CHAPTER 13

CONTROLS

13.1 General Requirements and Architecture

The requirements of the Tevatron I control system go beyond those customary in many accelerators because of the long cycle time for antiproton collection. The system must monitor and control the repetitive sequence of antiproton production, transport, injection, debunching, cooling, and extracting over this entire cycle without significant loss of antiprotons. This will require extensive automatic control and feedback.

In addition, the Tevatron I control system must interface with the existing Energy Saver control system at several stages of the process. Their functions are so intertwined that it is efficient to build the Tevatron I control system as an extension of the Energy Saver control architecture and the description given in this chapter will follow that architecture.

In this note unless otherwise stated, a cycle means a standard Tevatron I 2-sec Debuncher cycle.

13.2 Computer Configuration

The complete Tevatron computer configuration is shown in Fig. 13-1. Four PDP-11's will be used for the Tevatron I control system. Three of these will run the three control consoles, and one will be the $\bar{p}$ front end called "DEC-P", a PDP 11/44. There are 3 Programmed Control Links (PCL) in the full system. As indicated, 5 console PDP-11/34's communicate directly with the Linac, Booster and DEC-P front ends through a PCL. Of course, the number of consoles available for Tev I operation is not fixed since, in principle, any console in the system can communicate with Tev I devices.

A CAMAC System similar to the Energy Saver system will be used. This system adheres to the IEEE 583 standard. Most modules will be those types developed by the controls group, but commercially available CAMAC modules will also be used for some applications.

Fifteen-Hz data rates are supported in the standard way, i.e. using the console-front end combination. Success with the Energy Saver is proof that this approach will work. CAMAC-190 modules, or other modules containing local buffer memories mandate the need for block-transfer facilities.

Each console supports the following devices: a color monitor, a storage scope, a color-graphics monitor, an alarm-message display monitor, a keyboard, a track ball, and a touch panel.

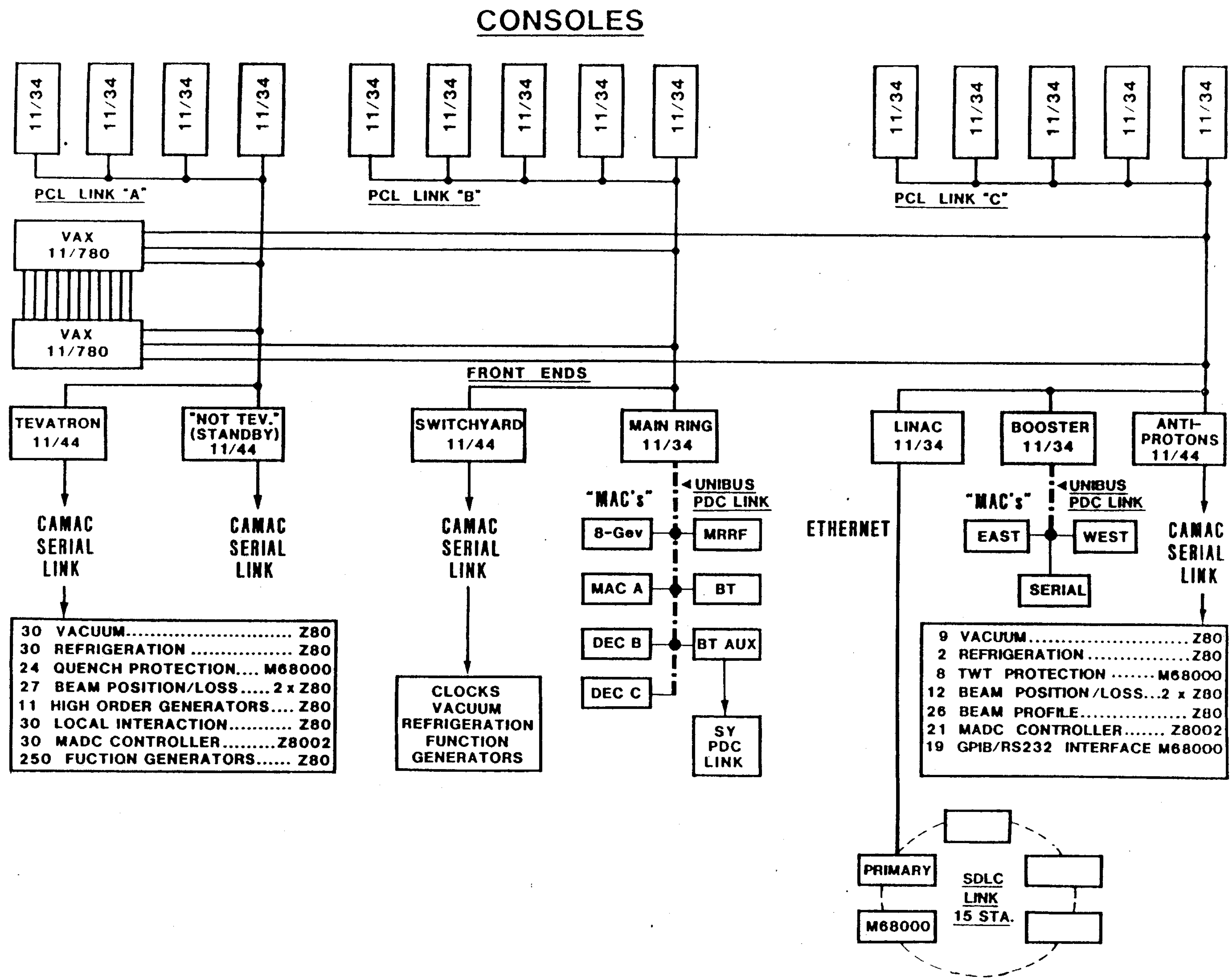
CONSOLES
11/34
PCL LINK "A"
PCL LINK "B"
PCL LINK "C"
VAX 11/780
VAX 11/780
FRONT ENDS
TEVATRON 11/44
"NOT TEV." (STANDBY) 11/44
SWITCHYARD 11/44
MAIN RING 11/34
LINAC 11/34
BOOSTER 11/34
ANTI-PROTONS 11/44
CAMAC SERIAL LINK
UNIBUS PDC LINK
"MAC's"
8-Gev
MRRF
MAC A
BT
DEC B
BT AUX
DEC C
SY PDC LINK
ETHERNET
EAST
WEST
SERIAL
30 VACUUM.......................... Z80
30 REFRIGERATION Z80
24 QUENCH PROTECTION.... M68000
27 BEAM POSITION/LOSS......2 x Z80
11 HIGH ORDER GENERATORS.... Z80
30 LOCAL INTERACTION.......... Z80
30 MADC CONTROLLER..........Z8002
250 FUCTION GENERATORS...... Z80
CLOCKS
VACUUM
REFRIGERATION
FUNCTION GENERATORS
9 VACUUM........................Z80
2 REFRIGERATION Z80
8 TWT PROTECTION M68000
12 BEAM POSITION/LOSS...2 x Z80
26 BEAM PROFILE.................Z80
21 MADC CONTROLLER....... Z8002
19 GPIB/RS232 INTERFACE M68000
PRIMARY
M68000
SDLC LINK 15 STA.

Figure 13-1

Devices in the Main Ring will be controlled from the "old" system. This includes F17 extraction. By late fall 1984, the Main Ring (MR) system will be accessible from a standard console. One will therefore be able to combine parameter pages and displays for MR parameters and Tevatron I devices. No problems are expected from having MR and Tevatron I devices related to extraction on two different PCL links.

13.3 Software

The required Tev I software effort falls into several categories:

1. Modification of existing microprocessor programs: CAMAC-170-Z80 (vacuum), CAMAC 080-Z80 (refrigerator for stochastic cooling), slow loop controls for stochastic cooling and RF, and Beam Position Monitors (BPM) similar to those in the ED.

2. New microprocessor programs: e.g. M68000 GPIB/RS-232 interface, M68000 TWT protection monitors.

3. DEC-Programs. The software philosophy followed is to keep the front-end programs in DEC-T, DEC-S, and DEC-P identical. Changes required to drive special devices are incorporated into all the front-end programs.

4. Applications programs. Some of these are adaptations of existing Energy Doubler (ED) programs; others will be specially written for Tev I.

13.4 Communications

The $\bar{p}$ link system is shown schematically in Fig. 13-2. Separate networks are required for DEC-P and consoles. Twelve 1/2-in. Heliax 50-ohm cables run from the Main Control Room to Service Bldg 10. From there six 3/8-in. Heliax 50-ohm cables branch to the Tevatron I locations: buildings 30, 50, target building, F23 and F27. Two 1/2-in. Heliax 50-ohm cables run from the Main Control Room to 30-2 and to TB-1 to support mini-consoles. Also two 3/8-in. Heliax 50-ohm cables run from service building 10 to 50-2 to support a mini-console in building 50. A mini-console is a semiportable 1 or 2 rack version of the standard 3 rack console.

An additional location is the power-supply building next to the Booster, called the Booster Stair Enclosure. Equipment there will tie in through the Booster front-end computer. It is assumed that Tevatron I devices in the Booster to Debuncher-line (AP-4) requiring equipment in the Booster West Gallery will be installed in existing CAMAC crates.

Buildings 10, 30, and 50 are each 216 ft long; there will be 3 control points in each of them. The target building is 144 ft long; two control nodes are planned there. In addition are F23, F27, and the Booster Stair

LINK SYSTEM - P BAR

RF LINKS: PIOX, PIOR, BTR, & TCLK (4)
TWO CONSOLES AT BLDG 10 (4)

MISC.: BEAM PERMIT LOOP (HIGH LEVEL D/C) SPARE

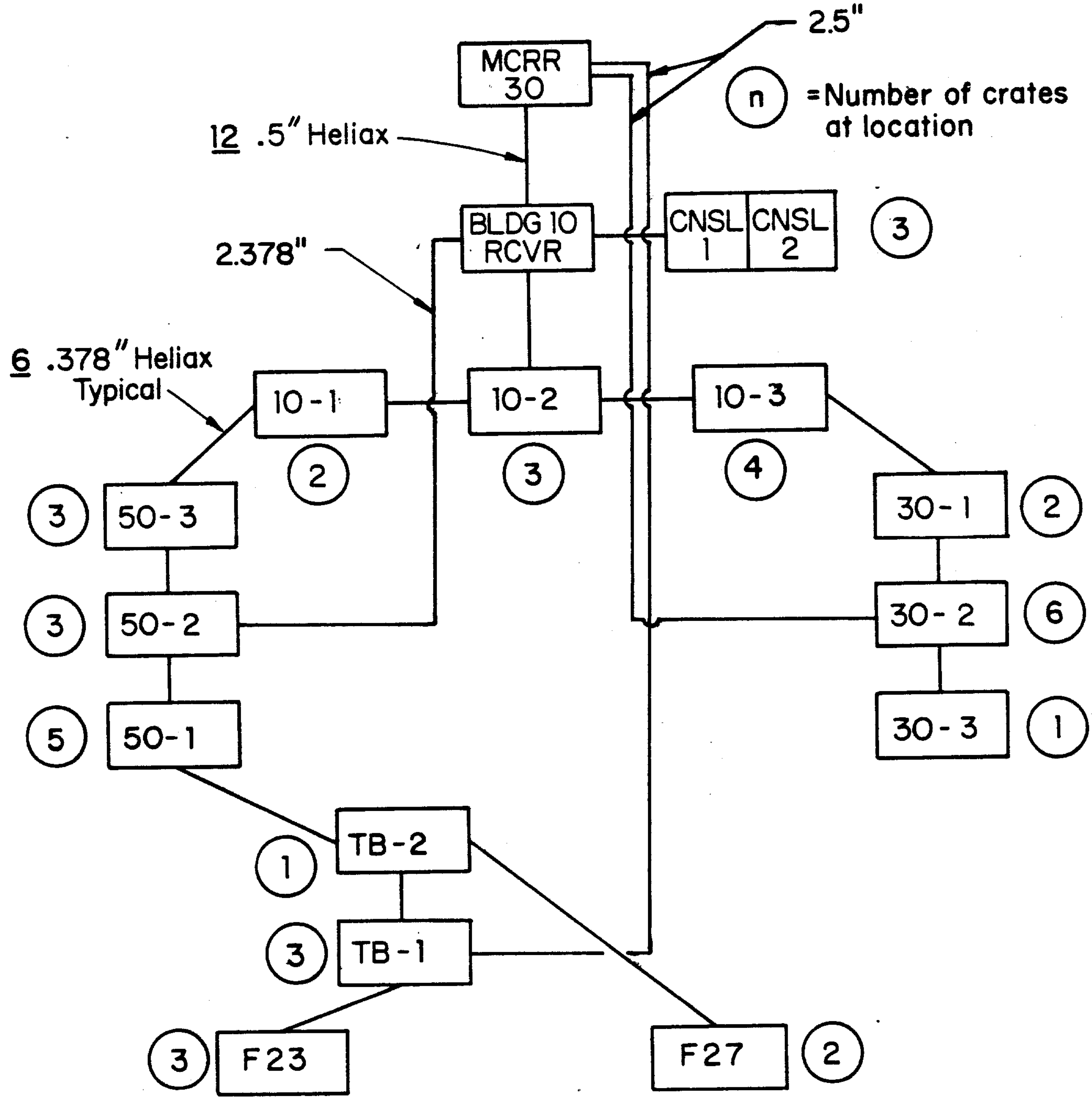

Figure 13-2

Enclosure, making a total of 14 nodes. The 13 repeaters that tie in through DEC-P are shown in fig. 13-2. In the same figure is shown the approximate number of crates controlled at each point. This is still being refined, as is the exact location within the buildings of the control clusters.

13.5 Magnet Controls

None of the main magnet power supplies require microprocessor control or function generators. Magnet protection (thermal interlocks, etc.) is read out in status bits. For magnet elements in series, the protective devices will be hardwired to the power supply for those elements. This will require several hardwire loops around the rings. Reversing ring polarities will be done manually by reversing cables of all appropriate elements.

The five main buses will be driven by 5 supplies, 3 delivering 1200 amps, 2 delivering 300 amps. Each will be regulated to 16-bit accuracy. Each supply will have an internal, commercially availabe 0-10 volt DAC (Analogic). 16 parallel lines will go from the CAMAC crate to opto-isolators at the power supply. One CAMAC-182 and one CAMAC-119 provide the 16 drivers plus the necessary status and control bits. Each supply will contain a commercial Racal-Dana DVM connected to the control system using a CAMAC-488 GPIB interface. In addition, measurement of the current ripple is needed. An internal comparator in each power supply will generate a difference signal which will be sent to a 12-bit MADC/190 channel.

Of the 78 DC power supplies (mostly for beam lines) requiring 14 bit control, 75 will use CAMAC-119's. A 16-bit DAC is built into a CAMAC-119. In the three 300-A Debuncher quad supplies, the DAC will be in the power supply cabinet. The 14-bit readback is accomplished with a new system that places the 14 bit ADC locally in the power supply and reads it back serially using a 1553 bus.

Correction elements are bipolar, 11 bits plus sign. They use a CAMAC-053 (quad unit) and standard MADC/190 channel.

Shunts need 12-bit accuracy but do not require control or status bits. Shunts will be controlled by a new DAC system, a CAMAC-054 designed for this application. The 054 is a single-width CAMAC module having 6 channels.

Ramped supplies and kickers require 14-bit accuracy and will use a CAMAC-165, a new module which also has applications in the switchyard.

13.6 Transfer Marker Timing System (XMR)

The main purpose of the XMR system is to synchronize and distribute timing pulses to pulsed septa, kickers, lithium lens, C-magnet, and SWIC scanners. These devices are used in ring-to-ring transfers of protons and antiprotons.

Timing of pulsed devices requires two programmable timers: (1) a programmable predet that counts revolutions, (2) a programmable 15-bit delay to set the time relative to the desired revolution to 1 ns resolution (using Lecroy 4222). The gap in the beam is used to trigger the revolution counter. This has to be done very stably (to 1 ns). It is necessary to measure and readback these time delays. This can be done with a commercial (Lecroy 4208) TDC with 1 ns resolution.

The XMR system consists of the following 4 sub-systems:

XMR#1 Transfers from Main Ring to Debuncher or Accumulator

A) Standard antiproton production
(MR to P-line to Target to I-line to D)
B) Proton forward injection to Debuncher
(MR to P-line to I-line to D)
C) Proton reverse injection to Accumulator
(MR to P-line to E-line to A)

XMR#2 Transfers between Debuncher and Accumulator

A) Antiprotons from Debuncher to Accumulator
(D to T-line to A)
B) Protons from Debuncher to Accumulator
(D to T-line to A)
C) Protons from Accumulator to Debuncher
(A to T-line to D)

XMR#3 Antiproton extraction
(A to E-line to P-line to MR)

XMR#4 Protons from Booster to Debuncher

XMR1 is the most complicated system. A clock is phase locked to the Main Ring revolution frequency (47713 Hz) and operated at the 209th harmonic (9.972 MHz). The signal is distributed with standard repeater hardware. An event to signal extraction time would be encoded on to this clock, and be decoded at all other repeater locations by standard CAMAC-177 octal timers. 177 modules provide 1 μsec resolution, while Lecroy 4222 modules provide 1 nsec resolution. Lecroy 4222 modules will be started from a 177 module trigger.

XMR#2 will use a coincidence signal generated by a pulse from a Tevatron clock driven 177 module, and the signal from either the gap in the Debuncher beam or the gap in the Accumulator beam. The coincidence signal will be distributed around the Debuncher and Accumulator rings on a dedicated cable. Devices requiring high resolution (better than 1 μsec) will use signals from Lecroy 4222 modules delayed from the coincidence signal. Other devices will use Tevatron clock driven 177 module pulses.

XMR#3 and XMR#4 use similar hardware but are not yet completely defined.

13.7 Vacuum Controls

At each of 7 locations is a CAMAC-170 module and a Controls Interface Adapter (CIA). An eighth unit will be purchased and can serve as a spare or be hooked up to the control system and used in a vacuum development laboratory. Locations are 2 each in service buildings 10, 30, 50, (one for the D and one for the A), and one in the target building. Sector valve control is done by a hard wire system. The devices controlled and/or monitored by these 7 CIA crates are: 133 ion pumps, 21 Pirani gauges, 21 cold-cathode gauges, 26 ionization gauges, 16 sector valves, and 134 sublimation pumps.

Additional vacuum systems to be controlled are roughing (23 each roughing pumps, turbo pumps and roughing valves), Accumulator bake-out and Accumulator residual gas analysis (3 units).

13.8 RF Control Systems

The location of equipment to be controlled or monitored is in buildings 10 and 50. There are 2 main systems in the Debuncher: (1) the 53 MHz system which uses inversion of the drive phase and counter phasing to reduce voltage to a low value, and (2) the gap preserving system. In the Accumulator are (1) a stacking system, h=10, 6.289 MHz, (2) an unstacking system and (3) a 53 MHz rebunching system.

The controls use standard modules. Local microprocessors will be used for slow loop control. A precision frequency meter will require a GPIB interface.

There are additional RF controls needed for the MR $\bar{p}$ production cycle:

1. Main Ring phase lock to Booster for single batch acceleration
2. Low level RF system for single batch acceleration and bunch rotation

There are controls needed for MR and ED p and $\bar{p}$ acceleration:

1. 53 MHz RF system

2. 2.5 MHz RF system including second harmonic

3. Phase locking of the Main Ring to the Energy Saver

4. Colliding region position control.

All of the above controls are being implemented with Standard Tevatron Controls hardware.

13.9 Stochastic Cooling Controls and Monitoring

Stochastic Cooling Controls and Monitoring are centralized in building 30. For control and monitoring purposes the following classification may be useful: (1) beam pickup electrodes, (2) low level electronics (including preamplifiers), (3) medium level electronics (including gain and phase correction, circuits, filters, etc), (4) high level electronics (including TWT), (5) kicker electrodes.

1. TWT power supplies. There are 62 travelling wave tube power supplies distributed as follows: A20 tunnel or stub room, 3; A30 tunnel or stub room, 18; A30 service building, 41. Each supply requires the following monitoring and controls:

    1. 5 status bits: timeout state off/on, standby state off/on, beam on/off, local/remote, fault.

    2. Analog helix voltage remote monitor output, 1 mV per volt. 1% accuracy implies 7 bits + sign is adequate.

    3. 3 control bits: AC power on/off, fault reset, beam voltage on/off.

    4. DAC to control the helix voltage.

    5. Turn on permit signal.

2. TWT protection monitor. All 33 systems are located in Service building 30. Each monitor measures forward and reverse TWT power as well as power delivered to the kickers. Each monitor will contain an M68000 microprocessor. The output from the microprocessor to the control system will be values of powers and status bits.

3. Trombones. There are 74 located as follows: 17 of these are in service building 30 and the remaining 57 are in the tunnel or stub rooms: A60, 11; A10, 10; A20, 8; A30, 28. Trombones are delay lines whose length is changed by a stepping motor actuator. Readback of the position can be done either with a linear pot with a local voltage reference or by a shaft position encoder.

4. Microwave Amplifier power supply regulators. There are a total of 96. 44 of them are in service building 30; the remaining 52 are in the tunnel or adjoining stub rooms distributed as follows: A60, 23; A10, 26; A20, 3. A raw power source feeds a tightly regulated supply to a microwave amplifier. The regulator requires a single control signal for on/off and provides 5 bits of status readback on the microwave amplifier.

5. PIN diode switch. There are 9 distributed as follows: A60 tunnel or stub room, 2; A10 tunnel or stub room, 4; service building 30, 3. The switch is a 1 bit device to pass or block a single RF signal. The input is TTL compatible; switch is "on" at logic "0" and "off" at logic "1". The switch does not provide any status information. Power requirements are 5 volts, 60 mamp and -5 volts, 20 mamp.

6. PIN diode attenuators. There are 13 distributed as follows: A60, 5; A10, 4; service building 30, 4. The attenuator is an 8 bit device producing 256 levels of attenuation for RF signals. Inputs are TTL compatible. The attenuator does not provide any status information. Power requirements are 12 volts, 128 mamp and -12 volts, 35 mamp.

7. Coaxial relays. These will be used for a variety of functions. Test signals can be inserted into amplifiers. Multiplexed coaxial relays switch the spectrum analyzers and the network analyzer to different places. Coaxial relays in trunk lines (medium level electronics) are used to inject and extract signals, and also used while beam is on. The total number is 100, but provision will be made in the control system to add more later. They are all in the tunnel or adjacent stub rooms distributed as follows: A60, 15; A10, 20; A20, 9; A30, 56. Each relay requires a control bit and a status bit.

8. 3 spectrum analyzers, 2 in bldg 10 and 1 in bldg 30 require GPIB interfaces.

9. The network analyzer in building 10 requires a special interface to the HP-9826 computer. This will consist of two separate parts: (1) an interface between an 080 module and one of the GPIB buses in the HP computer for block data transfer. Data rates expected are 100-200 Kbytes every 20 minutes or so during startup of the system. Data will be passed through DEC-P to the VAX without any work done on it by DEC-P. (2) an interface using GPIB to another bus of the HP computer for "chit-chat," a short list of commands that load already written programs from the Winchester Disk into the HP computer and make inquiries as to whether or not the processing is done or how far along it is. A command will also allow termination of the program in the HP.

10. Refrigeration and compressor control and monitoring will be done in a way similiar to the Energy Saver and use multibus REF crates connected to the CAMAC system by 080 modules.

11. Thermocouple refrigeration monitoring points (A10: 10, A20: 10, A30: 15, and A60: 30) will go to ADC channels.

12. There will be a small number of devices to control cryogenics valves, and monitor flows. These will use Standard CAMAC modules. Dewars each have a He level controller. A status bit indicates that the level is high enough to cover the filter.

The system being developed to control and monitor the microwave amplifiers, pin diode switches and alternators, and coaxial relays (items 4-7 in above list) is shown schematically in fig 13-3. The motivating design criterion has been to remove CAMAC equipment from the tunnel enclosure for purposes of reliability and access for repairs.

The CAMAC crate with the associated Crate Controller and connections to the Link are all standard Tevatron components. The Interface Box and the Patch Box are new designs. The Power Supplies are to provide power to the pin attenuators, pin switches, and microwave regulators. The cables terminate at the Patch Box in the tunnel. With this arrangement it is possible to include the power lines in a single cable which runs from the Patch Box to a particular attenuator, regulator, etc.

It is proposed that each location be served with the equipment shown in the block diagram. An exception is the CAMAC crate which has sufficient slots to accommodate more than one system.

The system provides 3 key features:

1. Signal conditioning, amplification, optical coupling, etc. are accomodated in one location, the Interface Box.

2. Provision is made for future expansion. Sufficient cables are proposed to support additional devices if they become necessary. This additional capacity is also incorporated in the Interface and Patch Boxes.

3. The Patch Box provides a central point from which individual cables are run to the various pieces of equipment. All necessary signals for that equipment are included in that one cable.

The CAMAC 180 is well suited for status readback. This module has provision for storing 16 sixteen-bit words giving a total of 256 input channels. The module provides 4 output lines to control a multiplexor which selects one of the 16 words. This word is latched in the 180 and the module scans ahead to read the next word at a 500 kHz rate. Any of the 16 words are easily accessed through the CAMAC system. Output signals for

STOCHASTIC COOLING CONTROLS BLOCK DIAGRAM

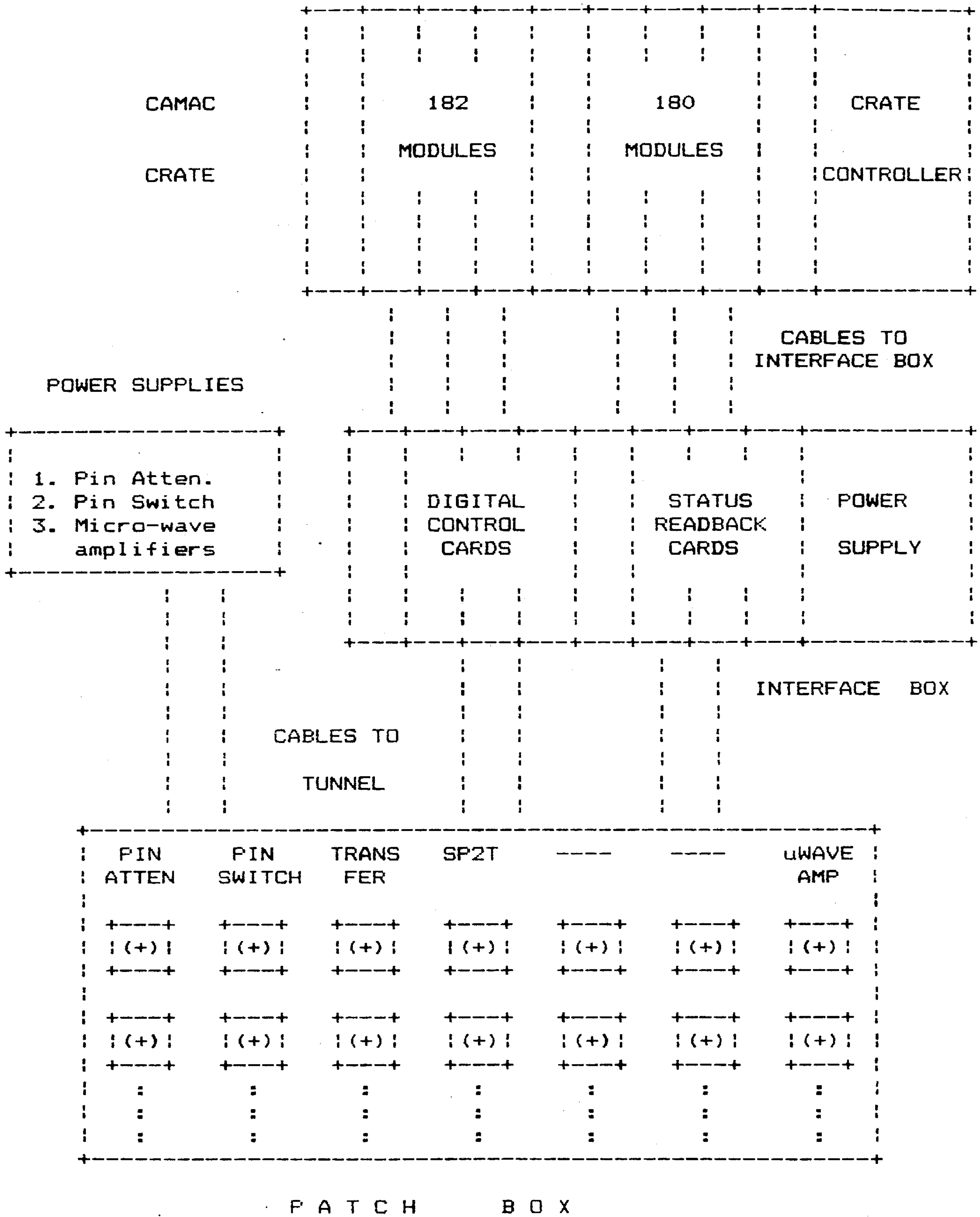

Figure 13-3

controlling switches, setting attenuators, etc., are provided by the CAMAC 182 module. It consists of 32 output channels and can be configured to control individual output channels or to operate at the word (16 bits) level.

The Interface Box has several major functions: (1) provide multiplexing for the CAMAC 180 module; (2) provide optical coupling and filtering of incoming status signals; (3) provide contact closure monitoring for the various coaxial relays; (4) provide high voltage (28 V), high current (60 mA) signals for the coaxial switches; and (5) provide a convenient and reliable means of grouping and terminating the cables which go to the tunnel. The Interface Box is built around a 21-slot double-high Eurocard cage and accommodates Eurocards of 233 x 220 mm. This card size has an area of approximately 80 square inches. A typical CAMAC card has an area of about 84 square inches. Appropriate power supplies are housed in the Interface Box. Two types of cards are used with the Interface Box: an input card called the Status Readback Card and an output card called the Digital Control Card.

The Status Readback Card has 32 channels for input signals. Depending on jumper position a channel monitors TTL signals received optically or a channel monitors relay contacts. Current through the contacts when they close is 5 mA. The interface Box contains up to 8 Status Readback Cards providing 256 input channels. The 8 cards are multiplexed and supply data to a single CAMAC 180 module. One-shots provide 100 msec outputs with either a positive or negative edge acting as the trigger. A transistor driver is used to drive a relay coil.

The Patch Box is simply a means for terminating the multiconductor signal cables and power cables which run from the service buildings to the tunnel areas and distributing these signals to the appropriate Burndy style connectors. The Patch Box is wall mounted with a hinged front door for easy access inside. The box is of the style presently used in the Booster as a fan-in box for analog signals. Cables from the service building enter the Patch Box from the top while the sides are used for the various Burndy connectors. Various connector blocks are mounted inside the Patch Box for the distribution of the power signals to the attenuators, pin switches, and microwave amplifiers.

The digital Control Card contains 32 channels of output with several options available for each channel. The Interface Box contains up to 8 Digital Control Cards which are driven by 8 CAMAC 182 modules.

13.10 Tev I Beam Diagnostics Interface to the Controls System

13.10.1 Beam Position Monitors. This section is condensed from TM-1254 (T. Bagwell, S. Holmes, J. McCarthy, R. Webber, "Anti-proton Source Beam Position System") and mainly emphasizes the controls aspect of that system.

The Tev I Beam Position Monitor (BPM) system is designed to provide a useful diagnostic tool during both the commissioning and operational phases of the antiproton source. The design goal is to provide single-turn-beam position information for intensities of greater than $1x10^9$ particles, and multi-turn (closed orbit) information for beam intensities of greater than $1x10^7$ particles, both with sub-millimeter resolution. The system will be used during commissioning for establishing the first turn through the Debuncher and Accumulator, for aligning injection orbits, for providing information necessary to correct closed orbits, and for measuring various machine parameters (e.g. tunes, dispersion, aperture, chromaticity.) During normal antiproton operation the system will be used to monitor the beam position throughout the accumulation process.

There are 210 beam pickups in the system--120 in the Debuncher and 90 in the Accumulator. Usually there is one pickup at each quadrupole (with horizontal pickups at F quadrupoles and vertical pickups at D quadrupoles.) This results in more than five position measurements per view per betatron wavelength in each ring, and provides more than sufficient information for precision alignment of closed, injection, and extraction orbits. The pickups themselves are either cut cylinders or rectangles, depending on location, with signals capacitively coupled from the beam. To maximize signal levels the pickups cover the full azimuth and every effort has gone into minimizing their capacitance to ground. The pickups are bidirectional to accommodate beams circulating in either direction and in the Accumulator also function as clearing electrodes.

During the commissioning period approximately $1x10^{10}$ protons will be injected into the Debuncher and Accumulator rings. These protons will be delivered from the Booster in 80 bunches at 52.8 MHz, either directly (via the Booster-Debuncher line), or by way of the Main Ring to the Debuncher (forward injected via the Target-Debuncher line) or to the Accumulator (reverse injected through the Accumulator-Target line.) For these modes to operation there is capability to measure orbits both over a single turn and averaged over multiple turns.

During the normal accumulation cycle approximately $7x10^7$ antiprotons are injected into the Debuncher once every 2 seconds. These antiprotons arrive in a train of 80 bunches with a spacing of 53.1 MHz. In the Debuncher they are rotated one quarter of a turn in longitudinal phase and allowed to debunch. A low level wideband system is provided to preserve the 200 nsec gap which is present at injection. After approximately 2 seconds in the Debuncher the beam is extracted and sent to the Accumulator. The $7x10^7$ antiprotons are placed orbit with an average momentum 0.93% above the central orbit of the Accumulator. They are then quickly moved to the tail of the accumulated antiproton stack by a 6.3 MHz RF system and subsequently cooled by the stochastic cooling systems. Eventually a core of up to $5x10^{11}$ antiprotons is collected at an average momentum lying 0.69% below the central orbit value. Following accumulation approximately $1x10^{11}$ antiprotons, in thirteen 52.8 MHz bunches, are moved onto a momentum displaced extraction orbit and kicked out the extraction line in a single turn. The BPM system has been designed with the capability of observing the (single turn) injection orbit and circulating closed orbit in the Debuncher, and the (multi-turn) injection orbit, core orbit, and extraction orbit in the Accumulator.

Parallel systems are used for the signal processing of single turn and multiple turn measurements. Single turn-by-turn measurements are processed by a high frequency (53 MHz), wide bandwidth (5 MHz) system which relies on 53 MHz signals produced by the bunched beam. This system is very similar to the present Energy Saver detection system. Multiple turn (closed orbit) measurements are processed through lower frequency (2.4 MHz in the Debuncher and 6.3 MHz in the Accumulator), narrow bandwidth (100-1000 Hz) systems which rely on naturally occurring gaps in the circulating beam, Schottky noise, and/or modulation produced by low frequency RF for signal generation. The bandwidth of these systems is chosen simply to cover the momentum spread in the beam. The narrow bandwidth produces an analog average which typically extends over several hundred turns and is necessary to reduce the contribution to position resolution from noise in the system. In addition to analog averaging there is digital averaging up to 256 measurements at any particular pickup to obtain sub-millimeter resolution even at very low signal levels. Twelve systems of each type exist in each ring. Signals from the pickups are multiplexed so that each system services between 7 and 10 pickups.

The digital signal processing is done through a multibus based system which is very similar to that used in the Energy Saver. This allows a large amount of hardware and software to be directly copied from the Energy Saver system. Provisions are made for testing and monitoring of the entire system.

Sum and difference signals from each position monitor are processed through gain switchable amplifiers within the tunnel and are then received in the service buildings through a modified version of the Main Ring multiplexor. Twelve service stations exist in the total system--six each in the Debuncher and Accumulator. Each station handles both the horizontal and vertical position monitors for one sixth of one ring. This implies ten BPM's per multiplexor in the Debuncher and seven/eight per vertical/horizontal multiplexor in the Accumulator system. Following, the multiplexor, position and intensity signals are generated through both the high and low frequency systems. The fast (53 MHz) position and intensity signals are then sent to a fast A/D converter which communicates with the Turn By Turn card in a multibus crate. Multiturn orbit measurements are digitized through the Saver Analog Box operating in Flash Mode. Only two of a possible twelve daughter cards are actually present in the Analog Box. Input to the Analog Box is selected from either the high or low frequency detector. Provisions are made for both magnifying and offsetting the position signal in order to utilize more effectively the eight bit resolution provided by the digitizers.

The multiplexors need to be able to switch inputs at speeds measured in milliseconds. This is because for multiple turn measurements in which bandwidths of 1 KHz are used one must wait up to tens of milliseconds for the input levels to the analog box to stabilize once a change is made. For measurements which utilize digital averaging to improve resolution it will be necessary to cycle through the multiplexor 100-200 times during the course of a measurement. For a measurement of the antiproton core for example, a bandwidth of 70 Hz is chosen. If 256 measurements are taken at each of eight multiplexor positions the entire measurement period lasts 60 seconds. For the Debuncher coasting beam it should be possible to make approximately 100 measurements at each pickup during the 2 seconds the beam is present on each cycle.

Special provisions have to be made for triggering the Analog Box in flash mode since the narrow bandwidth of the multiple turn system precludes any rapidly changing intensity signals entering the box. Flash mode will be initiated by a software generated lowering of the preset intensity threshold within the box at a specific time. The fast A/D will be self triggering on the intensity signal. The bandwidth of the high frequency system is about 5 MHz. This means that the associated time constant is 32 nsec, or 1.7 bunches. In order for the trigger circuit to be able to recognize a gap in the beam, and hence distinguish subsequent turns, approximately eight empty bunches are needed.

A great deal of flexibility is built into the system as a consequence of the need to detect and measure circulating beams with vastly different characteristics. Among the parameters of the system which are variable are,

1. Pickup Signal Level: Switchable between either 0 db (normal) or 40 db attenuation through a capacitive divider at the preamp input.

2. Tunnel Switched Gain Amplifier: Variable gain between 0-60 db in 20 db steps.

3. Multiplexor Cycle Pattern.

4. Oscillator Frequency: In the low frequency detector. Variable over ±.05%.

5. Position Gain and Offset: Gain x 1,2,4 and seven offset positions.

6. Filter Bandwidth: Variable 75 Hz to 1000 Hz in four steps.

7. Test Signal Generator: Generates difference and sum signals for monitoring scale of offset of position measurement.

All control of variable parameters is through the multibus External Device Bus.

Each multibus crate is controlled by an 8004 microprocessor and an associated M080 processor which handles communications to the host computer through CAMAC. The multibus crate used is identical to what is used in the Energy Saver system except for the addition of a Fast Access Board needed to control the fast A/D. As mentioned earlier, existing software will be used to the fullest extent possible.

13.10.2 Beam Loss Monitors. No clear plan has been developed for beam loss monitoring except in the AP-1 line. There standard Energy Saver loss monitors and controls hardware to read them will be installed. Some use will be made of standard high energy physics detectors and electronics, initially without an interface to the accelerator control system.

13.10.3 Beam Current Monitors. There needs to be one in each ring and one in each beam line. In the D one needs to measure pulse to pulse variations to accuracy of about 1% for optimizing targeting. Sensitivity desired is 0.1 μA or 10^7 $\bar{p}$'s. The precision current monitors will use GPIB interfaces to the control system. The use of a "SQUID" (Superconducting Quantum Interference Device) is under consideration.

13.10.4 Beam Profile Measurements. There are several possibilities: flying wire scanners, SWIC's, segmented or grid SEM's, gas jets with collection of ions. SEM grids appear to be the best solution for the beam lines and gas jets for the Debuncher and Accumulator rings and these are the devices currently under construction.

Each SEM grid will use the microprocessor system used in the FNAL secondary beam line SWIC scanners. This generates a digitized profile, calculates the mean and sigma of the distribution, and has snapshot capability. This information can be viewed on the TV system. It will also be interfaced into the control system using a CAMAC-032. Once done, graphical displays, emittance measurements, etc. are possible using the VAX. The numbers needed are approximately AP-1, 8 (including 3 special high resolution SEM-grids near the target); AP-2, 7; AP-3, 7; T-line, 4; for a total of 26.

Some of the characteristics of the SEM grid system are the following:

1. All are remotely retractable by the Control System from the beam.

2. The number of channels/monitor is 32x, 32y.

3. The grids are made of 10μ. titanium and are of three types: 1 mm wide strips, 1.5 mm apart; 2 mm wide strips, 3 mm apart; and special high resolution target region grids.

4. The goal is to achieve a least count of 5×10^{-15} coulombs.

13.11 Utility Monitoring for the Antiproton Source

The FIRUS System is the standard Fermilab fire protection system. It can also serve to monitor utilities whose failure can hamper operations or endanger equipment. There is no connection between the FIRUS and ACNET systems envisioned.

The purpose of the utility portion of the FIRUS system is to alert people in the main control room, at the fire station, and in the building 10 control room when either environmental conditions are unhealthy for antiproton source devices, or electrical or mechanical equipment is malfunctioning. The FIRUS system consists of the following equipment:

1. FIRUS mini-computers for Tev I (wall mounted--one for fire, others for utility)

2. Emergency power supply (also wall mounted)

3. Coax hardline communication cable

4. Junction boxes

5. Contact points and analog transducers

6. Three-pair 18 gauge shielded cable

7. Silent printer

Each mini can monitor 16 contact points or 15 analog points or a combination of contact and analog points. Each contact point can be more than one physical point if the points are wired in series. An alarm then indicates any one of a group of points has opened.

The following devices/quantities will be monitored by the utility portion of the FIRUS system:

1. sump pumps

2. LCW (Low Conductivity Water)

3. auxiliary generator

4. service building temperatures

5. stub room/tunnel temperature

6. stub room/tunnel humidity

Two contact sets per sump pump would be used. The first opens when a controlling float reaches a high water position, and the second opens upon loss of 120 VAC power to the pump.

The LCW cooling system for the rings enclosure will be derived from new equipment in the Central Utility Building (CUB). One transducer for water pressure and one transducer for water temperature will be located just downstream of the 1000 gpm, 150 psi pump in CUB. The LCW cooling system for the Antiproton Target Hall and Pretarget Enclosure will be extended from the Main Ring LCW system at Service Building F-23. Since the Main Ring LCW system is already monitored by FIRUS, no additional monitoring is necessary, as is true of the hot water (HTW) and chilled water (CHW) systems used for heating and airconditioning.

The auxiliary power generator (to be located outside Service Building 50) has a panel (to be located inside Service Building 50) with 8 monitors of contacts. A FIRUS contact will be wired such that if any one of these 8 monitors trips, the FIRUS contact will open, indicating trouble with the auxiliary power system.

Service Building temperatures will be monitored with either one to three distributed contacts that open upon a high temperature limit and one contact that opens upon a low temperature limit or two distributed analog temperature sensors with FIRUS software set limits. The Service Buildings are heated and airconditioned, so temperature monitoring provides a check on the correct operation of the air handling units. The high temperature limit will insure a healthy environment for the electronic equipment, and the low temperature limit will protect water pipes from freezing in winter.

An analog temperature sensor with FIRUS software set limits will be used for the stub rooms. Human access to the Antiproton Rings Enclosure will be prohibited if a beam is present. Remote monitoring of environmental temperature allows an operator to comfortably assess any long term danger to electronic equipment and decide if and when an access should be performed to investigate a high temperature indication. Also, during bakeout of the Accumulator, access to the rings enclosure will be possible, but not comfortable. The high temperature limit for electronics is higher when electronics are not operating, and the analog temperature sensor will be useful.

The rings enclosure is heated and indirectly air-conditioned by Service Building forced air ventilation. The possibility of electrical equipment damage due to condensation exists in the summer when warm, humid air could be cooled in the nearly constant temperature, below ground rings enclosure. An analog humidity sensor, with a FIRUS software set limit in selected stub rooms provides a check on the ventilation system.