VIII. Utilities

A. Water systems

Cooling water is used to carry excess heat away from power supplies, magnets and other systems in the Antiproton Source. The most extensive water system found in Pbar is the 95° Low Conductivity Water (LCW) system. The Pbar 95° LCW system provides cooling for components in the Rings and Transport enclosures as well as the AP0, 10, 30 and 50 service buildings. LCW is water which has had free ions removed, increasing its resistance to electrical current. This attribute is critical if a device has cooling channels that also act as electrical conductors. Most Rings and beamline magnets, for example, have hollow copper electrical windings that the LCW flows through. The Pbar 95° LCW system is not only used to cool most magnets and their power supplies, but also magnet shunts and TWT amplifiers used in the stochastic cooling systems.

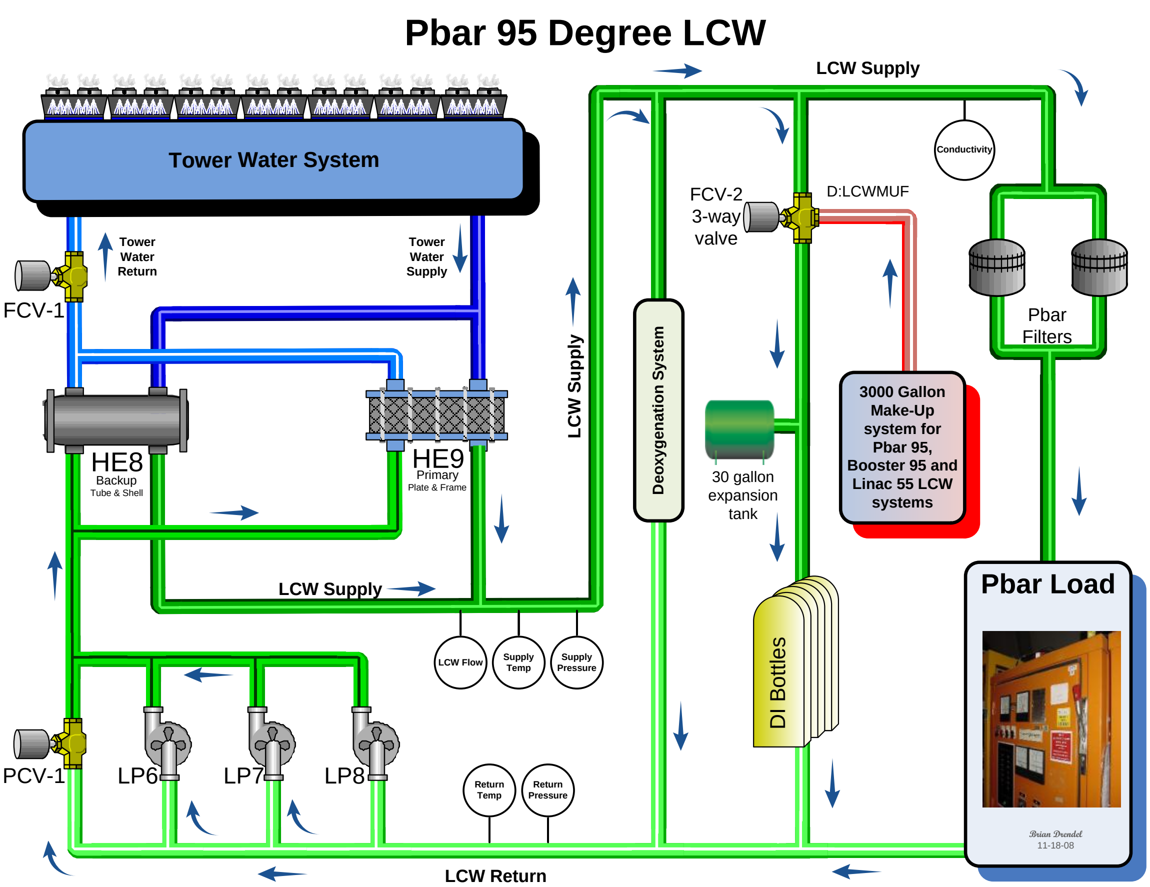

Figure 8.1 Pbar 95° LCW system
(expanded from the MetaSys controls diagram used by FESS)

Figure 8.1 is a block diagram of the Pbar 95° LCW system. The two heat exchangers, three pumps, a thirty gallon expansion tank, and a filter system can all be found on the second floor (frequently referred to as the mezzanine) of the Central Utility Building (CUB). In addition, a 3,000 gallon make-up system, deionizing (DI) equipment and deoxygenation skid are located on the first floor of CUB. The three pumps used to circulate Pbar 95° LCW are called LP6, LP7 and LP8. During normal operation, two of the three pumps are run, which allows flexibility if a pump requires repair. Most of the Pbar 95° LCW flows through one of two large "full-flow" filters before leaving CUB and heading to pbar. Part of the LCW is diverted through two loops that bypass the path to pbar. The first loop has the three-way valve that connects to the 3,000 gallon make-up tank, a 30 gallon expansion tank and the deionizing bottles. The deionizing bottles "polish" the LCW by removing ions. The other loop contains the deoxygenation skid, which removes free oxygen in the LCW. Free oxygen coming in contact with the copper LCW pipes and magnet conductors can cause the formation of a copper oxide (CuO). Deposits of the copper oxide can line the inside of the magnet conductors and can even cause blockages that lead to overheating.

The Pbar 95° LCW heat exchanges with Tower Water (TW), which originates from a 26,000 gallon storage tank located in the northeast corner of CUB. There are two Pbar 95° heat exchangers, but only one of them is used at a time. The primary heat exchanger is a plate and frame heat exchanger called HE9. It is rectangular in shape, much like the heat exchangers used for the Booster 95° LCW system. The backup heat exchanger is an older shell and tube type called HE8. This heat exchanger is cylindrical in shape, much like those in the Tevatron service buildings. HE8 hangs from the ceiling of the mezzanine right next to the plate and frame heat exchanger. Regardless of which heat exchanger is used, a large valve called FCV-1 controls the LCW temperature by regulating how much Tower Water circulates through the heat exchanger.

Figure 8.2 is a block diagram of the Tower Water system. Tower Water is used to provide cooling for the Pbar 95° LCW system as well as LCW systems used by other accelerators. Tower Water can also be used to cool the 55° Chilled Water systems in the winter months. Tower Water is pumped out of the 26,000 gallon storage tank by three Tower Water pumps called TWP-1, TWP-2 and TWP-3. These pumps circulate the Tower Water through the

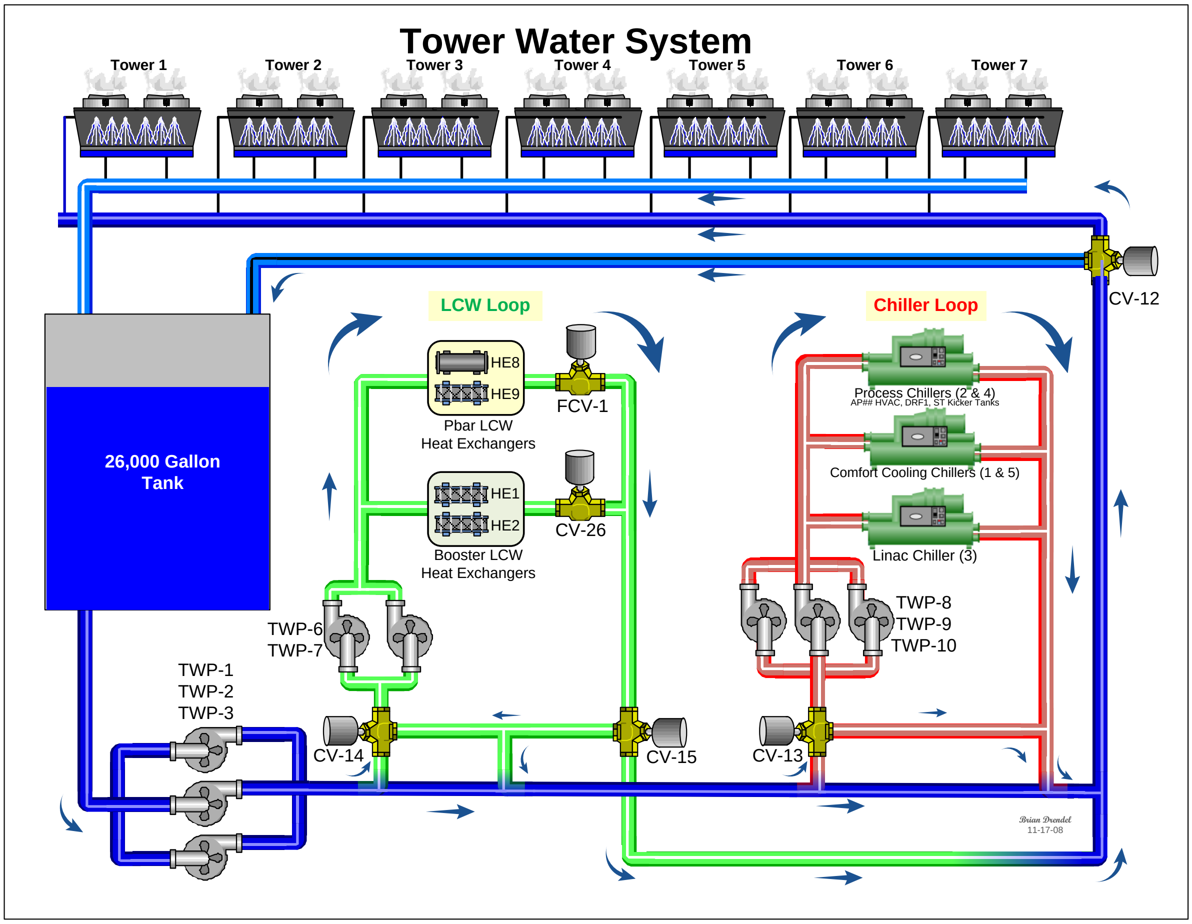

Figure 8.2 Tower Water System

(expanded from the MetaSys controls diagram used by FESS)

primary Tower Water loop which goes up to the cooling towers on the roof of CUB and back down to the storage tank. These pumps are also variable speed so that they can match the flow through the heat exchanger and chiller loads. As the flow increases through the loads, so does the speed of these pumps.

Depending on cooling demands, cooling towers can be valved out of the system. During the summer months, when the efficiency of the cooling towers is at its lowest, all seven pairs of towers are needed. The towers are staged based on the discharge water temperature out of the 26,000 gallon tank. The cooling towers use ambient air to cool the Tower Water with a combination of direct contact and evaporation. On warm days, most of the heat removal comes from evaporative cooling.

Figure 8.3[2] shows the air and water flow through a cooling tower. The warm return Tower Water from the Pbar heat exchanger is pumped into the top of the cooling tower, and is sprayed downward onto a wet deck in the tower. Simultaneously, outside air is drawn in through inlet louvers at the base of the tower and travels upward through the wet deck. As long as the outside air is cooler than the Tower Water, the Tower Water will be cooled by direct contact with the air. A small portion of the Tower Water is evaporated into the air passing through the tower, removing heat from the remaining water. The warm moist air is drawn to the top of the cooling tower by a fan and is vented into the atmosphere. The cooled Tower Water drains to a basin in the bottom of the tower. This water is returned to the 26,000 gallon tank and then pumped back to the heat exchangers. During the summer months, the outside air is very warm and humid. On these days, both the direct contact and evaporative cooling mechanisms are much less efficient. On the worst of the hot and humid summer days, the Tower Water temperature can't be maintained, causing the Pbar and Booster LCW to warm. FESS uses the term "Wet Bulb Temperature" to describe the cooling potential of the outside air[3]. A high wet bulb temperature (above about 75° F) will likely cause both the Booster and Pbar 95° LCW systems to lose temperature regulation during the hottest part of the day.

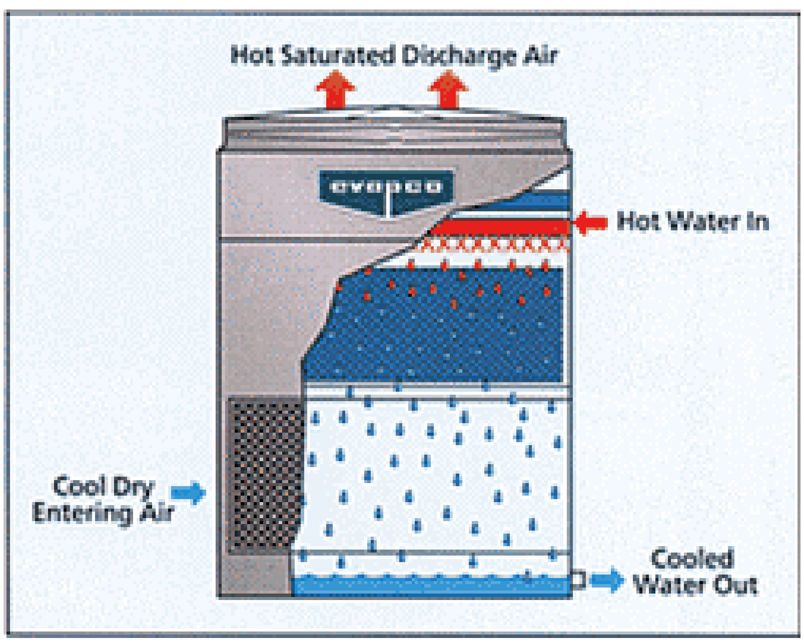

Figure 8.3 Cooling Tower diagram from Evapco website[2].

There are two secondary Tower Water loops which are labeled "LCW Loop" and "Chiller Loop" in figure 8.2. For the "LCW loop," two water pumps called TWP-6 and TWP-7 pull Tower Water from the primary loop to the secondary loop that includes both the Booster 95° and Pbar 95° LCW heat exchangers. The temperature of the Tower Water in this loop can be controlled by regulating how much of the water in this secondary Tower Water loop is re-circulated and how much is put back in the primary Tower Water loop. This is done using a bypass line and two valves called CV-15 and CV-14. On the Tower Water output side of the heat exchangers, valve CV-15 is either fully open or closed. When open, all of the water in the secondary loop is routed back to the primary Tower Water loop. This configuration provides maximum cooling and is used during the summer. When CV-15 is closed, the water is sent down a bypass line, where another valve, CV-14, regulates how much Tower Water is recirculated in the secondary loop. This mode of operation is used during cooler weather.

Tower water also provides cooling to the Chilled Water (CHW) system via the "Chiller Loop" shown in figure 8.2. Three secondary pumps called TWP-8, TWP-9 and TWP-10 pull Tower Water from the primary tower water loop to a secondary loop that provides cooling to five process chillers used in three different cooling systems. Chiller CH-3 provides cooling for the Linac 55° LCW, Chillers CH-1 and CH-5 provide cooling to the "Comfort Cooling" (Wilson Hall, HVAC), and chillers CH-2 and CH-4 provide cooling to the "Process CHW" which is used by Pbar. The Tower Water of this secondary loop is temperature controlled by regulating a valve called CV-13 which regulates how much water is recirculated in the secondary loop.

Figure 8.4 is a block diagram of the "Process" Chilled Water (CHW) system, which provides cooling water for the Pbar service building air conditioning units, the DRF1 cavities, and the stochastic cooling kicker tanks. It also removes heat from the closed loop LCW systems at AP0 and F27, which are described below. Process CHW is strained and chilled to approximately 45° Fahrenheit. In periods of warmer weather, the Process CHW is circulated by two chillers running in parallel (CH-2 and CH-4). Two valves called CV-2 and CV-3 control how much flow is sent through CH-2 and CH-4 respectively. During the winter months, there is an option to run through a heat exchanger called HX-1 instead of the chillers. HX-1 is a free flowing heat exchanger that gets its cooling from the Tower Water system mentioned above.

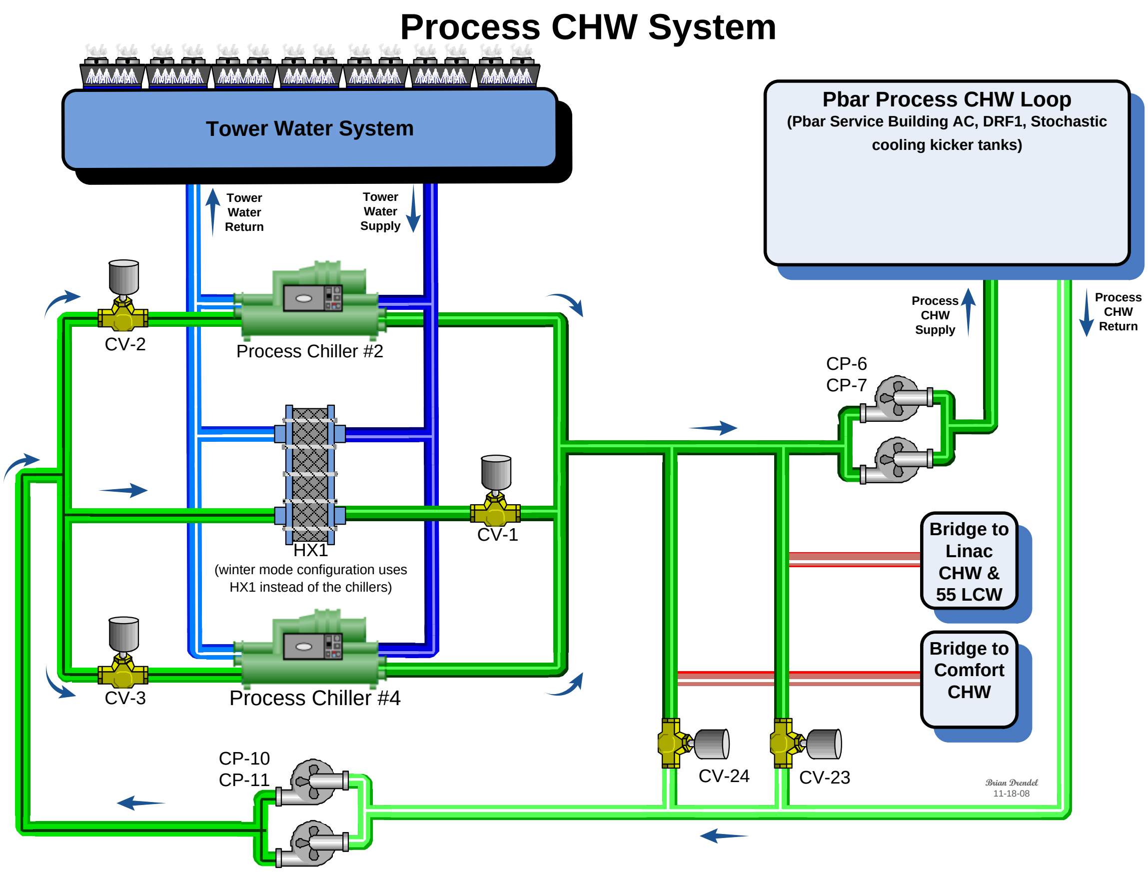

Figure 8.4 Process Chilled Water

(expanded from the MetaSys controls diagram used by FESS)

The CHW system is sometimes confused with the ICW system. ICW (Industrial Cooling Water) makes up the fire hydrant network and is unrelated to the Chilled Water system. To add further confusion, CW (condenser water), ICW and TW (Cooling Tower water) all eventually go through the 26,000 gallon tank.

Tevatron 95° LCW flows through the AP1 and AP3 line magnets in the Pretarget and Prevault enclosures. Tevatron LCW is also used to cool power supplies at the F23 service building. LCW from the Tevatron system was used for reasons of convenience and economy.

There are four closed loop, stand-alone LCW systems in the Pbar complex. Each of these systems consists of a pump, heat exchanger, deionizer bottle, expansion tank, and associated plumbing and instrumentation, similar to the low energy Linac water systems. Chilled Water is used to heat exchange with each closed loop LCW system. Three of the systems are located in AP0: one provides cooling for the Lithium Lens and transformer, one for the beam dump and one for the Pulsed Magnet and collimator. When needed, make-up water to fill these systems is taken manually from the Pbar 95° LCW header located on the wall nearby. The other closed loop system is located in the F27 service building and provides cooling water for the power supplies in that building. When required, LCW at F27 is made up by Water Group personnel from a 55-gallon drum of de-ionized water. When the F27 service building was built, there weren't any LCW lines in the vicinity. It was more convenient (and economical) to tee off of an existing chilled water header that ran between CUB and the RF building.

Important water system parameters are monitored via ACNET and/or FIRUS. Temperature, pressure, oxygen level, turbidity and conductivity monitoring for the Pbar 95° LCW system can be found on page P75. Temperature and pressure readbacks for the Chilled Water and Tower Water loops can also be viewed from P75. In addition, the amount of water leaking out of the Pbar LCW system can be determined through the ACNET parameter D:LCWTOT. This device reads back the total amount of make-up water that has been transferred from the 3,000 gallon tank over an arbitrary amount of time (normally 24 hours, beginning at midnight). The Pbar 95° LCW system has a 30 gallon reservoir, shown in figure 8.1, which is filled up every time that amount of LCW has leaked out of the system. Under normal no-leak running conditions, 50 to 100 gallons per week is added to the system. A plot of D:LCWTOT would indicate 30 gallon increments at regular intervals if there were a leak (this parameter is reset to 0 gallons every day at midnight). D:LCWMUF monitors the flow into the makeup tank and normally reads zero. Only when the LCW system is automatically filling the 30-gallon reservoir should this parameter have a non-zero reading.

FIRUS also alarms if certain parameters are out of limits. In general, poor conductivity, incorrect pressures or tripped chillers or cooling towers should be brought to the attention of on-shift plant maintenance personnel (i.e. the Duty Mechanic). Pressure or temperature alarms should be checked against their ACNET counterparts. Generally, the ACNET devices have more accurate alarm set points.

B. Vacuum systems

All of the Pbar beam lines and both Rings have unique vacuum systems, sometimes isolated from each other via vacuum windows. In all cases, distributed ion pumps provide most of the pumping. The beamline and Rings vacuum systems can broken into smaller segments with beam valves. A number of pump-out ports are built into each system to provide easy connection of mobile turbo molecular pump stations. Tevatron-style CIA crates are used to control the vacuum components. Beam valves are interlocked to close if three or more ion pumps in a section are tripped or indicate poor vacuum. Each of the systems is outlined below. For the sake of clarification, Torr is normally the unit of measure used for vacuum although millibar (mbar) is the proper metric unit. The units are very similar in magnitude, average atmospheric pressure is 760 torr or 1,013 mb. Since the units are so close in magnitude, Torr and mbar's can be used interchangeably.

Vacuum in the AP-1 line is common to that of the P2 line on the upstream end and AP-3 on the downstream end. Beam valve M:BV100, located immediately downstream of the second (of two) 'C' magnets in the AP-1 line, is interlocked to close if too many pumps trip in either P2, AP-1 or AP-3. A vacuum window located just inside the Target Vault isolates AP-1 from the Target Station. Beam Valve D:BV926 can isolate AP-1 from AP-3. The nominal AP-1 line pressure of 10^{-8} Torr is maintained by distributed sputter ion pumps rated at 270 liters/second. Pump supplies and controls hardware for this system can be found in the AP0 service building.

The Target Vault is not under vacuum and serves as the break between AP-1 and AP-2 vacuum. Another window within the Target Vault isolates the AP-2 line at its upstream end. AP-2 vacuum is common with the Debuncher, although there used to be a vacuum window immediately upstream of the Debuncher injection septum magnet. After an upgraded septum magnet with better aperture was installed, the vacuum window was removed and beam valve D:BV728 installed. Like AP-1, the injection line vacuum is maintained through the use of distributed sputter ion pumps rated at 270 l/s. The nominal pressure of the beamline is 10^{-8} Torr.

The Debuncher, similarly, has its vacuum maintained with sputter ion pumps. The average Debuncher pressure is a decade better than the beamlines, 10^{-9} Torr. Beam valves at each '10' location can effectively subdivide the Debuncher into 6 separate vacuum sectors. Beam valve D:BV610 doubles as the safety system coasting beam stop for the Debuncher.

The D to A line is a stand-alone vacuum system with vacuum windows at the upstream end of the Debuncher injection septum magnet and the downstream end of the downstream Accumulator injection septum. Ion pumps keep this line's vacuum in the 10^{-8} Torr range.

Because the Accumulator was designed for use as a storage ring, its vacuum requirements are the most stringent. One of the significant considerations in determining the beam lifetime in a storage ring is the beam-gas interaction rate. Improving the vacuum lowers this interaction rate, thereby reducing beam loss. The design pressure of the Accumulator is 3×10^{-10} Torr. This level of vacuum is accomplished through the use of sputter ion pumps and titanium sublimation pumps supplemented by a bake-out system. As with the Debuncher, the Accumulator has six vacuum sectors. Beam valves in sectors 10 through 30 and 60 are found at the '7' locations. The valves for the 40 and 50 regions were moved from their original location to immediately upstream and downstream respectively of straight section 50. This provided isolation for the experiment that was located in the A50 Pit, so that work could be done there with minimal impact on the Accumulator. As a consequence, the Accumulator 40 and 60 vacuum sectors are larger than the others. Like D:BV610 in the Debuncher, beam valve A:BV607 acts as the safety system coasting beam stop for the Accumulator.

Titanium sublimation pumps are used in the Accumulator to provide the additional pumping required for a vacuum of 3×10^{-10} Torr or better. A sublimation pump is a form of getter pump that operates on the principle that chemically stable compounds are formed between gas molecules (H_2, N_2, O_2, CO, CO_2) and the getter (titanium). The SNEG in the Tevatron is another form of a vacuum getter pump. The getter is the material that gas molecules combine with. Noble gases (such as helium) cannot be pumped by getters, but can be pumped by ion pumps. In a sublimation pump, a filament containing a high titanium content is heated resistively and the boiled off titanium forms a thin layer on the surrounding walls of the vacuum chamber. For the Accumulator, the walls are adjacent to the beam pipe rather than being the beam pipe itself. As gas molecules impinge on the getter film, stable compounds are formed and the vacuum pressure improves since there are fewer gas molecules in the beam pipe volume. However, this decreases the amount of getter material available to capture other gas molecules.

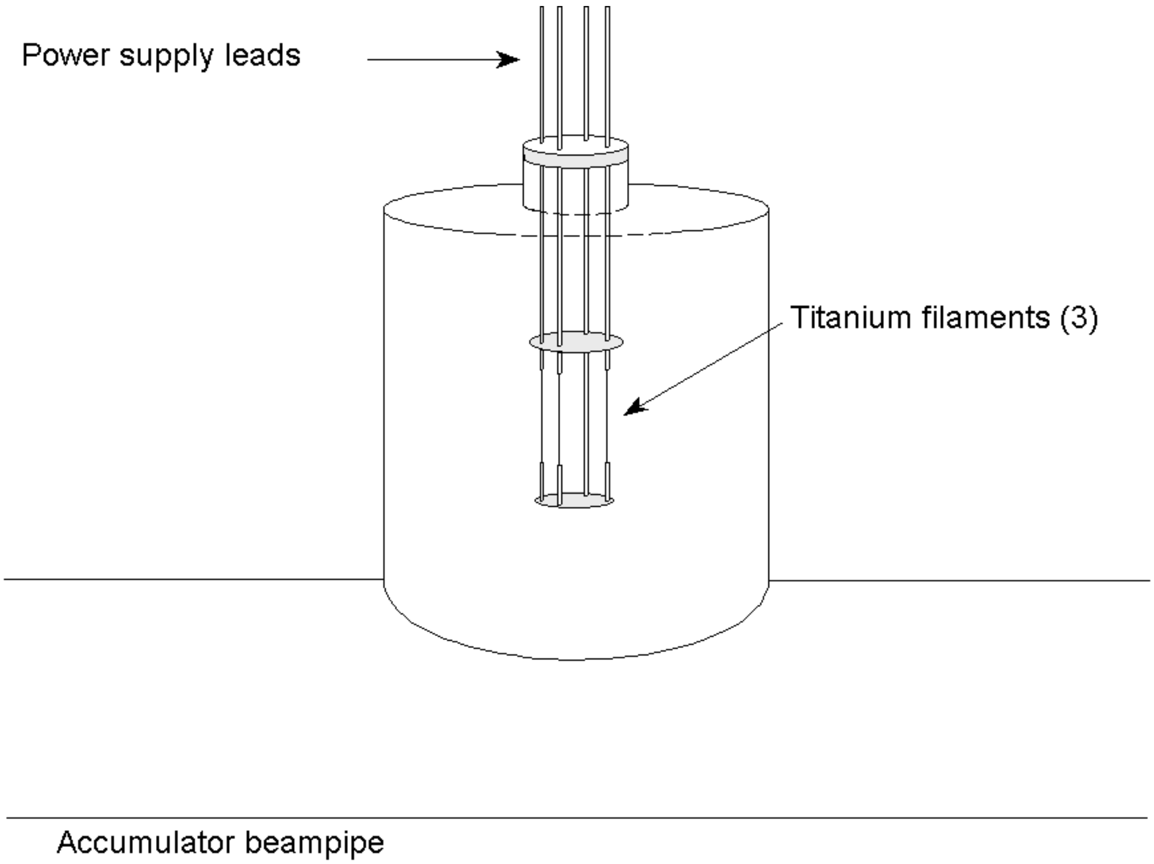

Figure 8.5 Titanium sublimation pump

Unlike ion pumps, which are powered all of the time, the sublimation pumps in the Accumulator are powered infrequently. The sublimation pumps are "fired" over 90 seconds to sublimate approximately 10 monolayers of titanium onto the pump's interior surface. During normal operation, sublimations are spaced weeks or months apart. Each Accumulator sublimation pump contains 3 filaments to extend the lifetime of the pump, although only one filament at a time is sublimated (see figure 8.5). Because sublimation pumps have no effect on inert gases, sputter ion pumps are still an important component of the system. To date, the best average vacuum in the Accumulator has been 6.8 x 10^{-11} Torr (as read by ion gauges), although a typical value is 1 - 3 x 10^{-10} Torr.

A permanently installed bake-out system in the Accumulator makes it possible to bake each of the six sectors independently when conditions warrant. Usually when a portion of the Accumulator is let up to air, a bake-out follows the work. Baking the beam pipe makes it possible to liberate water vapor on the inner surface of the beam pipe and remove deep-seated impurities. Bake-out temperatures range from 130° C for stochastic cooling

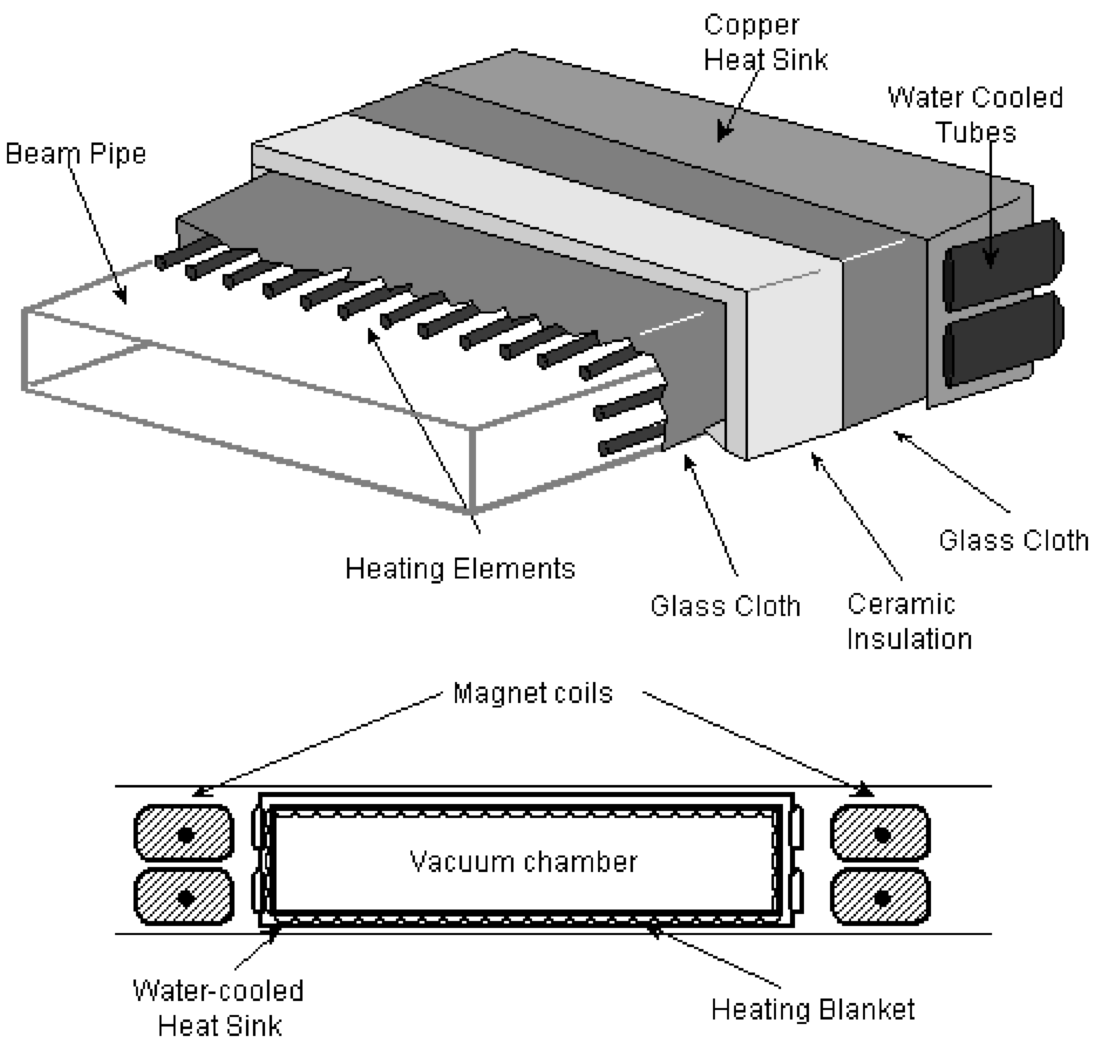

Figure 8.6 Accumulator dipole bake-out components

tanks to 250° C for quadrupoles. Pumping during a bake is achieved by using mobile turbo-pump carts. The bake is controlled by a single microprocessor in AP10 while an ACNET applications program is used for human interface. The processor receives inputs from thermocouples located in the tunnel and controls heaters to regulate the temperature. It typically requires several days to heat the components to the desired temperature, hold that temperature during the bake and slowly cool back down to room temperature. Heaters and insulation coexist in the blankets, which are wrapped around the beam pipe and non-magnetic components. The magnets are not encased in blankets, rather, special channels for LCW lines and heating elements are sandwiched between the beam pipe and magnet laminations (see figure 8.6). Such an arrangement permits the beam pipe to be baked while protecting the magnet.

The AP-3 line vacuum is common to the Accumulator because of concerns that a vacuum window at the junction of the Accumulator and the beam line would cause excessive transverse emittance blowup during transfers. Despite the absence of a vacuum window, Accumulator vacuum does not degrade significantly near the junction because of additional capacity built into the ion pumps at the upstream end of the line. A beam valve, BV900, provides protection in case there is a loss of vacuum in either the Accumulator or AP-3 line. Vacuum is maintained in AP-3 with 270 l/s sputter ion pumps. The pressure is typically 10^{-8} mbar. Beam valve D:BV926 located in the Prevault enclosure provides isolation between the AP-1 and AP-3 lines.

C. Electrical systems

Power requirements for most of the Antiproton source complex is provided by feeder 24, a 13.8 kV feeder, which is the output of transformer 83A in the Master Substation. 13.8 kV is stepped down to 480 V in transformers outside of AP0, 10, 30, 50, and F27. Breaker panels and additional transformers distribute power to all tunnel and house loads as well as nearly every power supply. The Debuncher and Accumulator bend bus supplies have separate outdoor transformers connected to feeder 24 at AP50 (see figure 8.7). A 13.8KV distribution switch called DSTR-AP50-1 allows the bend bus transformers to be isolated from the house power transformer.

There are two sources of power for F23: one source for the large power supplies and one for the lighting, trim power supplies and rack power. Power for the large AP1 line supplies come from feeders 94/95, the beamline feeders, which are downstream of the manual operated switch called MOS 89. Feeders connected to MOS 89 cover the beamline (P1, P2 and P3) supplies in F-Sector (some elements spill over into Transfer Hall), as well as MI-52 (Main Injector Sextupoles). As a result, anytime an access is made into Main Injector, F-Sector or Transfer Hall, MOS 89 is switched off and power is lost to the large supplies at F23. F23 lighting, trim and rack power comes from an

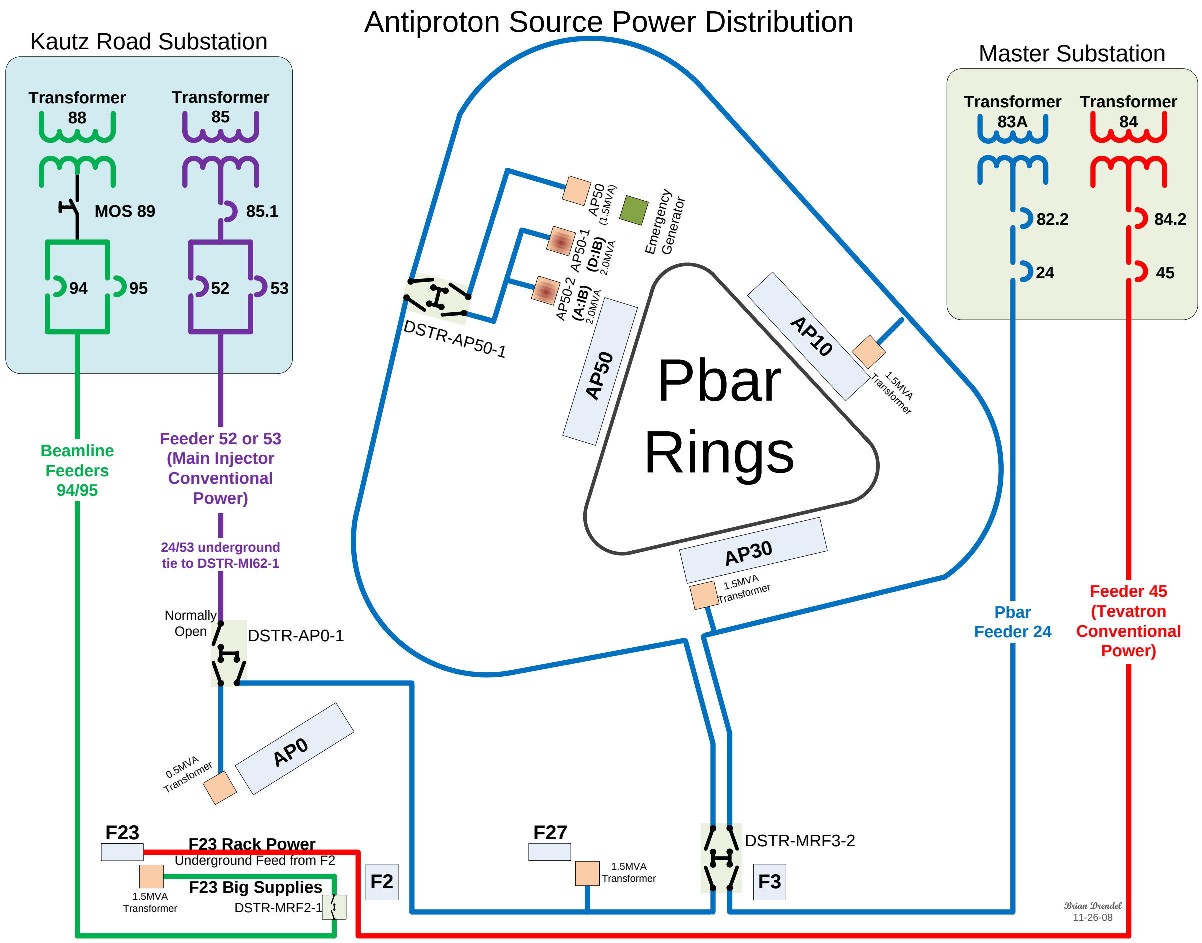

Figure 8.7 Antiproton Source Power Distribution

underground feed from the F2 service building. This power originates from Master Substation Feeder 45 (Tevatron conventional power), and is not interrupted when accesses are made.

The Antiproton Source can be powered by Kautz Road Substation feeder 52 or 53, which powers Main Injector service buildings, by means of a transfer switch called DSTR-AP0-1. This is not used during normal operation and is reserved for long shutdown maintenance activities. Normally, feeder 24's sole load (and transformer 83A) is the Antiproton Source.

In case of a power outage, an emergency diesel generator located at AP50 keeps Antiproton Source sump pumps, ventilation equipment, and the overhead crane in AP0 operational. When power is lost at AP0, 10, 30, or 50 the generator is automatically turned on and the emergency feeder energized. Meanwhile, transfer switches in or below the building(s) without power switch in the emergency feeder. The generator is automatically tested on Wednesdays around noon. Controls for the generator are located at AP0.

D. Cryogenic systems

Liquid helium is used to cool the pickup electrodes and low level amplifiers for all of the Debuncher stochastic cooling systems, as well as the Leg 1 stacktail notch filter located at AP30. Similarly, liquid nitrogen is used on pickups for the stacktail and core 2-4 GHz momentum cooling systems. Liquid nitrogen is also used as a shield for the liquid helium flowing through the transfer lines. By reducing the temperature of the stochastic cooling pickup electronics, the electronic noise they generate is greatly reduced. Electronic noise scales linearly with absolute temperature so there is a considerable reduction in the noise level. The signal to noise level is especially critical in the stacktail and Debuncher cooling systems, which operate on low intensity beams. Pickups for the core systems detect a much larger signal due to the beam intensity. The core 2-4 GHz momentum cooling system pickups use liquid nitrogen only because the pickup tank is located in A20 next to the stacktail pickups. Performance of the system is only improved by a minimal amount, but little additional hardware was required to provide liquid nitrogen to the tank.

Cryogens are provided to the A60 (stacktail and core 2-4 GHz momentum) and D10 (Debuncher) locations by means of transfer lines traveling above ground from AP30. They then pass downwards through penetrations into the tunnel. AP30 houses a satellite refrigerator, which is connected to the Tevatron cryogenic system via helium and nitrogen lines between it and the F3 refrigerator building. There is a refrigerator room within the AP30 service building that contains the wet and dry engines and other cryogenic components normally found in a Tevatron refrigerator building. The heat exchanger is suspended from the ceiling of AP30, outside of the refrigerator room.

Control for the majority of the pbar cryogenic systems is identical to that of the Tevatron and Switchyard refrigerators. Feedback loops manipulate valves to control each stochastic cooling tank's temperature. The house names for the two microprocessors servicing Pbar are: 'PR' for the Pbar Refrigerator equipment at AP30, and 'P1' for the area 10 and 60 loops.

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