |
| 1 | Deionizer Loop with Filters | | 6 K |
| 1 | Control System including Contactors | | 20 K |
| ~100 ft. | 8" Black Iron Pipe | | 1 K |
| 6 | 8" Cast Flanges | | .9K |
| 4 | 8" x 3" Cast Reducers | | .3K |
| 8 | 8" 90 Deg Ells | | .6K |
| 2 | 8" Disk Valves | | .6K |
| | Pressure Guages, Vent Valves, Gaskets, Mis. | | 8 K |
| | Sub Total | | 195.7K |
| | Fitter Costs Estimated | | 50 K |
| | Electrical Costs Estimated | | 10 K |
| | **Total** | | **255.7K** |

**5.4.5.1.3.2**

**D0 IR5 ( 2.6 MW ) Estimated Costs**
**Pump Room Only ( 1988/89 )**

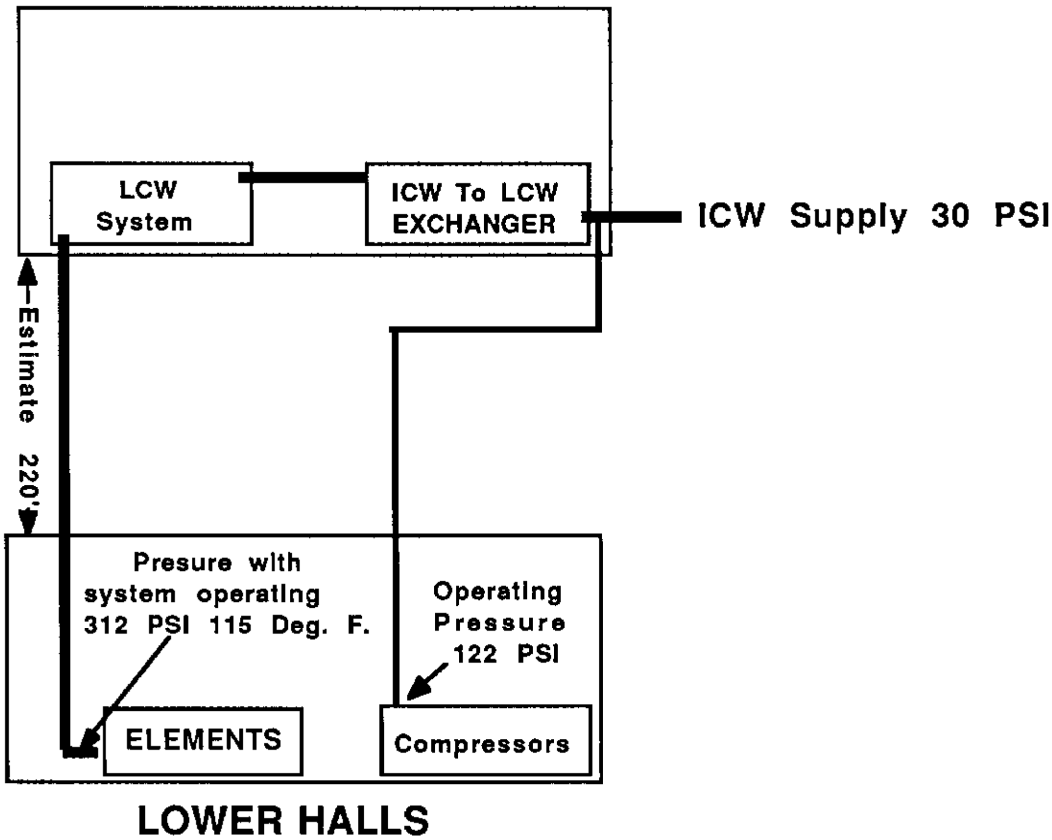
| Quainty | Item | | Cost |
|---|---|---|---|
| 3 | 100 HP. Pumps (1 Stand-by) | 17 K each | 51 K |
| 3 | Pump Bases | 1 K each | 3 K |
| 1 | 2.6MW Water to Water Heat Exchanger | | 27 K |
| 1 | 2" Pressure Control Valve | | ~2 K |
| 4 | 4" S.S. Ball Valves | 1.5K each | 6 K |
| 4 | 4" Disk Valves | .1K each | .4K |
| 3 | 4" S.S. Strainers | 1.8K each | 5.4K |
| 1 | 3" Temperature Controllers | | 3.4K |
| 6 | 4" S.S. Bellows | .8K each | 4.8K |
| 3 | 4" Check Valves | .9K each | 2.7K |
| ~100 ft. | 4" S.S Pipe | | 1.2K |
| ~100 ft. | 6" S.S. Pipe | | 2 K |
| 12 | 4" S.S. 90 Deg Ells | | .9K |
| 4 | 6" S.S. 90 Deg Ells | | .8K |
| 14 | 4" S.S. Flanges | .2K each | 2.8K |
| 2 | 6" S.S. Flanges | .3K each | .6K |
| 8 | 6" x 4" S.S. Tees | | 3 K |
| 5 | 4" x 2" Reducers S.S. | | .4K |
| 1 | Expansion Tank S.S. 250 Gallon | | 3.5K |
| 1 | Deionizer Loop with Filters | | 6 K |
| 1 | Control System including Contactors | | 20 K |
| ~100 ft. | 6" Black Iron Pipe | | .8K |
| 6 | 6" Cast Flanges | | .6K |
| 4 | 6" x 3" Cast Reducers | | .2K |
| 8 | 6" 90 Deg Ells | | .4K |
| 2 | 6" Disk Valves | | .4K |
| | Pressure Guages, Vent Valves, Gaskets, Mis. | | 8 K |
| | Sub Total | | 157.3K |
| | Fitter Costs Estimated | | 48 K |
| | Electrical Costs Estimated | | 10 K |
| | **Total** | | **215.3K** |

### 5.4.5.1.4 SSC Considerations for the LCW Systems

The operating temperature of these LCW systems using air towers as the main heat dissipater could be 110 to 125 degrees fahrenheit. If the elements and power supplies can operate at this temperature, the return temperature to the towers would be approximately 140 to 155 degrees fahrenheit. Manufactures of evaporative air towers recommend that the maximum surface temperature be less than 150 degrees fahrenheit or encrustations will build-up on the tubes, affecting the overall efficiency of the towers.

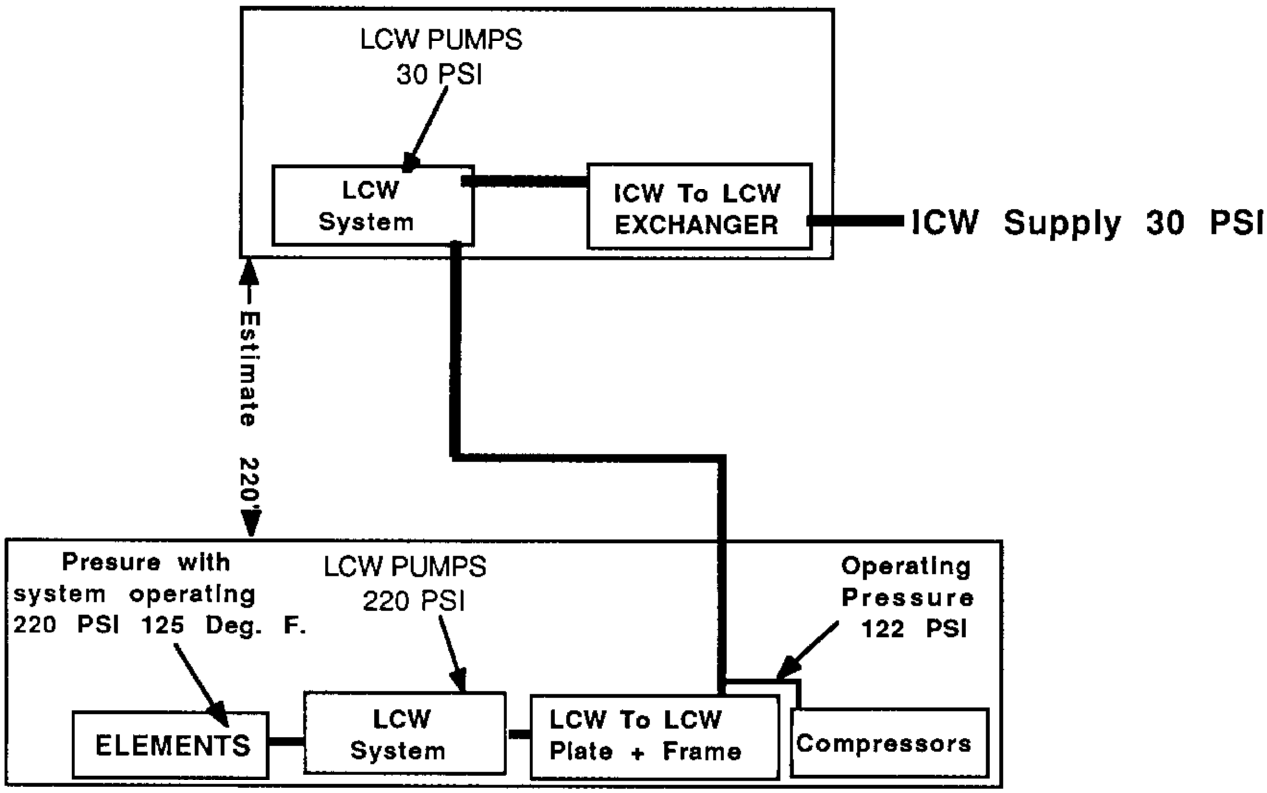
The static pressure on the elements in the halls could be reduced, if it poses a problem. This could be accomplished almost the same way that the CERN Laboratory resolved the problem. The above ground system could be a low pressure ( 30 pounds per square inch ) high flow standard type of LCW system. A branch of the above ground LCW system would require a booster pump to increase the pressure so that the power supplies and the deionizer loop would receive the proper flows. This system could supply cooling water to a plate and frame heat exchanger, to the compressors and chillers in the halls. At this location the plate and frame type of heat exchanger is the best approach since they are the most efficient and clean LCW would be used on both sides of the exchanger, keeping the fouling to a minimum. The pressure at the plate and frame heat exchanger in the hall would be 122 pounds per square inch. In the halls a standard high pressure LCW system could be installed, static pressure on the elements would be approximately 10 pounds per square inch. A problem is encountered using double heat exchangers if evaporative air towers are used for the primary heat removal on the above ground LCW system. The LCW supply temperature to the elements in the halls could approach approximately 125 to 135 degrees fahrenheit. Illustrated on the following pages are three possible system considerations.

# System #1

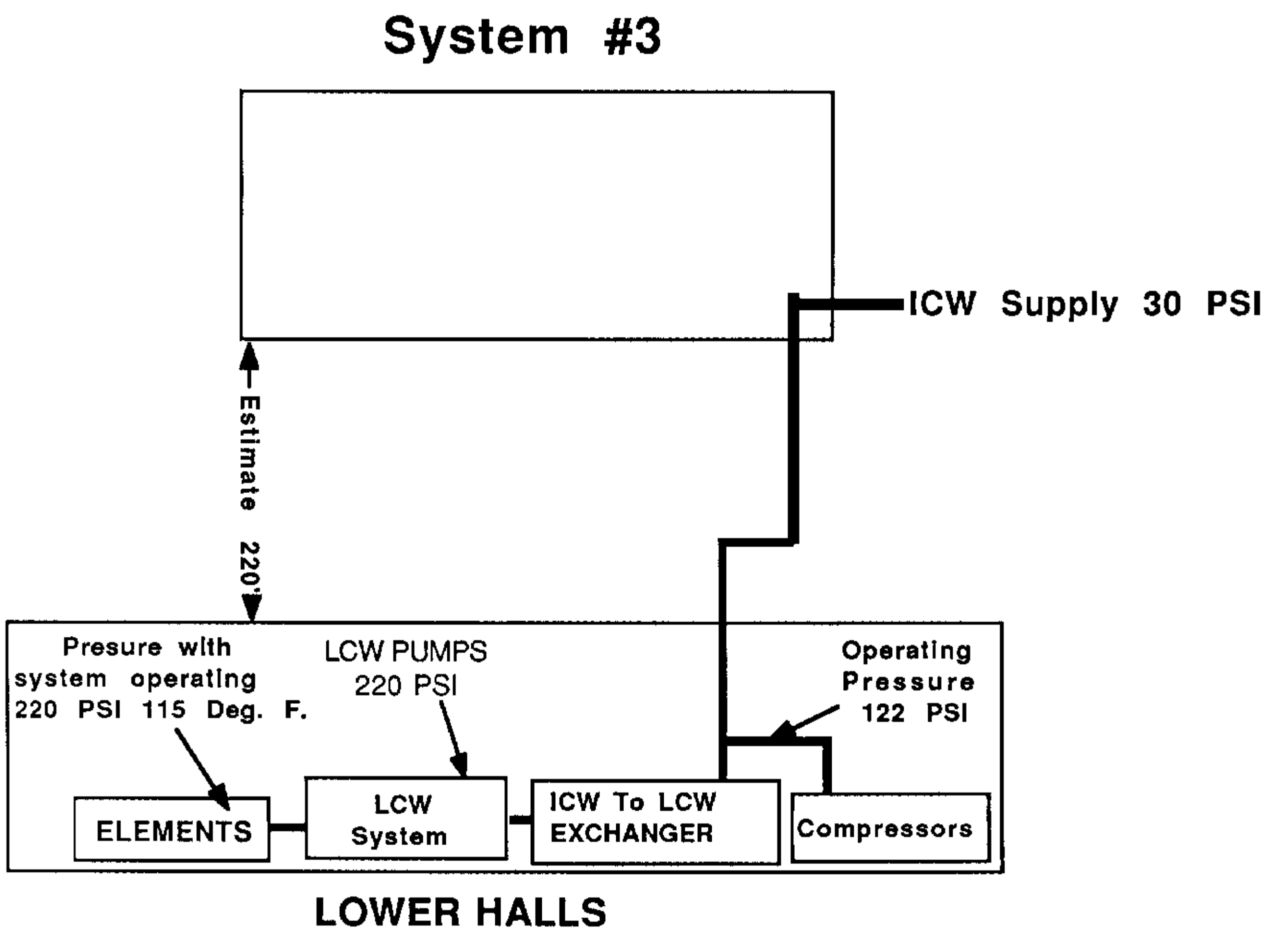



Notes: The high pressure could cause a design problem with the elements. Due to the high LCW pressure the compressors could not be connected to the LCW system. ICW would be required, with the same problems as encountered in System #3.

## System #2




Notes: The LCW supply temperature of this system is very high. The elements would be at a lower pressure. The compressors could be connected to the low pressure LCW system. The low pressure system would have a small volume of water, compared to Systems #1 and #3. Possible flooding of the halls with ICW would be reduced.




Notes: The elements would be at a normal operating pressure, the LCW supply temperature would be lower than a two heat exchanger system. If for any reason the ICW main ruptured, water would continue to flow until valves in the upper level building were closed. Control valving would be a crucial item with this type of system. Sprinkler requirements should also be considered.

**5.4.5.1.5 LCW Flow Requirements for LSD IR2**

| | | | |
|---|---|---|---|
| Central Muon Toroid | 2.3 MW | 7,849,900BTU/HR | 535 |
| Intermediate Toroid | 1.2 MW | 4,095,600BTU/HR | 279 |
| Forward Toroids | .4 MW | 1,365,200BTU/HR | 96 |
| 2 125 HP LCW Pumps | 186 KW | 636,000BTU/HR | 43 |

**Gallons per Minute of LCW At 115 Degrees F. 953**

**5.4.5.1.6 LCW Flow Requirements for L* IR3**

| | | | |
|---|---|---|---|
| Solenoid | 20 MW | 68,520,144BTU/HR | 4650 |
| 2 400 HP LCW Pumps | 596 KW | 2,034,000BTU/HR | 138 |

**Gallons per Minute of LCW At 115 Degrees F. 4788**

**5.4.5.1.7 LCW Flow Requirements for D0 IR5**

| | | | |
|---|---|---|---|
| Central Muon Toroid | .95 MW | 3,241,300BTU/HR | 223 |
| End Toroids (2) | 1.68 MW | 5,733,840BTU/HR | 392 |
| 2 100 HP LCW Pumps | 149 KW | 508,850BTU/HR | 35 |

**Gallons per Minute of LCW At 115 Degrees F. 650**

**5.4.5.1.8 LCW Flow Requirements for BCD IR8**

**N.A. At this time.**

**Total LCW Flow Required All Systems**
**6,391 GPM at 115 Degrees F.**

## 5.4.5.2

### 5.4.5.2.1 Description of an ICW Cooling System

The Industrial Cooling System (ICW) supplies water to many systems, sub systems and provides make-up water to these systems when required. This ICW also supplies water required for the fire protection systems. This water is the main source for heat removal from the chillers, LCW systems and the RAW systems. The electrical power for the ICW system should have a full standby electrical power system for fire protection integrability.

The removal of heat with an ICW cooled system is more efficient than any other type of heat removal available. This does not take into account the energy required to operate a ICW pumping system. With other methods of removing heat, the temperature of the secondary system depends directly on the outside ambient temperature and the relative humidity. With an ICW supply system the pond temperature remains fairly constant, and doesn't fluctuate between day and night temperatures. Since the temperature difference is at a minimum, the temperature controls on the secondary system are less complicated.

The supply pressure of an ICW system is normally 90 to 95 pounds per square inch, return pressure 5 pounds per square inch. **Note: Static pressure at the elements in the SSC hall would be 92 pounds per square inch.** The supply temperature of an ICW system is normally 82 Degrees fahrenheit, return temperature 125-135 Degrees fahrenheit. **Note: The ICW supply temperature at the SSC would be 95 Degrees.**

## 5.4.5.2.2 Components of an ICW Cooling System

A. ICW Pumps
B. The Reservoir or Storage Ponds
C. Heat Exchangers
D. Surge Tanks
E. Piping
F. Control System

A. The ICW pump or pumps in a water cooling system are a crucial part of the design. These pumps should be self-priming. If at all possible a flat curve ( constant pressure ) pumps should be specified to operate at a pressure between 90 to 95 pounds per square inch. Specifications for the pumps should not include the term "non-overloading". Pumps with this specification cannot be properly protected by the motors electrical contactor overload circuit.

B. The Reservoir or Storage Ponds should have a depth of at least five foot minimizing direct absorption of solar energy. The surface area required by Cooling Ponds, is designated by Watts per Square foot induced into the pond that will be rejected. Most cooling in these ponds comes from evaporation of a small part of the water surface. Other factors also affect a cooling ponds performance, The Wind Velocity, Atmospheric Solar Extinction, Absolute Humidity, Air Temperatures, Pond Bottom Heating and Aeration. There will be water evaporation to reject the induced heat. System ( C ) rate of loss would be approximately 270 Gallons per Minute. System ( A ) rate of loss would be approximately 360 Gallons per Minute. Sun loading evaporation loss for the Chicago Area is stated as 11.2 Gallons per Minute per acre. The SSC can receive 20% more possible sunshine. The loss rate would be 14 Gallons per Minute per acre. Average loss over a 24 hour period, 7 Gallons per Minute per acre. Water loss due to seepage has not been taken into account. **Note : ( C ) and ( A ) refer to electronics models.**

| | |
|---|---|
| **Pond "a" 25.647 Acres 30 Watts/Sq.Ft. (C)** | **Sun (179)** |
| **Evaporation Gallons Per Minute Loss** | **Total 449** |
| **Pond "b" 37.927 Acres 30 Watts/Sq.Ft. (A)** | **Sun (265)** |
| **Evaporation Gallons per Minute Loss** | **Total 625** |
| **Pond "c" 19.262 Acres 40 Watts/Sq.Ft. (C)** | **Sun (135)** |
| **Evaporation Gallons per Minute Loss** | **Total 405** |
| **Pond "d" 28.401 Acres 40 Watts/Sq.Ft. (A)** | **Sun (199)** |
| **Evaporation Gallons per Minute Loss** | **Total 559** |

**Note : ( C ) and ( A ) refer to electronics models.**

The numbers below assume that the low level of the pond is the 2 foot, and that the normal operating level of the pond is 5 foot, and the high level of the pond is 10 foot. The following table summarizes equivalent days of storage without any rainfall or well water make-up. **Assuming the pond is the only Heat Exchange for the System.**

## Pond Sizing

**Pond "a" Acres 25.647** Water Loss 24 hour Period = 646,560 Gallons

| | | | |
|---|---|---|---|
| Pond 2 Foot Level | 16,714,201 Gallons | 51.3 acre feet | |
| Pond 5 Foot Level | 41,785,502 Gallons | 128 acre feet | |
| Pond 10 Foot Level | 83,571,005 Gallons | 257 acre feet | |
| Usable water at 5 Foot | 25,071,301 Gallons | 76.7 A. F. | 38 Days |
| Usable water at 10 Foot | 66,856,804 Gallons | 205.7 A. F. | 103 Days |

**Pond "b" Acres 37.927** Water Loss 24 hour Period = 900,000 Gallons

| | | | |
|---|---|---|---|
| Pond 2 Foot Level | 24,717,101 Gallons | 76 acre feet | |
| Pond 5 Foot Level | 61,792,754 Gallons | 190 acre feet | |
| Pond 10 foot Level | 123,585,508 Gallons | 380 acre feet | |
| Usable water at 5 Foot | 37,075,653 Gallons | 114 A. F. | 41 Days |
| Usable water at 10 Foot | 98,868,407 Gallons | 304 A. F. | 109 Days |

| | | | |
|---|---|---|---|
| **Pond "c" Acres** 19.262 | Water Loss 24 hour Period = 583,200 Gallons | | |
| Pond 2 Foot Level | 12,553,083 Gallons | 39 acre feet | |
| Pond 5 Foot Level | 31,382,709 Gallons | 97 acre feet | |
| Pond 10 Foot Level | 62,765,419 Gallons | 193 acre feet | |
| Usable water at 5 Foot | 18,829,626 Gallons | 58 A. F. | 23 Days |
| Usable water at 10 Foot | 50,212,336 Gallons | 154 A. F. | 86 Days |
| **Pond "d" Acres** 28.401 | Water Loss 24 hour period = 804,960 Gallons | | |
| Pond 2 Foot Level | 18,508,988 Gallons | 57 acre feet | |
| Pond 5 Foot Level | 46,272,471 Gallons | 143 acre feet | |
| Pond 10 Foot Level | 92,544,942 Gallons | 284 acre feet | |
| Usable water at 5 Foot | 27,763,483 Gallons | 86 A. F. | 34 Days |
| Usable water at 10 Foot | 74,035,954 Gallons | 227 A. F. | 91 Days |

Although the 30 Watt/Sq. Ft. Pond would have a higher water loss the temperature of the pond would not vary as much, and the heat removal capacity is much safer. The 40 Watt/Sq. Ft. Pond would have a tendency to become saturated on very hot, calm days during the summer. The Ponds should have ample volume for fire protection, storage, for systems that require make-up water and be able to supply water as required under drought conditions.

C. The ICW discharge from the LCW and CWS systems using it for cooling purposes should be piped back to the pond to reduce absorption, evaporation and weed growth that would be present in open ditches. The ICW discharge should be passed through an evaporative air towers to reduce heat loading on the pond. The fans on these towers should be controlled by the pond temperature, and the temperature difference between the return ICW and the ambient air temperature. The discharge from the towers should be piped in such a way that the actual outlet of the pipe is 2 to 3 foot above the normal operating level of the pond. This method enhances the aeration of the pond water.

D. At the end of each of the halls or utility buildings the ICW mains should have a device similar to a bladder type surge tank. This tank would absorb the hydraulic pressure variations caused by the opening and closing of the valves in the system and the cycling of the ICW pumps. The surge tanks are normally Steel ASME rated at 150 pounds per square inch at a temperature of 150 degrees fahrenheit.

E. A self-flushing full system strainer should be installed within the piping of the ICW system. There should be two ICW mains to provide integrity and interconnection from the ICW pumping system to the halls requiring fire protection.

F. Proper control of the ICW system is very important and must able to supply ICW at all times. The main interlock for this type of system would be the pond level. In case there was a catastrophic failure of a ICW main that could drain the pond. For pressure control the following would be possible. If the output pressure drops below a pre-determined set point for the number of pumps operating, another pump would automatically be staged on. This would be possible since a flat curve pump can only produce an acceptable pressure until the flow output for the pump is exceeded. This control process could be computer controlled. The flows in all supply and return mains for the ICW system should be monitored.

### 5.4.5.2.3 Costs of an ICW Cooling System

| | | |
|---|---|---|
| One 400 H.P. - 215 ft. head at 5000 GPM ICW Pump | 6/88 | 35K |
| Soft Start Controller | | 7K |

### 5.4.5.2.4 SSC Considerations for ICW cooling

The wells around the SSC site should only be used to maintain a normal operating level of the pond. They should not be used as the primary fire protection or cooling, unless they are backed-up by temporary power and secondary piping.

## 5.4.5.2.5 ICW Flow Requirements for LSD IR2

| | | | ICW At 95 Degrees F. |
|---|---|---|---|
| Central Muon Toroid | 2.3 MW | | 734* |
| Intermediate Toroid | 1.2 MW | | 382* |
| Forward Toroids | .4 MW | | 137* |
| 3 400 HP Compressors | 894 KW | | 70 |
| 2 125 HP LCW Pumps | 186 KW | | 61* |
| ** Chiller 45 Deg. F. | 1.2 MW | (C) | 684** |
| ** Chiller 45 Deg. F. | 5.2 MW | (A) | 3100** |

* This Flow represents LCW to ICW Heat Exchanger
** Not known if model A or C will be used for the electronics**

| | | |
|---|---|---|
| **Total Gallons per Minute** | **(C)** | **2068** |
| **Total Gallons per Minute** | **(A)** | **4484** |

### 5.4.5.2.5.1 ICW POND Requirements for LSD IR2

| | Pond Design | At 30 | Watts/Sq. Ft.*** | Acres |
|---|---|---|---|---|
| Central Muon Toroid | 2.3 MW | 734* | 76,693 | 1.761 |
| Intermediate Toroid | 1.2 MW | 382* | 40,014 | .92 |
| Forward Toroids | .4 MW | 137* | 13,338 | .307 |
| 3 400 HP Compressors | 894 KW | 70 | 29,827 | .685 |
| 2 125 HP LCW Pumps | 186 KW | 61* | 6,213 | .143 |
| ** Chiller 45 Deg. F. | 1.2 MW (C) | 684** | 40,014 | .92 |
| ** Chiller 45 Deg. F. | 5.2 MW (A) | 3100** | 173,417 | 3.99 |

* This Flow represents LCW to ICW Heat Exchanger
** Not known if model A or C will be used for the electronics**
*** Assuming the pond is the only Heat Exchange for the System

| | | | | |
|---|---|---|---|---|
| **Total Gallons per Minute** | **(C)** | **2068** | **Acres** | **4.736** |
| **Total Gallons per Minute** | **(A)** | **4484** | **Acres** | **7.806** |

| | Pond Design | At 40 | Watts/Sq. Ft.*** | Acres |
|---|---|---|---|---|
| Central Muon Toroid | 2.3 MW | 734* | 57,520 | 1.321 |
| Intermediate Toroid | 1.2 MW | 382* | 30,010 | .69 |
| Forward Toroids | .4 MW | 137* | 10,080 | .23 |
| 3 400 HP Compressors | 894 KW | 70 | 22,370 | .514 |
| 2 125 HP LCW Pumps | 186 KW | 61* | 4,660 | .107 |
| ** Chiller 45 Deg. F. | 1.2 MW (C) | 684** | 30,010 | .69 |
| ** Chiller 45 Deg. F. | 5.2 MW (A) | 3100** | 130,063 | 2.986 |

* This Flow represents LCW to ICW Heat Exchanger
** Not known if model A or C will be used for the electronics**
*** Assuming the pond is the only Heat Exchange for the System

| | | | | |
|---|---|---|---|---|
| **Total Gallons per Minute** | **(C)** | **2068** | **Acres** | **3.552** |
| **Total Gallons per Minute** | **(A)** | **4484** | **Acres** | **5.848** |

### 5.4.5.2.6 ICW Flow Requirements for L* IR3

| | | | ICW At 95 Degrees F. |
|---|---|---|---|
| Solenoid | 20 MW | | 6500* |
| 2 400 HP LCW Pumps | 596 KW | | 191* |
| ** Chiller 45 Deg. F. | 1.2 MW | (C) | 684** |
| ** Chiller 45 Deg. F. | 5.2 MW | (A) | 3100** |

* This Flow represents LCW to ICW Heat Exchanger
** Not known if model A or C will be used for the electronics**

**Total Gallons per Minute (C) 7375**
**Total Gallons per Minute (A) 9791**

#### 5.4.5.2.6.1 ICW POND Requirements for L* IR3

| | | Pond Design | At 30 Watts/Sq. Ft.*** | Acres |
|---|---|---|---|---|
| Solenoid | 20 MW | 6500* | 669,440 | 15.372 |
| 2 400 HP LCW Pumps | 596 KW | 191* | 19,872 | .475 |
| ** Chiller 45 Deg. F. | 1.2 MW (C) | 684** | 40,014 | .92 |
| ** Chiller 45 Deg. F. | 5.2 MW (A) | 3100** | 173,417 | 3.99 |

* This Flow represents LCW to ICW Heat Exchanger
** Not known if model A or C will be used for the electronics**
***** Assuming the pond is the only Heat Exchange for the System**

| | | | | |
|---|---|---|---|---|
| **Total Gallons per Minute** | **(C)** | **7375** | **Acres** | **16.767** |
| **Total Gallons per Minute** | **(A)** | **9791** | **Acres** | **19.837** |

| | | Pond Design | At 40 Watts/Sq. Ft.*** | Acres |
|---|---|---|---|---|
| Solenoid | 20 MW | 6500* | 502,081 | 11.528 |
| 2 400 HP LCW Pumps | 596 KW | 191* | 14,904 | .343 |
| ** Chiller 45 Deg. F. | 1.2 MW (C) | 684** | 30,010 | .69 |
| ** Chiller 45 Deg. F. | 5.2 MW (A) | 3100** | 130,063 | 2.986 |

* This Flow represents LCW to ICW Heat Exchanger
** Not known if model A or C will be used for the electronics**
***** Assuming the pond is the only Heat Exchange for the System**

| | | | | |
|---|---|---|---|---|
| **Total Gallons per Minute** | **(C)** | **7375** | **Acres** | **12.561** |
| **Total Gallons per Minute** | **(A)** | **9791** | **Acres** | **14.812** |

## 5.4.5.2.7 ICW Flow Requirements for DO IR5

| | | | ICW At 95 Degrees F. |
|---|---|---|---|
| Central Muon Toroid | .95 MW | | 312* |
| End Toroids (2) | 1.68 MW | | 543* |
| 2 100 HP LCW Pumps | 149 KW | | 49* |
| ** Chiller 45 Deg. F. | 1.2 MW | (C) | 684** |
| ** Chiller 45 Deg. F. | 5.2 MW | (A) | 3100** |

* This Flow represents LCW to ICW Heat Exchanger
** Not known if model A or C will be used for the electronics**

**Total Gallons per Minute (C) 1588**
**Total Gallons per Minute (A) 4004**

### 5.4.5.2.7.1 ICW POND Requirements for DO IR5

| Pond Design At 30 | | | Watts/Sq. Ft.*** | Acres |
|---|---|---|---|---|
| Central Muon Toroid | .95 MW | 312* | 31,667 | .727 |
| End Toroids (2) | 1.68 MW | 543* | 56,019 | 1.29 |
| 2 100 HP LCW Pumps | 149 KW | 49* | 4,971 | .115 |
| ** Chiller 45 Deg. F. | 1.2 MW (C) | 684** | 40,014 | .92 |
| ** Chiller 45 Deg. F. | 5.2 MW (A) | 3100** | 173,417 | 3.99 |

* This Flow represents LCW to ICW Heat Exchanger
** Not known if model A or C will be used for the electronics**
*** Assuming the pond is the only Heat Exchange for the System

**Total Gallons per Minute (C) 1588 Acres 3.052**
**Total Gallons per Minute (A) 4004 Acres 6.122**

| Pond Design At 40 | | | Watts/Sq. Ft.*** | Acres |
|---|---|---|---|---|
| Central Muon Toroid | .95 MW | 312* | 23,750 | .546 |
| End Toroids (2) | 1.68 MW | 543* | 42,014 | .965 |
| 2 100 HP LCW Pumps | 149 KW | 49* | 3,728 | .086 |
| ** Chiller 45 Deg. F. | 1.2 MW (C) | 684** | 30,010 | .69 |
| ** Chiller 45 Deg. F. | 5.2 MW (A) | 3100** | 130,063 | 2.986 |

* This Flow represents LCW to ICW Heat Exchanger
** Not known if model A or C will be used for the electronics**
*** Assuming the pond is the only Heat Exchange for the System

**Total Gallons per Minute (C) 1588 Acres 2.287**
**Total Gallons per Minute (A) 4004 Acres 4.583**

**5.4.5.2.8 ICW Flow Requirements for BCD IR8**

| | | | ICW At 95 Degrees F. |
|---|---|---|---|
| 2 200 HP Compressors | 298 KW | | 24 |
| ** Chiller 45 Deg. F. | 1.2 MW | (C) | 684** |
| ** Chiller 45 Deg. F. | 5.2 MW | (A) | 3100** |

** Not known if model A or C will be used for the electronics**

| | | |
|---|---|---|
| **Total Gallons per Minute** | **(C)** | **708** |
| **Total Gallons per Minute** | **(A)** | **3124** |

**5.4.5.2.8.1 ICW POND Requirements for BCD IR8**

| | | **Pond Design At 30** | **Watts/Sq. Ft.*** ** | **Acres** |
|---|---|---|---|---|
| 2 200 HP Compressors | 298 KW | 24 | 7,456 | .172 |
| ** Chiller 45 Deg. F. | 1.2 MW (C) | 684** | 40,015 | .92 |
| ** Chiller 45 Deg. F. | 5.2 MW (A) | 3100** | 173,417 | 3.99 |

** Not known if model A or C will be used for the electronics**
*** **Assuming the pond is the only Heat Exchange for the System**

| | | | |
|---|---|---|---|
| **Total Gallons per Minute (C)** | **708** | **Acres** | **1.092** |
| **Total Gallons per Minute (A)** | **3124** | **Acres** | **4.162** |

| | | **Pond Design At 40** | **Watts/Sq. Ft.*** ** | **Acres** |
|---|---|---|---|---|
| 2 200 HP Compressors | 298 KW | 24 | 7,456 | .172 |
| ** Chiller 45 Deg. F. | 1.2 MW (C) | 684** | 30,010 | .69 |
| ** Chiller 45 Deg. F. | 5.2 MW (A) | 3100** | 130,063 | 2.986 |

** Not known if model A or C will be used for the electronics**
*** **Assuming the pond is the only Heat Exchange for the System**

| | | | |
|---|---|---|---|
| **Total Gallons per Minute (C)** | **708** | **Acres** | **.862** |
| **Total Gallons per Minute (A)** | **3124** | **Acres** | **3.158** |

**Total Area ICW Flow Required (C) 11,731 GPM at 95 Deg. F.**
**Total Area ICW Flow Required (A) 21,403 GPM at 95 Deg. F.**

5.4.5.3

**5.4.5.3.1 Description of an CWS Cooling Systems**

Closed-loop systems to provide air conditioning and cooling of the electronics at a supply temperature between 45 and 55 degrees fahrenheit.

**5.4.5.3.2 Components of an CWS Cooling Systems**

**A.** Compressors
**B.** Pumps
**C.** Heat Exchangers
**D.** Piping and Valves
**E.** Control Systems

**5.4.5.3.3 Cost of CWS Cooling Systems**

**N.A. At this time.**

**5.4.5.3.4 SSC Considerations for CWS Cooling Systems**

**N.A. At this time.**

### 5.4.5.3.5 CWS Requirements for LSD IR2

** Chiller 45 Deg. F. 1.2 MW (C) 584 GPM 15 Deg. Rise**
342 Tons of Refrigeration / 4,095,600 BTU/HR

** Chiller 45 Deg. F. 5.2 MW (A) 2500 GPM 15 Deg Rise**
1550 Tons of Refrigeration / 18,600,000 BTU/HR
** Not known if model A or C will be used for the electronics**

### 5.4.5.3.6 CWS Requirements for L* IR3

** Chiller 45 Deg. F. 1.2 MW (C) 584 GPM 15 Deg. Rise**
342 Tons of Refrigeration / 4,095,600 BTU/HR

** Chiller 45 Deg. F. 5.2 MW (A) 2500 GPM 15 Deg Rise**
1550 Tons of Refrigeration / 18,600,000 BTU/HR
** Not known if model A or C will be used for the electronics**

### 5.4.5.3.7 CWS Requirements for D0 IR5

** Chiller 45 Deg. F. 1.2 MW (C) 584 GPM 15 Deg. Rise**
342 Tons of Refrigeration / 4,095,600 BTU/HR

** Chiller 45 Deg. F. 5.2 MW (A) 2500 GPM 15 Deg Rise**
1550 Tons of Refrigeration / 18,600,000 BTU/HR
** Not known if model A or C will be used for the electronics**

### 5.4.5.3.8 CWS Requirements for BCD IR8

** Chiller 45 Deg. F. 1.2 MW (C) 584 GPM 15 Deg. Rise**
342 Tons of Refrigeration / 4,095,600 BTU/HR

** Chiller 45 Deg. F. 5.2 MW (A) 2500 GPM 15 Deg Rise**
1550 Tons of Refrigeration / 18,600,000 BTU/HR
** Not known if model A or C will be used for the electronics**

## 5.4.5.4

### 5.4.5.4.1 Description of RAW Cooling Systems

This is a type of Closed Loop Water Cooling system designed for the ease of replacement, repair, uniformity, portability, computer readouts, and variable flow rates. These systems have the rated capacity of 100 kw. and flow rates from 5 g.p.m. to 60 g.p.m., with a constant pressure of 115 p.s.i. and is known as the RAW System (radioactive water).

Where the loads required cooling water at a lower temperature or have the max. load of 100 kw. we have installed an ICW heat exchanger that precools the LCW to a lower temperature. This eliminates the need for costly and complicated chillers that have been used in the past. All of these systems do require the LCW cooling to satisfy the Radiation Safety Group, but not the ICW. The surge tanks in these systems are open to the atmosphere to release any hydrogen build-up that may occur and eliminates the need for recombiners and extra alarms. These systems have the features of auto or manual make-up from a remote location, and at the remote location it is indicated if the system has the auto fill on. The RAW systems have two temperature readouts and one flow readout, these are analog readouts and may be processed by the main computer system. There are (13) status points that are available from these systems along with the (3) analog points. These status points will indicate if a pump is operating, if the flow is proper, if the temperature is ok, if the surge tank is at the proper level, ect..

Raw water from the pump is pushed to the load of the system. The RAW water removes the heat from the beam induced load and returns through the LCW to RAW heat exchanger to remove the heat. After the LCW to RAW heat exchanger the RAW water is returned to the suction side of the RAW pump. The supply and return temperatures, and flow is monitored in this loop. LCW from the main LCW system enters the ICW to LCW heat exchanger through the LCW flow regulator ( adj. from 10-60 g.p.m.) this precools the LCW if required. After the ICW to LCW heat exchanger the LCW enters the LCW to RAW heat exchanger removing the heat from the RAW water and then returns to the main LCW system. All RAW systems require LCW cooling and are interlocked with the LCW flow switch. If precooling is required, then the system is interlocked with the ICW flow or pressure switch.

Apx. 5 g.p.m. of the RAW water is pushed through the deionizer loop at a pressure of 10 p.s.i. then through the string filter and back to the surge tank. This system has the capability of auto or manual make-up, if in the auto make-up an indication of this is on the front of the control box. When the water is made-up it passes through the deionizer loop and filter before entering the surge tank.

### 5.4.5.4.2 Costs of RAW Cooling Systems

| | |
|---|---|
| Standard RAW System with Controls | 16K |

### 5.4.5.4.3 RAW Requirements for the SSC

**N.A. At this time.**