Chapter 14

Experimental Facilities

The proceeding chapters have focussed on the detector, and have not addressed a number of important issues related to the interface with the Tevatron, the experimental infrastructure and hall. We discuss below pertinent aspects of the the solenoid and cryogenics, the beam pipe design, Tevatron monitors, Tevatron shielding, the detector gas supply systems, and the heating, ventilation, and air conditioning (HVAC) systems.

14.1 Solenoid and Cryogenics

The CDF detector employs a large magnetic field volume instrumented with tracking devices to determine the trajectories, sign of electric charge, and momenta of charged particles. The magnetic field is provided by a superconducting solenoid. The solenoid provides an axial magnetic field of 1.5 Tesla over a useful volume 2.8 m in diameter and 3.5 m long. The solenoid was designed by a collaboration of physicists and engineers from Fermilab and Tsukuba University in Japan. The coil was built in Japanese industry. The power supply, controls, and refrigeration system were built by Fermilab. The solenoid provides a 1.5 Tesla uniform axial field by creating a cylindrical current sheet with a uniform current density of 1200 A/m. The magnet is indirectly cooled (no direct contact between LHe and the superconductor) and employs a high purity Aluminum stabilized NbTi conductor with a maximum operating current of 5000 Amps. For most of the magnet's life an operating current of 4650 Amps has been used corresponding to a central field of 1.41 Tesla. The high purity aluminum conductor is "soft" and is supported against the large electromagnetic loads produced via an external support cylinder of 5083 Aluminum. Turn-to-turn insulation is Kapton with b-staged epoxy. Ground plane insulation is G-10 and polyester resin. The refrigeration is provided by a STAR version Tevatron satellite refrigerator located in B0 with 600 W capacity. The magnet was first operated in 1985 and has run regularly for high energy physics and cosmic ray data taking with a field availability of $> 99\%$.

14.1.1 Lifetime

The initial design of the coil specified a "10 year lifetime". However, the entire coil structure was designed to operate well within the elastic limits of the materials chosen and therefore it is expected to have a lifetime not limited by fatigue considerations. Similar design rules were used for the support structures which are subjected to cyclic stresses each time the magnet is powered. The entire coil structure is subject to cooldown stresses each time the magnet is cooled to its LHe temperature operating point. The magnet cooldown procedures followed are intended to limit stresses on the coil materials such that stresses are limited and fatigue failures are not a problem. The materials chosen for the coil construction were all chosen to be radiation tolerant at the several mega-Rad level. This is well beyond the expected radiation dose the coil will receive during a Run-II exposure of 2 fb^{-1} ($<$ few kRad at the radius of the coil) The coil package was deliberately designed using welded construction with a minimal number of O-rings. Where O-rings were employed the design used "double" O-rings with a vacuum pumpout between for reliability. The 24 radial support adjustments each have two "double" O-rings as does the main cryostat vacuum relief port. We believe that whatever age related failures might occur in these devices will be soft failures that would not interrupt the run in progress.

14.1.2 Necessary Repairs

A small vacuum leak has been present in the CDF magnet's "Control Dewar" since it was commisioned. The Control Dewar contains the 5000 AMP He gas cooled current leads that make the transition from the cold LHe temperature superconductor to the warm 5000 Amp copper bus. Since the coil is indirectly cooled, the superconductor resides in the insulating vacuum space. Inside the Control Dewar, the superconductor makes a transition from the vacuum space into a "pot" of LHe via 5000 Amp ceramic insulators (the pot serves to thermally anchor the bottom of the gas cooled leads). Since failure of the ceramic insulators would represent a single point failure mode for the magnet if they were to leak LHe into the insulating vacuum space, a secondary vaccuum space and a second backup set of insulators were provided. This turned out to be useful in that a very small leak of the primary insulators was observed shortly after the magnet was commissioned. The decision was made to "live" with the leak rather than repair it since the net effect of this leak was that the small secondary vaccuum space had to be pumped out periodically (approximately once per 2 weeks). This insured that the vacuum remained good enough to provide adequate electrical insulation during a fast discharge of the coil. The leak rate into this space was essentially unchanged over many years of operation and over several cooldown cycles.

During a refrigerator interruption and subsequent rapid recooling of the magnet during Run Ib we observed an increase in this leak rate by a factor of about four. Although still a small leak manageable by pumping, this change suggests that we should consider repairing this problem before Run II. Changing the insulator is possible but would require substantial effort in disassembly and reassembly of this complicated component. It is our intention to study less drastic repairs using a bore-scope first. Provided adequate engineering manpower is provided in a timely fashion to study and address this problem, this repair should not be difficult. Even assuming the worst (i.e. replacing the entire control dewar), the schedule for Run II should not be affected. The cost of the repair will vary depending on the technique chosen.

14.1.3 Controls upgrade

The cryogenic controls system used to operate the Satellite refrigerator and CDF solenoid was designed in 1983 and first became operational in 1984. The system uses many components, display devices, and software "borrowed" from the accelerator controls system (ACNET). CDF received support from the Accelerator Division to maintain and operate this system. For Run II much of the Accelerator controls system that operates the satellite refrigerators will be upgraded by the Accelerator Division. The old system components and software will no longer be supported. Therefore CDF must upgrade its cryogenic controls system.

The Research Division plans to replace the CDF refrigerator control system with a modern commercial control system using a Moore APACS controller with Intellution's FIX-DMACS man machine interface software. This same package has been installed for other helium refrigerators operated by the Research Division. As part of the control system replacement, we also plan to simplify and upgrade the solenoid interlock system.

14.2 Beam Pipe

The CDF beam pipe will consist of three pieces which span the B0 interaction region between the B0 low beta quadrapoles. A schematic diagram of the B0 beam pipe system is shown in Fig. 14.1.

The center section, which is inside the CDF tracking volume, will be a 1.0625" inside diameter, 0.020" wall beryllium pipe. The maximum outside diameter of the beryllium beam pipe will be 1.438", occurring at the low profile end connections of the pipe. For reference the Be pipe in Run I had an inside diameter of 1.335" and an outside diameter of 1.5". In the current design, the beryllium portion consists of three roll-formed and brazed sections joined by two machined beryllium couplings. The total length of the beryllium is 131". Two inch long stainless steel end pieces will be brazed to the ends of the beryllium to provide a surface for the knife edges of the low profile vacuum flange connections. The resulting Run II beam pipe will have an overall length of 135". A 1.0625" inside diameter pipe of this length is an acceptable aperture in the Tevatron at B0 [1], including anticipated deformations (sag, out of roundness).

Spanning the gap between the beryllium pipe and the low beta quadrapole magnets on each side of the collision hall will be a low mass stainless steel bellows pipe. The exact dimensions of this section are not completely defined, however, the design will be

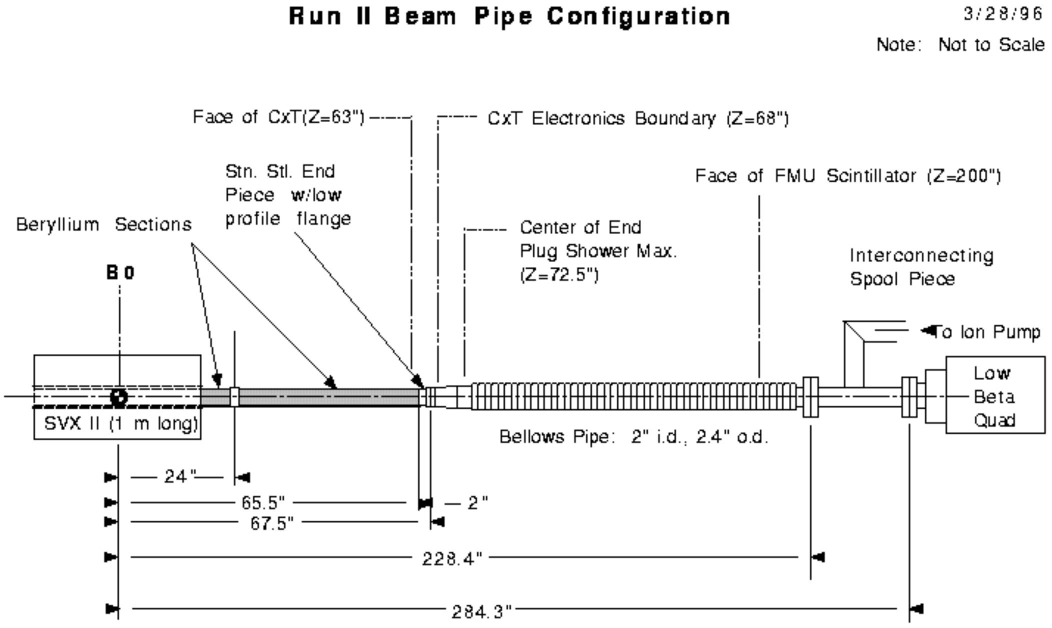

Figure 14.1: CDF beam pipe design for Run II.

quite similar to the Run Ib bellows-pipe. That pipe consisted of a 130" long stainless steel bellows section with end transition pieces and flanges for an overall length of a 133". The ID was 2" and the OD was 2.4". The pitch between each convolution was 0.144", and the wall thickness was 0.006". For Run II the bellows-pipe section would have the same ID and OD, with an overall length of roughly 161".

A low mass flange has been designed for the connection between the Be pipe and the bellows pipe. This flange is smaller in every dimension than the Run Ib flange and is constructed primarily of aluminum rather than stainless steel. For comparison, the Run I flange system consisted of approximately 1.5 pounds of stainless steel, where the Run II low mass flange will be approximately 0.22 pounds of Aluminum. This design, with its smaller cross section, and mass should result in significantly reduced background rates, even compared with the acceptable Run Ib flange. However, before deciding on the final lengths of the Be section, the low mass flange and the bellows-pipe design, we intend to perform a detailed simulation to study possible backgrounds.

Historically, the connecting spool piece from the bellows-pipe to the low beta quads was designed and constructed by the accelerator division. The Run Ib spool piece will not work because the location of the vacuum pipes will be different in Run II, due to the relocation of the forward calorimeter and the forward muon toroids. We will work with the Accelerator Division to ensure that this piece (which could also cause backgrounds in our detector) is low profile and low mass, and is included in our beam-background simulations.

14.3 Tevatron Monitor

The Tevatron Monitor in Run II for CDF consists of two fundamental parts: the luminosity/loss monitor and the beam-position/profile monitor.

Although the luminosity monitor is essential to CDF for Run II, its design is relatively simple and its implementation can be quickly accomplished. In addition, it will use technology that is well understood and similar to the Run I luminosity monitor, with which we have a great deal of experience. Although the instantaneous luminosity will increase from $2.0 \times 10^{31} cm^{-2} sec^{-1}$ in Run I to $2.0 \times 10^{32} cm^{-2} sec^{-1}$ in Run II (chiefly by increasing the number of bunches from 6 to 36), the average luminosity per bunch will not increase dramatically. Therefore the plan for the Run II monitor is similar to that of Run I, and uses arrays of scintillators on both sides of the interaction region. Coincidence timing defines luminosity as particles moving in both directions away from the interaction region, while a separate coincidence defines Tevatron losses as particles moving through the interaction region in the proton or pbar directions.

In Run I, CDF determined the transverse beam position by analyzing the CTC and SVX tracks coming from the vertex. The track data were obtained from the CDF DAQ and analyzed on-line by a dedicated VAX Alpha work-station. Running on this computer, the software of the beam-position monitor was able to provide an ± 5 micron estimate of the beam position in about 5 minutes, sending the information to the Tevatron via ACNET immediately, and saving it in the CDF database for use in the offline data analysis. The same data was analyzed to give estimates of the beam slopes, transverse beam profiles, and interaction region betastars with a slower update frequency (about 2 hours). In Run II, we plan to enhance the monitoring software to accommodate the increase in the number of bunches, and substitute a faster computer if one is available at a reasonable cost. At this time, we forsee no further design changes, but leave open the possibility for further enhancements. One possible enhancement is use of the SVT trigger processor (see section 13.9) to calculate the beam parameters at CDF with a 1 Hz update frequency.

Radiation monitoring for Run II will be very similar to the Run I system for CDF [2] with only minor technical modifications. The system uses PIN diodes and Tevatron Beam Loss Monitors to detect fast losses and set alarms. During Run I the system was used to abort the Tevatron beam cleanly under well defined conditions, avoiding large radiation doses on the SVX detectors.

14.4 Tevatron Shielding

Backgrounds appear in the detector from real collisions at the interaction point and from the single beams (protons or antiprotons) as they pass through the focusing quads. The muon systems are most sensitive to these backgrounds and require shielding in Run II.

14.4.1 Shielding from real collisions

As discussed in Section 10.6, the CMX muon detectors are sensitive to losses from the Tevatron. The mechanism is production of particles at the interaction point followed by secondary interactions of these particles in the far forward parts of the beampipe. Since the the CMX trigger is based on pattern recognition of radial tracks, low energy secondary particles produced in the beampipe can fake a muon track stub. Building on similar work done for Run I [3], we are beginning to model this Run II loss pattern using CDFSIM and GEANT.

Preliminary Monte Carlo work indicates that a shield around the beampipe will be essential in Run II and a conceptual shield attached to the back of the Plug Calorimeter is illustrated in Fig. 14.2. The shield will be mostly made of steel, but additional layers of polyethylene and lead are also being studied. Such a shield has mass near the beampipe and can produce even more radial backgrounds via the interplay between multiple scattering and the CMX radial pointing resolution. Evaluation of thinner shields having larger inside diameters (the outside diameter is constrained by the Plug Calorimeter PMT boxes) will be done before choosing the final design.

From measurements in Run I, we also know that most of the background rate in CMX occurs in the 1/3 of the chambers at highest rapidity. This area will be effectively shielded by the additional 60 centimeters of steel to be added to the toroids for the Intermediate Muon Upgrade (see Sec 10.6. Our Monte Carlo work indicates that this "IMU snout" will be crucial in the control of Run II background rates in the CMX.

14.4.2 Shielding from Proton and Antiproton Beams

The Tevatron also produces substantial losses from the individual proton and antiproton beams as they enter the collision hall from the Tevatron tunnel. In order to understand these losses, a special "proton only" test run was made during Run Ic. At the end of a normal store the $\overline{p}$'s were shifted in time by 1.75μsec, and the detector was triggered on the crossing clock, so the occupancy was due entirely to the circulating current of 1×10^{12} p's moving from west to east through the detector. We explicitly studied the E-775 Forward Muon system (FMU) of chambers located on the front, middle, and rear of the toroids. The results are shown in Figure 14.3, compared to a normal high luminosity 1.8 TeV collider run. The FMU occupancy is the total number of wire hits in all

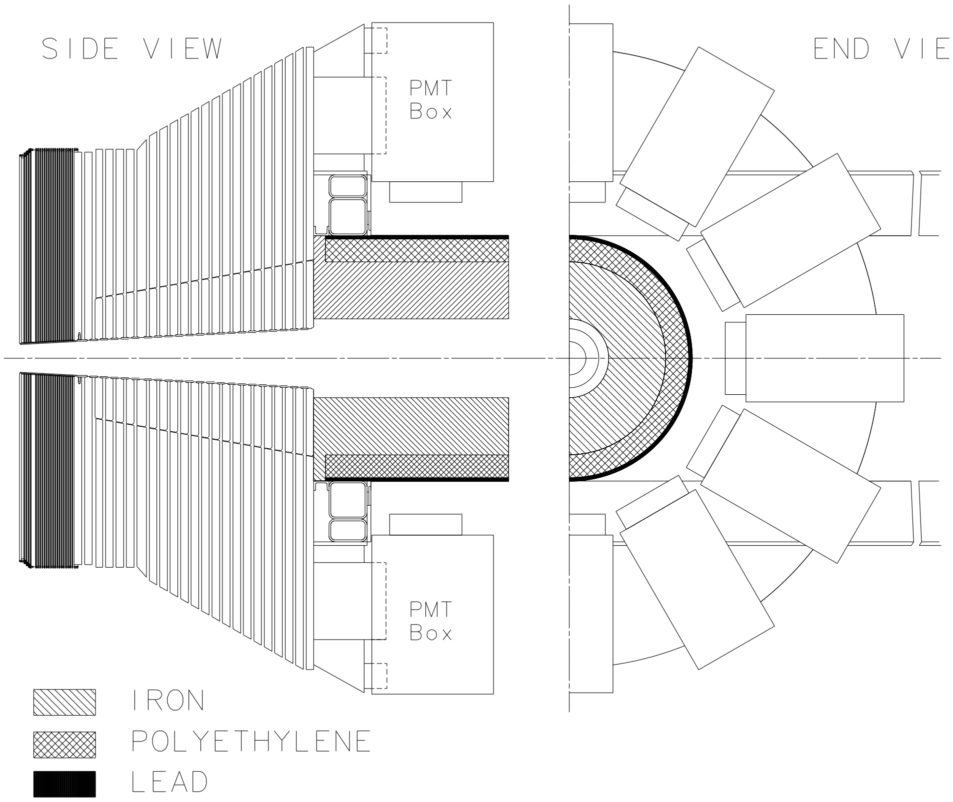

Figure 14.2: Conceptual design of a Tevatron Beampipe Shield for CMX

24 chambers of a given plane per CDF trigger. Note that for the proton only store there were almost no hits anywhere except in the west rear planes, where the occupancy was comparable to that observed under normal colliding beam conditions. This radiation was attenuated by more than a factor of 15 by the 1 meter thick toroid steel between the rear and mid planes. This special run also produced data on the radial and azimuthal pattern of the losses.

Calculations of Tevatron losses using the MARS code have been done[4] for the CDF specific case, begining with the special Run Ic proton only conditions discussed above. By comparing the observed Run I total rate, azimuthal rate, and radial rate to the MARS Monte Carlo, we have gained confidence in the Monte Carlo and can use the Monte Carlo to understand the loss source(s) and optimum shielding arrangements for Run II. As of this writing, MARS models the rear FMU plane very well in both radial and azumuthal distributions, but seems to work less well (off a factor of three and generally too low) for the middle FMU plane.

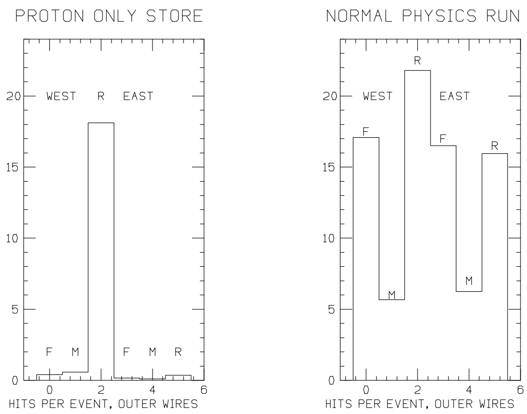

Figure 14.3: FMU Occupancies per CDF trigger

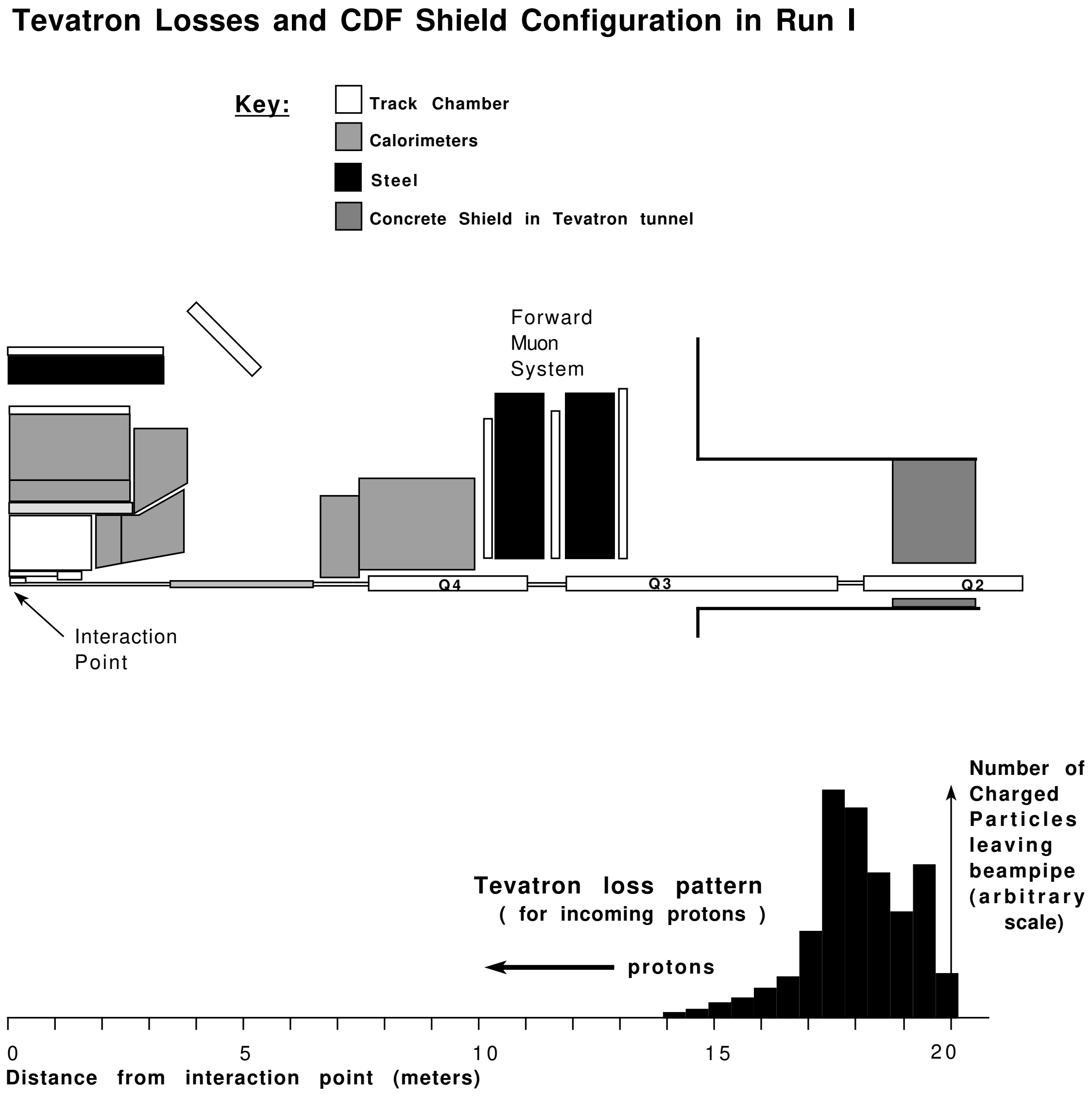

Figure 14.4: Tevatron Beamline losses superposed on the Run I geometry

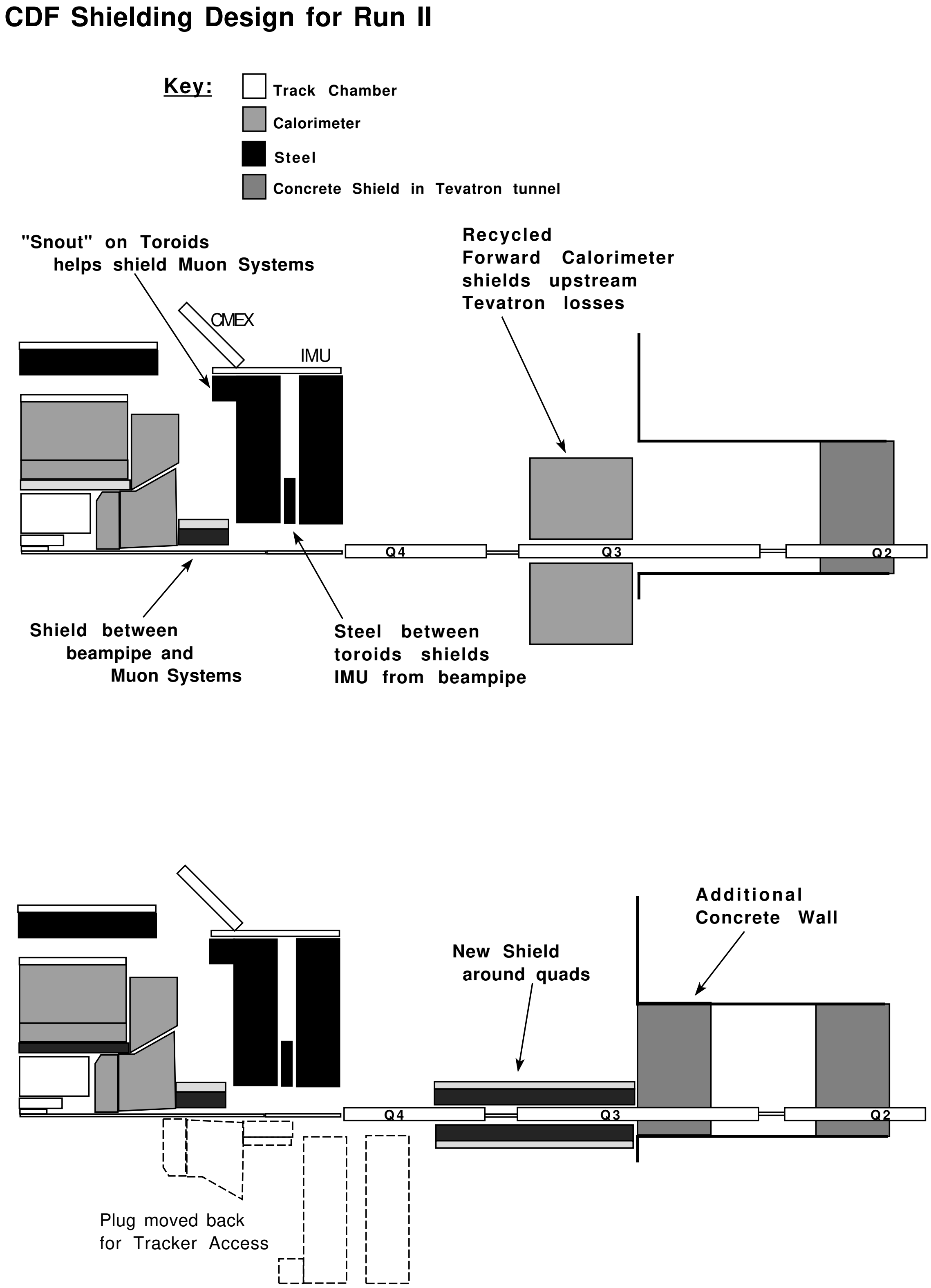

Figure 14.5: Tevatron Beamline shielding scenarios for Run II

Fig. 14.4 shows the CDF configuration during Run I with the MARS calculated loss density in the low beta quadrupoles superimposed. The calculated main loss point is the upstream end of the Q3 quad, but additional losses equal to that shown in the figure come from as far as 35 meters from the interaction point. These far upstream losses are partially shielded by a 6 foot thick concrete wall, but particles still enter the hall through an 18 inch radius hole in the concrete wall around the quads. In Run I this hole was stuffed with bags of polyethylene beads and the MARS code shows that bags of sand with 10% polyethylene would give a clear improvement.

Two possible shielding scenarios for Run II are shown in Fig. 14.5. The upper diagram shows the E-775 Forward Hadron Calorimeter[6] steel repositioned behind the toroids and interleaved with polyethylene in the slots originally occupied by the Forward Hadron proportional chambers. This shield would have a total of 1.37 m of steel and 0.69 cm of polyethylene in 27 layers with a 4 m x 4 m cross section centered on the Tevatron. Thirty layers of 0.5 cm thick lead with a 3 m x 3 m cross section are also available via recycling the E-775 Forward Electromagnetic Calorimeter and could be used in place of some polyethylene.

The lower diagram in Fig. 14.5 shows a shield like that proposed for Dzero[5] with a box around the Q4 / Q3 quads composed of 40 cm of steel, 10 cm of polyethylene, and 4 cm of lead. The lower diagram also shows an additional 6 foot thick concrete wall at the mouth of the tunnel. So far, studies with MARS indicate that the shield box scheme is better (by a factor of 15) than the recycled calorimeter, but these studies have been restricted to the losses seen at the rear of the toroids.

Given the measured Run I attenuation from the 1 meter thick toroid alone, it is possible that no additional shielding will be required for the IMU muon system beyond upgrading to sandbags around the quads. After additional MARS studies of losses in the mid toroid plane and at the outside radius of the toriods where the IMU chambers and scintillators are positioned, we will choose a final shield design based on need, effectiveness, and cost.

14.5 Mixing Facility for Detector Gases

The CDF complex includes a gas mixing system for Argon + Ethane built for Run I. The Argon source is boil-off from a liquid storage tank, while the Ethane source is tube trailers of purchased gas with a tight specification on allowed contaminants. This system allows a mixture of 50% Argon + 50% Ethane with an error on each component below 0.1 % via comparison to gravametric standard gases. The 0.1 % specification was set by the gain stability required for the Run I gas calorimeters. The system has a storage capacity of 17,880 standard cubic feet (SCF) to service a total detector chamber volume of 3,200 SCF. The total operational flow in Run I was 128 Standard Cubic Feet per Hour (SCFH), but the system had a flush rate capacity of 200 SCFH. Each subsystem using this gas added individual amounts of Ethanol or Isopropyl Alcohol, and none of the gas was recycled. As discussed in section 5.5.1, chamber aging effects seen in Run I lead to an extensive examination and cleaning of this gas system and even more cleaning may be required. Specifically we are considering replacing a fraction of the stainless steel piping and cleaning four large storage tanks.

For Run II the gas calorimeters and several drift chambers have been removed, reducing the total chamber volume to 2,300 SCF. The total required flow is reduced to 85 SCFH with most of this flow (60 SCFH) used by the muon systems. This reduced flow will simplify operations by increasing the mean time between mixes by 50%.

The new COT tracker will require 25 SCFH but must have CF_4 added at the 5-15% level (see section 5.5.2). The plan is to use the mixed 50% Argon + 50% Ethane as input to a separate new mixing system for the COT as shown in Fig. 14.6, then adding CF_4 and Argon to effectively replace a percentage of the Ethane. The COT system may include recirculation of the gas due to the cost of CF_4. The muon systems do not require CF_4, and they cannot tolerate gas recirculation due to outgassing materials used in their construction.

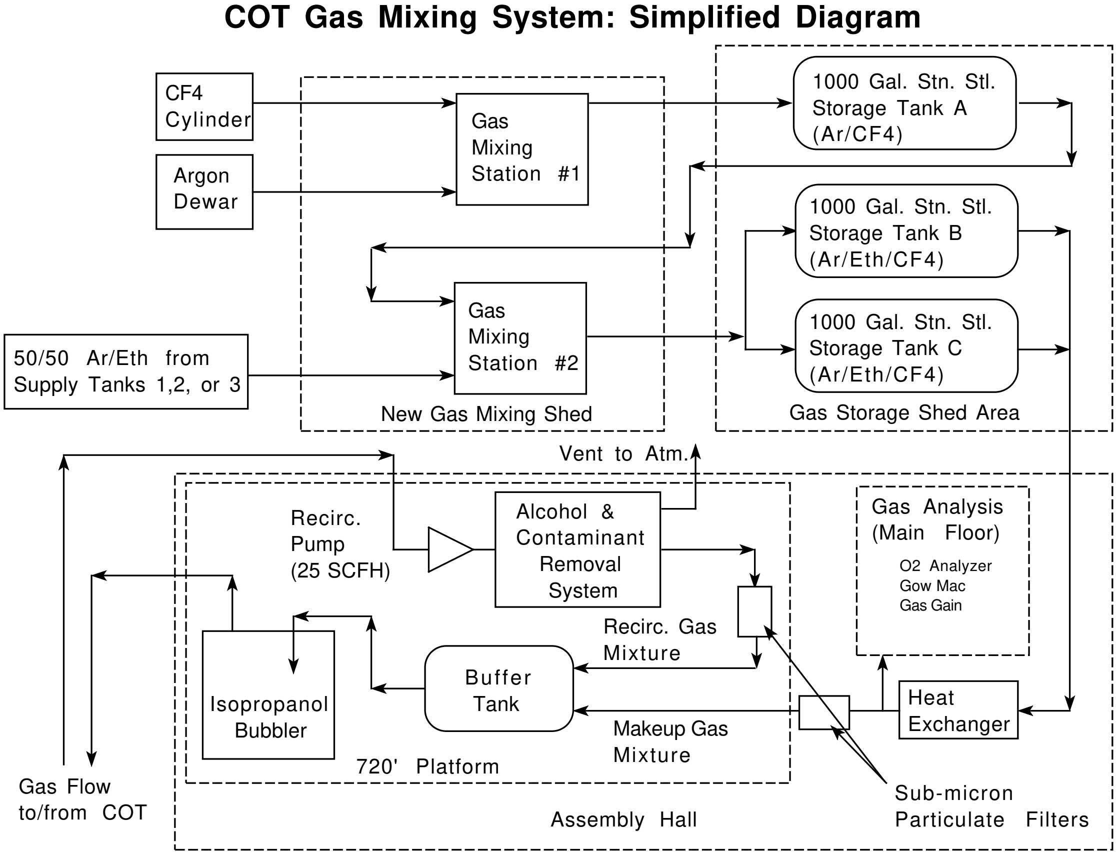

Figure 14.6: CF4 Gas Mixing System for Run II.

14.6 Heating, Ventilation, and Air Conditioning

14.6.1 Overview

The CDF upgrade for Run II forces changes to the Heating, Ventilation, and Air Conditioning (HVAC) plant in the CDF Assembly Hall and the B0 Collision Hall. The heat loads in the Collision Hall change because of additional electronics for new detector components and because of repositioned electronics systems for existing detectors. The loads are generally more difficult to reach with air cooling because they are boxed inside the muon upgrades. The heat loads in the Assembly Hall counting rooms will also change. A large portion of the air cooled load in the first floor counting room will not exist in Run II, and experience in Run I shows that other counting room loads are less difficult to cool than envisioned in the 1981 design.

Additional changes to the HVAC system are driven by operational and maintenance concerns for Run II. Some of the existing equipment is very old and at the end of its useful life. Other equipment has proven difficult to maintain and new options are now available. For completeness the entire HVAC plan is described here, even though some parts fall more naturally in the equipment budget (e.g. new air-water heat exchangers for new upgrade electronics crates), while other parts will be covered within the operating budget (e.g. replacement of the existing unmaintainable humidifiers).

With input from CDF on environmental specifications and estimates of the electronics heat loads in Run II, The Fermilab Facility Engineering Services Section has completed a Criteria Review Set[7] This is a design at the 30% level, equivalent to Title I and with project contingencies understood at the 25% level. The elements of this design are described in the next three sections.

14.6.2 Collision Hall Specification and Design

The environmental specifications for the Collision Hall during Run II are detailed in Table 14.1 and compared to the observed conditions in Run I. Table 14.2 shows the expected heat loads and Criteria Review Set design cooling sources for the Collision Hall. Three separate balance sheets are shown for the airborne heat load, the chilled water heat load, and the low conductivity water (LCW) heat load. Actual numbers are shown for Run I during steady state operations and for Run I during repair access periods. Estimates are shown for Run II.

During Run I, the heat load in the Collision Hall was distributed among four main sources: the electronics crates, a standard building load of 3.5 kW per 200 sq. ft., the power load for four large fan coil cooling units in the hall, and the forward muon toroid coils. Cooling in Run I was supplied by two outside air handlers (AC-2 and AC-3), the four fan coil units, and LCW to the toroid coils. The cooling capacity was adequate during collider operations but insufficient during repair periods, causing degraded data quality following repair periods.

For Run II we have done a bottoms up calculation of the electronics heat loads and find that all the new VME crates should generate less than 0.6 kW each. For the HVAC design, we have used 1.0 kW per crate to insure adequate headroom. The real difficulty in Run II is caused by the toroids, which are moved closer to the interaction point and will block airflow to the crates. Similar airflow restrictions already existed in Run I due to the Central Muon Upgrade walls and the Central Muon Extension stands. The Run II toroid position just provides the final cork to the bottle.

The plan is to split detector cooling in the Collision Hall between air cooling and direct chilled water cooling via air-water heat exchangers associated with every electronics crate. The new use of direct cooling accommodates the severe space constraints, increases cooling efficiency, and improves temperature control in local areas. The direct cooling chilled water system will run in a copper pipe header with festoons to moveable sections of the detector. A similar alternate header in the Assembly Hall will supply chilled water to the detector during commissioning.

In addition, the existing fan-coil units in the Collision Hall will be removed, eliminating 25% of the Run I heat load. Air cooling in Run II will be entirely supplied by upgraded replacements of the existing outdoor air handlers, AC-2 and AC-3. Small local fans inside the Collision Hall will assist in maintaining stable temperature stratification patterns. The toroid LCW system will also be upgraded by switching from pond water cooling (which operates with 16 - 41°C water depending on the season) to a constant temperature chilled system maintained at 18°C. This follows the scheme employed successfully at Dzero, will further remove airborne heat load from the collision hall, and will contribute to improved temperature stability. Air temperature within the collision hall will be lowered by 2°C from the present conditions. Beam-off repair accesses into the collision hall will not require adjustment of the cooling system, resulting in temperature stability during all data taking periods.

14.6.3 First Floor Counting Room Specification and Design

The specification for the Counting Rooms is identical to the Collision Hall except the pressure requirement is dropped and we expect only modest stratification between the floor and the ceiling. Table 14.3 shows the expected heat loads and Criteria Review Set design cooling sources for the First Floor Counting Room. Actual values seen in Run I are also shown for comparison.

The heat load in the first floor counting room will be reduced by about 25% in Run II. Twenty racks of air cooled electronics will be removed and the existing water cooled Fastbus crates will be converted to water cooled VME crates. A bottoms up estimate of the heat loads in each VME crate does not yet exist, so an estimate has been done with an administrative limit of 2.5 kW per crate imposed on the electronics design. We expect to meet this administrative limit with ease on most crates, allowing flexibility for some crates to push beyond the limit to the "CDF specific VME crate" power limit of 6 kW.

Air cooling for this counting room will continue to be supplied by two Liebert AC units in the room and by cooling from the building AC unit, AC-1. AC-1's capacity will be beefed up by eliminating a kitchen area and two restrooms from its zone, thus devoting AC-1 to the single purpose of electronics cooling with most of the additional cooling diverted to the second floor.

Variable	Run I observation	Run II specification	Notes (below)
Temperature Stability (°C)	± 3	± 1	(1)
Temperature range, top to bottom of hall (°C)	18-29	16-27	(2)
Relative humidity	40-60%	40-60%	(3)
Delta pressure relative to outside (inches of water)	0.014	0.050	(4)

1. During Run I, the temperature stability in a given location reached this level after the hall had been closed for a week following an access. Even larger temperature swings occurred during an access because part of the cooling had to be turned off for hearing protection. The Run II specification is set by the $(0.4 \pm 0.6)\%$ gain per degree Centigrade seen in the central EM calorimeter phototubes. This temperature variation has a direct impact on precision measurements with electrons, e.g. the W mass.
2. This is the same range but with a reduced maximum intended to increase electronics component lifetime.
3. The range observed in Run I is that during stable operation. However, the system was notoriously unstable and swings from 20% to 80% relative humidity were observed during frequent equipment failures. This has a direct influence on some trigger rates due to increased sporadic electrical breakdown around phototube photocathodes in the central calorimeters.
4. In Run I this specification was set by the need to keep fragile windows on gas calorimeters from popping their seals. With the replacement of the gas calorimetry by scintillator, the specification can be relaxed to the more modest needs of the central tracker output bubblers.

Table 14.1: Environmental Specification for the Collision Hall

14.6.4 Second Floor Trigger & Control Room Design

Table 14.4 shows the expected heat loads and Criteria Review Set design cooling sources for the Second Floor Trigger and Control Rooms. Actual values seen in Run I are also shown for comparison.

Tests of the cooling system for the second floor rooms following Run I indicated that nearly all the Run I heat load was removed by the Fastbus chilled water system. These Fastbus crates were different from those in the first floor counting room because the power supplies were also water cooled. While the first floor Fastbus crates were operated with loads at the 2.5 kW limit, on the second floor the heat loads were much smaller. Most of the crates generated less than 1.0 kW, and five crates had essentially zero heat load. Meanwhile the Fastbus chilled water system supplied water to an air/ water heat exchanger for each crate capable of cooling 2.5 kW per crate. Since the racks were open to the room, the second floor Fastbus crates acted as a net cooling source.

In Run II the Fastbus crates will be converted to VME crates and these crates will be isolated from the room air. A bottoms up estimate of the heat loads in each crate has been done and we expect 0.86 kW per crate. For the HVAC design we have used 1.5 kW per crate as the water cooled load, insuring adequate headroom and using the same air/water heat exchangers planned for the first floor crates. The two Liebert AC units on the second floor will be removed to increase floor space by 50 square feet in a cramped area. Air from AC-1 will easily handle the remaining load on the second floor.

14.6.5 Other General HVAC Issues

To accommodate the changes described above another air cooled chiller will be installed outdoors and connected to the main chilled water supply loop. This will increase the total cooling capacity to 2800 kW, with 2 chillers @ 665 kW and 3 other chillers @ 490 kW each. Total chiller capacity is sized to allow any one unit out of service for repairs without downtime to the experiment.

The entire chilled water system plant will be converted to 40% propylene glycol to permit year round chiller operations outdoors, eliminate persistent coil freezing problems, and allow improved heat transfer to AC-2 and AC-3 through elimination of the present glycol heat exchanger and pump arrangement. Continuous operation will eliminate the seasonal turn-on and turn-off cycles which plagued the chilled water system during Run I, causing downtime due to cool-

Collision Hall Air	**Run I (kW) Operations**	**Run I (kW) in Access**	**Run II (kW) Ops=Access**
Heat to Air Load			
Air cooled electronics crates	98	98	7
Power supplies for air cooled crates	17	17	1
Crate muffin fans	24	24	1
Detector electronics outside crates	1	1	23
Plug PMTs (24 @ 100W in heating mode)	did not exist	did not exist	3
Silicon Detector chiller	1	1	4
Three Air loads from Water Cooled devices (assumes 10% inefficiency)			
Water cooled VME Crates	did not exist	did not exist	8
Power Supplies for crates	did not exist	did not exist	2
Air recirculation blowers in crates	did not exist	did not exist	1
400 Hz transformers	3	3	3
Building Load	87	87	87
Controls for Pressure, Relative Hum.	35	35	35
4 Fan Coil Units	90	off	removed
Toroid coils (LCW cooled)	24	off	off
Toroid jumper cables	5	off	off
Solenoid leads (LCW cooled)	7	7	0
Heat to air total:	392	273	175
Air Cooling			
4 Fan coil units	560	0	removed
Building Air Handler, AC-2	128	128	190
Building Air Handler, AC-3	128	128	190
Total air capacity:	816	256	380

Collision Hall Chilled Water	**Run I (kW) Operations**	**Run I (kW) in Access**	**Run II (kW) Ops=Access**
Heat to chilled water load (assume 90% efficiency)			
76 VME crates @ 1 kW each	did not exist	did not exist	68
Power Supplies (10% of 2 kW/crate)	did not exist	did not exist	14
Recirculation Blowers (10% of 430 W/crate)	did not exist	did not exist	3
Plug PMTs (24 @ 100 W in cooling mode)	did not exist	did not exist	3
Chilled water total:	0	0	88
Chilled Water Cooling Capacity	0	0	146

Collision Hall LCW	**Run I (kW) Operations**	**Run I (kW) in Access**	**Run II (kW) Ops=Access**
Heat to LCW load (80% efficiency in Run I, 100% in Run II)			
Toroid coils (@ 200 v, 600 amps)	96	off	off
Solenoid leads (@ 8 v, 4650 amps)	30	30	37
LCW total:	126	30	37
LCW Cooling Capacity	500	500	236

Table 14.2: Collision Hall Heat Loads and Cooling Capacities

First Floor Counting Room Air	**Run I (kW)**	**Run II (kW)**
Heat to Air Load		
Air cooled custom "MX" racks	41	removed
NIM and CAMAC crates @ 0.7 kW each	42	53
Gas Calorimeter High Voltage Crates	8	0
Calorimeter PMT High Voltage Supplies	4	8
Other High Voltage Supplies	19	19
5 Air loads from Water Cooled devices:		
Fastbus water cooled crates and PS	33	removed
(30% water cooling inefficiency in Run II)		
Water cooled VME Crates (10U version)	did not exist	9
VME Power Supplies (10U version)	did not exist	1
VME crates (6U version)	did not exist	1
VME Power Supplies (6U version)	did not exist	0
(10% water cooling inefficiency in Run II)		
Fans and miscellaneous equipment	3	3
Transformers	11	11
1st Floor Kitchen and Restroom load	11	removed
Building Load	16	16
Heat to Air total:	188	121
Air Cooling		
2 Liebert AC units in the room	182	182
Part of Building AC unit, AC-1	28	10
Total air capacity:	210	192

First Floor Counting Room Chilled Water	**Run I (kW)**	**Run II (kW)**
Heat to Chilled Water Load		
39 Fastbus crates and PS @ 2.5 kW each	65	removed
(Run I system was 70% efficient)		
42 (10U) VME crates @ 2.2 kW each	did not exist	83
42 VME Power Supplies @ 0.3 kW	did not exist	11
9 (6U) VME crates @ 1.1 kW each	did not exist	9
9 VME power supplies @ 0.1 kW each	did not exist	1
(Run II system aims at 90% efficiency)		
Chilled Water Total:	65	104
Chilled Water Cooling Capacity	98	173

Table 14.3: First Floor Counting Room Heat Loads and Cooling Capacities

Second Floor Trigger and Control Room Air	**Run I (kW)**	**Run II (kW)**
Heat to Air Load		
NIM and CAMAC crates @ 0.7 kW each	13	6
Trigger Room workstations @ 1.2 kW	1	1
Trigger Room monitors @ 0.25 kW	1	1
Control Room workstations @ 1.2 kW	6	6
Control Room monitors @ 0.25 kW	3	3
Miscellaneous PCs @ 0.6 kW	6	6
Four Air loads from Water Cooled devices:		
Fastbus water cooled crates	-26	removed
5 "empty" Fastbus water cooled crates	-10	removed
(Fastbus crates provided cooling in Run I)		
VME Crates (10U version)	did not exist	0
VME Power Supplies	did not exist	0
400 Hz transformer	1	1
Building Load	16	16
Heat to Air total:	11	40
Air Cooling Capacity		
Trigger Room Liebert AC unit	61	removed
Control Room Liebert AC unit	61	removed
Part of Building AC unit (AC-1)	14	60
Total air capacity:	136	60

Second Floor Trigger and Control Room Chilled Water	**Run I (kW)**	**Run II (kW)**
Heat to Chilled Water Load		
26 Fastbus water cooled crates @ 2.5 kW	65	removed
5 "empty" Fastbus water cooled crates	13	removed
(Includes Water cooled power supplies)		
42 (10U) VME crates @ 1.5 kW each	did not exist	63
42 VME Power Supplies @ 0.3 kW each	did not exist	13
Chilled Water Total:	78	76
Chilled Water Cooling Capacity	98	126

Table 14.4: Second Floor Trigger and Control Room Heat Loads and Cooling Capacities

ing trips in electronics racks.

The existing Fastbus cooling water pump system located in the first floor counting room will be replaced with a larger VME cooling water pump and heat exhanger system housed in the Assembly Hall (west mezzanine at the 725' level). The VME cooling water system will be a clean distilled water system, separated from the general chilled water system by a plate and frame water-water heat exchanger, and connected to both the collision hall and the counting rooms. The new VME system will run in new copper pipes since the existing Fastbus system in black iron pipes is fouled and has reduced flow. The water-water heat exchanger separation will allow the VME cooling water to be maintained without glycol for electronics protection and permit the outside air cooled chiller change to propylene glycol.

In Run I AC-2 and AC-3 each had "preheat" coils upstream of individual humidifiers in turn located upstream of the mixing point for the Collision Hall input air duct. One consequence was a ± 2 microradian low beta quad motion observed in Run Ib during periods when the two component AC system became untuned and developed $\pm 3°$C temperature swings with a 20 minute cycle time. For Run II the "preheat" coils will be replaced by a single "reheat" coil in the duct following mixing of air from the two AC units. A single Collision Hall humidifier steam dispersion panel will be downstream of the "reheat" coil with steam supplied by upgraded electric units insensitive to water conductivity changes. This mixing change should produce better humidity and temperature control. Additional HVAC monitoring will be installed to give information on temperatures at sensitive electronics crate locations and to provide some redundant monitoring for the controls system.

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