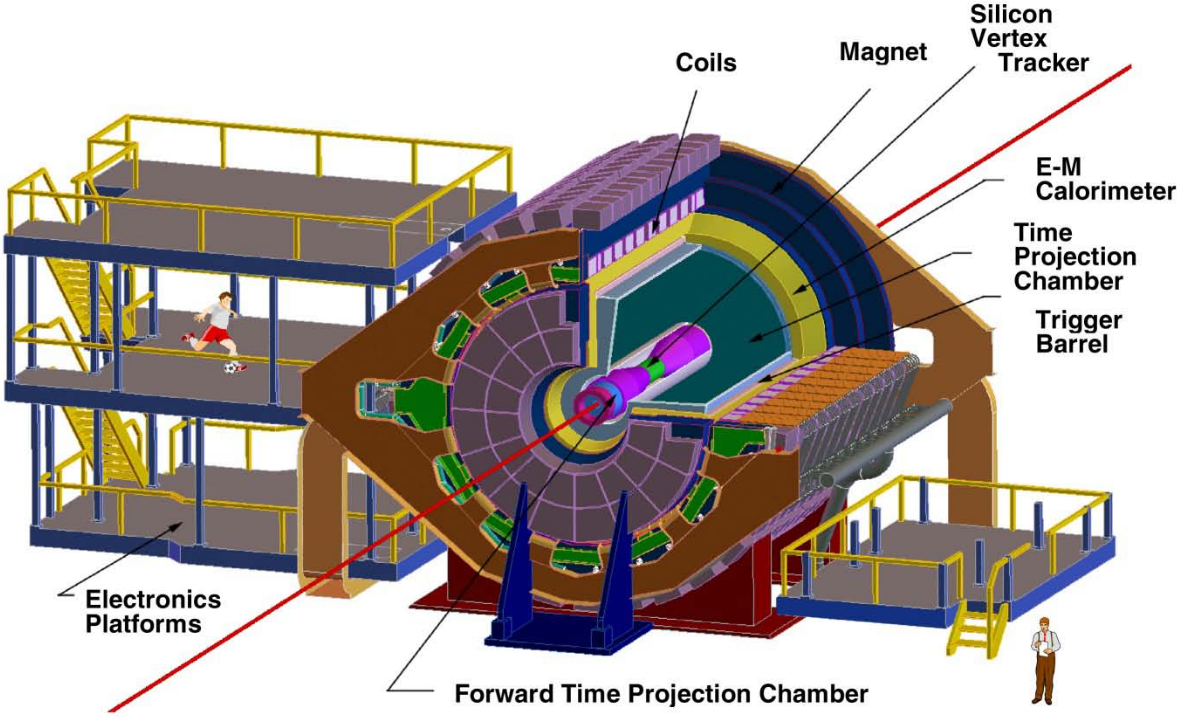
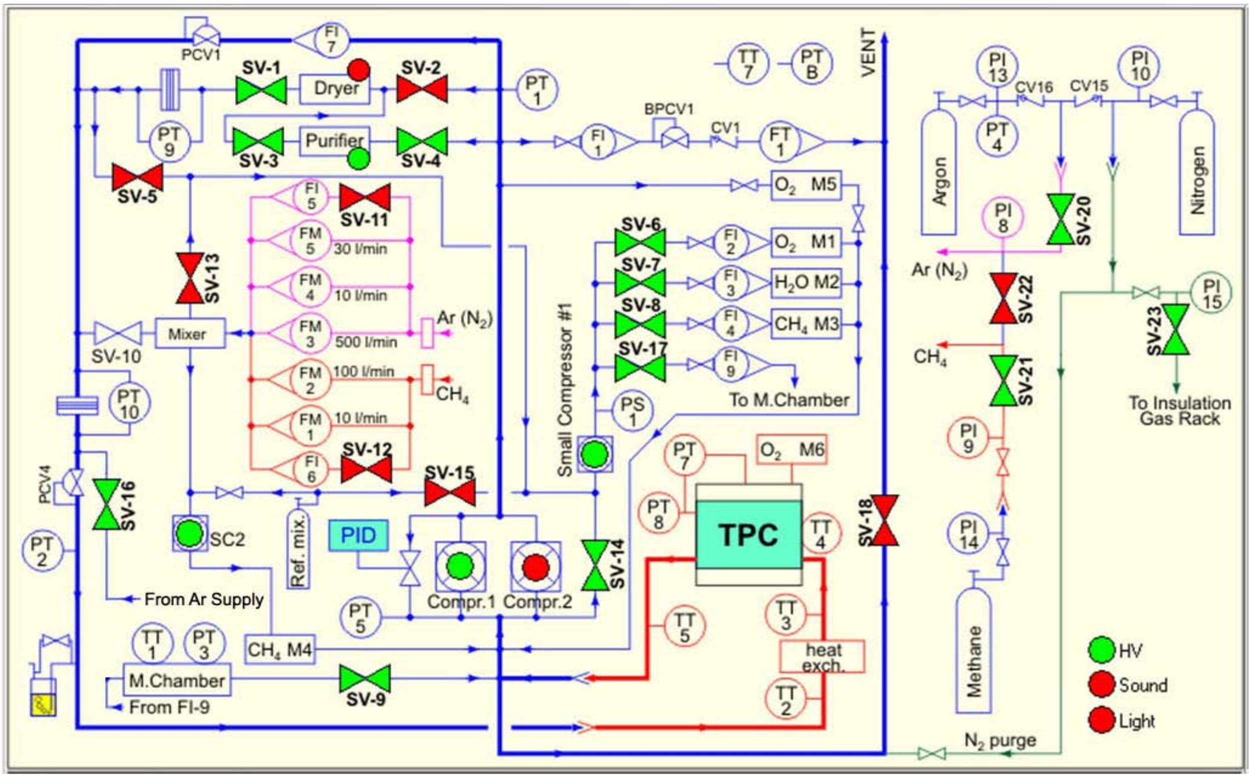
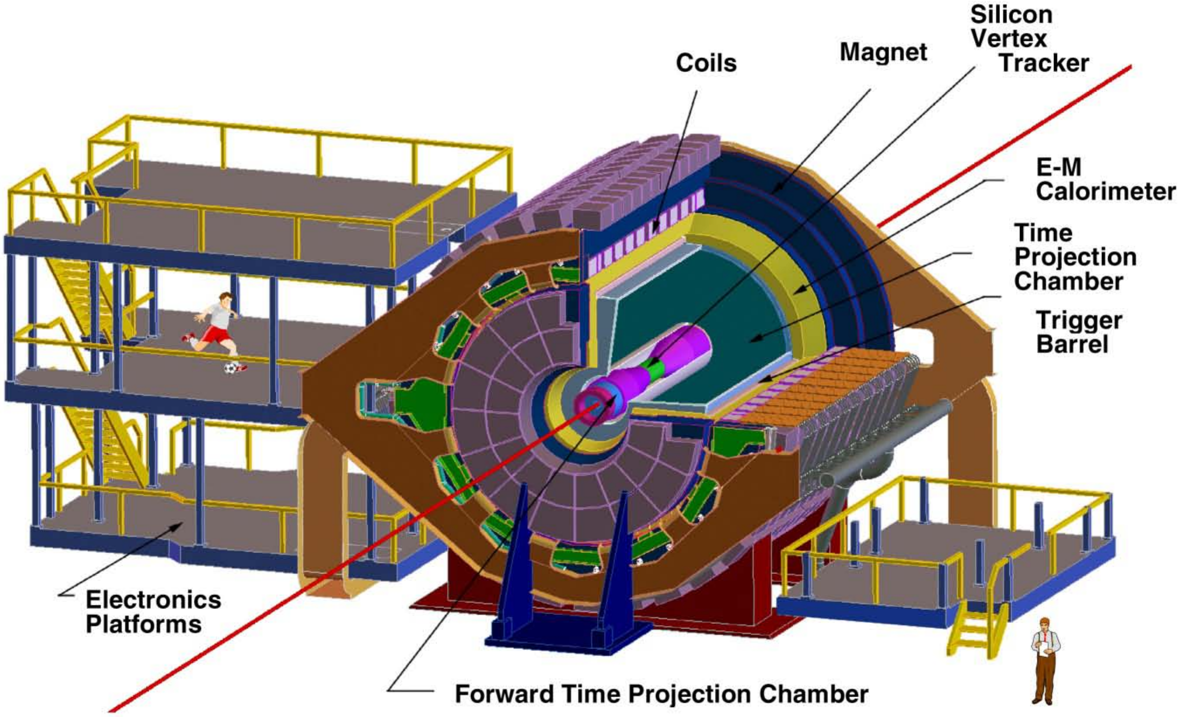
The STAR Time Project Chamber – Operating Procedures

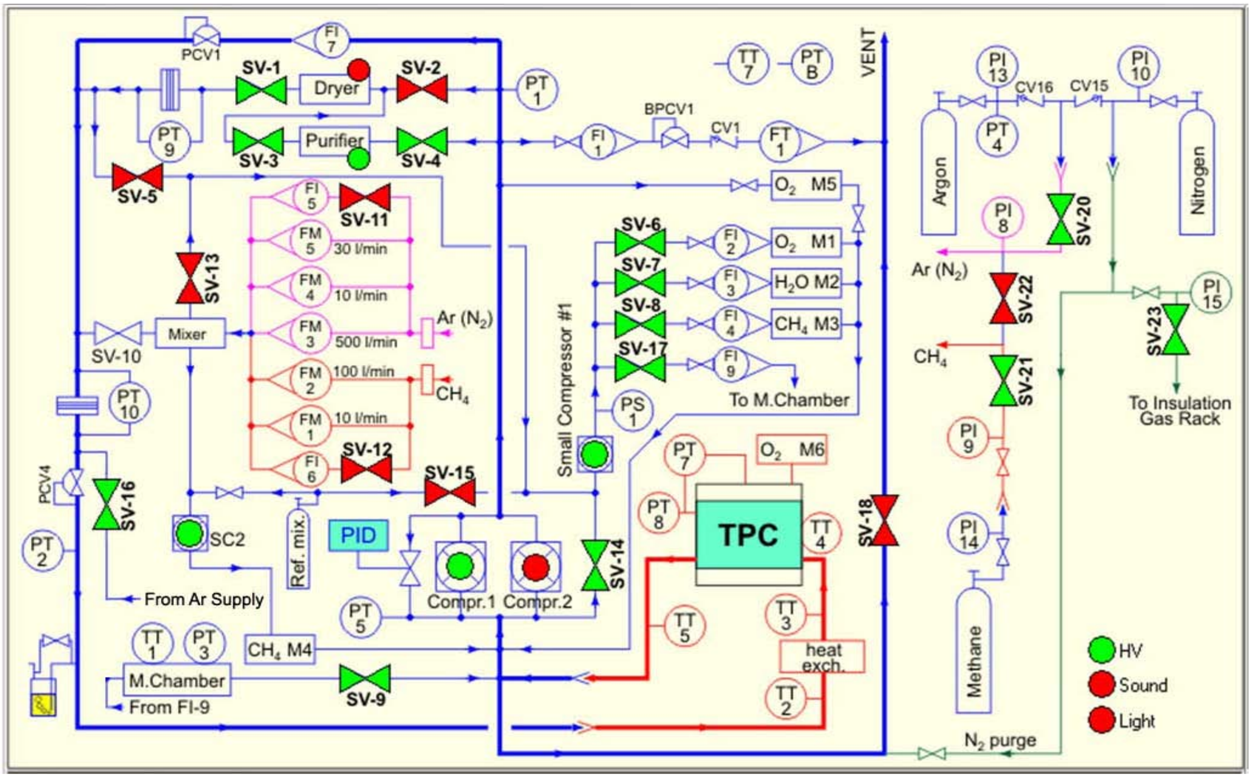




Introduction

The STAR TPC – Simplified Schematic of the Gas System





TPC passwords

Chaplin (TPC control PC in control room)	User: startpc Pass:
Sirius: PC in control room for alarm handler	Same as Chaplin
Deneb: (PC on second floor platform)	Same as Chaplin
Evp: event pool computer for pad monitor	User: startpc Pass:
Sc3: slow controls with fewer privileges	User: startpc Pass:
Sc5: new slow controls	User: sysuser Pass:
Gas System Computer in Gas room	User: sysuser Pass:
Startpc: Blair's computer in the counting house	User: stringfellow Pass:
RPS 1,2,3: remote power switches	No user Pass:

SGIS Global Interlocks (proceed with caution … you must be specially trained)

SGIS (Allen Bradley computer in DAQ room)	User: STAR Pass:

Silence the alarm (on the first page/screen). Check all of the screens (on different pages) for the system that led to the fault. Call Bill Christie or other authorized SGIS expert. Only an expert, while on the phone, can authorize you to proceed past this point. Bypass the alarmed system if you are certain that it is safe to do so and expert agrees. Fix whatever condition caused the alarm. Reset the alarm on the SGIS console screen. Look for Green screen everywhere before you clear the bypass, and then clear the bypass. (The system will alarm again if the alarm has not been cleared before you clear the bypass. This can be a real mess, so double check.) Logout.

If you had a water leak, and fixed it, then an expert must enter the STAR collision hall to reset the water leak sensor. The water leak detectors are located inside the SGIS rack on the 2nd floor of the South platform.

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The STAR time projection chamber: a unique tool for studying high multiplicity events at RHIC

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Abstract

The STAR Time Projection Chamber (TPC) is used to record the collisions at the Relativistic Heavy Ion Collider. The TPC is the central element in a suite of detectors that surrounds the interaction vertex. The TPC provides complete coverage around the beam-line, and provides complete tracking for charged particles within ±1.8 units of pseudo-rapidity of the center-of-mass frame. Charged particles with momenta greater than 100 MeV/c are recorded. Multiplicities in excess of 3000 tracks per event are routinely reconstructed in the software. The TPC measures 4 m in diameter by 4.2 m long, making it the largest TPC in the world.

PACS: 29.40.−n; 29.40.Gx

Keywords: Detectors TPC; Time projection chambers; Drift chamber; Heavy ions

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1. Introduction

The Relativistic Heavy Ion Collider (RHIC) is located at Brookhaven National Laboratory. It accelerates heavy ions up to a top energy of 100 GeV per nucleon, per beam. The maximum center of mass energy for Au + Au collisions is $\sqrt{s_{NN}} = 200\,\text{GeV}$ per nucleon. Each collision produces a large number of charged particles. For example, a central Au–Au collision will produce more than 1000 primary particles per unit of pseudo-rapidity. The average transverse momentum per particle is about 500 MeV/c. Each collision also produces a high flux of secondary particles that are due to the interaction of the primary particles with the material in the detector, and the decay of short-lived primaries. These secondary particles must be tracked and identified along with the primary particles in order to accomplish the physics goals of the experiment. Thus, RHIC is a very demanding environment in which to operate a detector.

The STAR detector [1–3] uses the TPC as its primary tracking device [4,5]. The TPC records the tracks of particles, measures their momenta, and identifies the particles by measuring their ionization energy loss ($\mathrm{d}E/\mathrm{d}x$). Its acceptance covers ± 1.8 units of pseudo-rapidity through the full azimuthal angle and over the full range of multiplicities. Particles are identified over a momentum range from 100 MeV/c to greater than 1 GeV/c, and momenta are measured over a range of 100 MeV/c to 30 GeV/c.

The STAR TPC is shown schematically in Fig. 1. It sits in a large solenoidal magnet that operates at 0.5 T [6]. The TPC is 4.2 m long and 4 m in diameter. It is an empty volume of gas in a well-defined, uniform, electric field of ≈135 V/cm. The paths of primary ionizing particles passing through the gas volume are reconstructed with high precision from the released secondary electrons which drift to the readout end caps at the ends of the chamber. The uniform electric field which is required to drift the electrons is defined by a thin conductive Central Membrane (CM) at the center of the TPC, concentric field-cage cylinders and the readout end caps. Electric field uniformity is critical since track reconstruction precision is submillimeter and electron drift paths are up to 2.1 m.

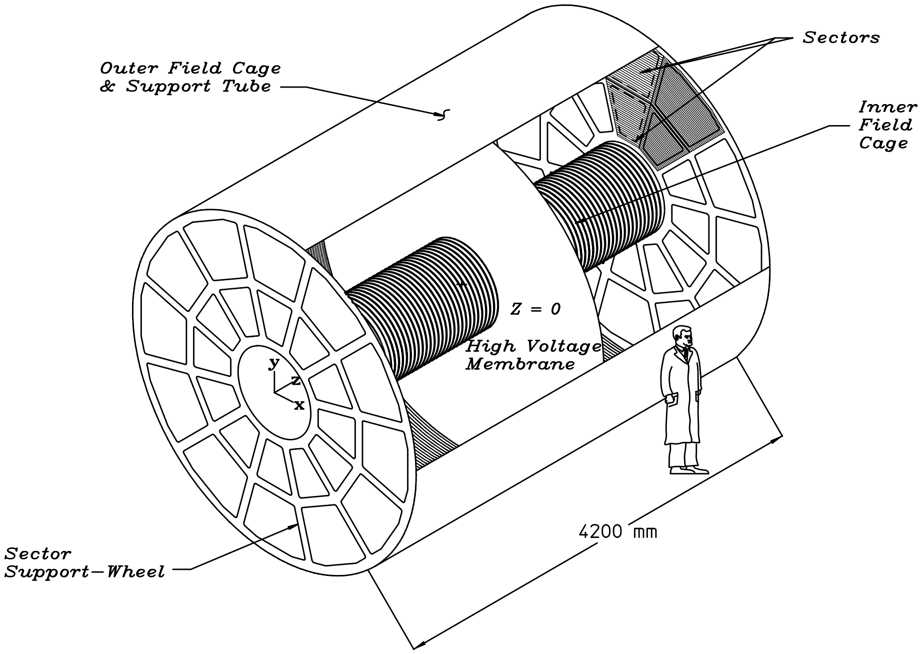

Fig. 1. The STAR TPC surrounds a beam–beam interaction region at RHIC. The collisions take place near the center of the TPC.

The readout system is based on Multi-Wire Proportional Chambers (MWPC) with readout pads. The drifting electrons avalanche in the high fields at the 20 μm anode wires providing an amplification of 1000–3000. The positive ions created in the avalanche induce a temporary image charge on the pads which disappears as the ions move away from the anode wire. The image charge is measured by a preamplifier/shaper/waveform digitizer system. The induced charge from an avalanche is shared over several adjacent pads, so the original track position can be reconstructed to a small fraction of a pad width. There are a total of 136,608 pads in the readout system.

The TPC is filled with P10 gas (10% methane, 90% argon) regulated at 2 mbar above atmospheric pressure [7]. This gas has long been used in TPCs. Its primary attribute is a fast drift velocity which peaks at a low electric field. Operating on the peak of the velocity curve makes the drift velocity stable and insensitive to small variations in temperature and pressure. Low voltage greatly simplifies the field cage design.

The design and specification strategy for the TPC have been guided by the limits of the gas and the financial limits on size. Diffusion of the drifting electrons and their limited number defines the position resolution. Ionization fluctuations and finite track length limit the dE/dx particle identification. The design specifications were adjusted accordingly to limit cost and complexity without seriously compromising the potential for tracking precision and particle identification.

Table 1 lists some basic parameters for the STAR TPC. The measured TPC performance has generally agreed with standard codes such as MAGBOLTZ [8] and GARFIELD [9]. Only for the most detailed studies has it been necessary to make custom measurements of the electrostatic or gas parameters (e.g., the drift velocity in the gas).

Table 1
Basic parameters for the STAR TPC and its associated hardware

Item	Dimension	Comment
Length of the TPC	420 cm	Two halves, 210 cm long
Outer diameter of the drift volume	400 cm	200 cm radius
Inner diameter of the drift volume	100 cm	50 cm radius
Distance: cathode to ground plane	209.3 cm	Each side
Cathode	400 cm diameter	At the center of the TPC
Cathode potential	28 kV	Typical
Drift gas	P10	10% methane, 90% argon
Pressure	Atmospheric +2 mbar	Regulated at 2 mbar above atm.
Drift velocity	5.45 cm/μs	Typical
Transverse diffusion (σ)	$230\ \mu m/\sqrt{cm}$	140 V/cm & 0.5 T
Longitudinal diffusion (σ)	$360\ \mu m/\sqrt{cm}$	140 V/cm
Number of anode sectors	24	12 per end
Number of pads	136 608	
Signal to noise ratio	20:1	
Electronics shaping time	180 ns	FWHM
Signal dynamic range	10 bits	
Sampling rate	9.4 MHz	
Sampling depth	512 time buckets	380 time buckets typical
Magnetic field	0, ±0.25 T, ±0.5 T	Solenoidal

2. Cathode and field cage

The uniform electric field in the TPC is defined by establishing the correct boundary conditions with the parallel disks of the CM, the end caps, and the concentric field cage cylinders. The central membrane is operated at 28 kV. The end caps are at ground. The field cage cylinders provide a series of equi-potential rings that divide the space between the central membrane and the anode planes into 182 equally spaced segments. One ring at the center is common to both ends. The central membrane is attached to this ring. The rings are biased by resistor chains of 183 precision 2 MΩ resistors which provide a uniform gradient between the central membrane and the grounded end caps.

The CM cathode, a disk with a central hole to pass the Inner Field Cage (IFC), is made of 70 μm

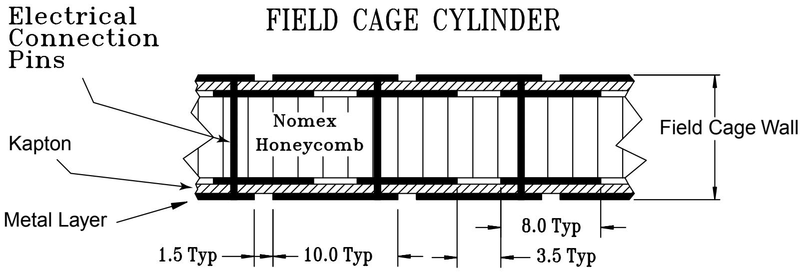

Fig. 2. An IFC showing the construction and composition of the cylinder wall. Dimensions are in mm.

thick carbon-loaded Kapton film with a surface resistance of 230 Ω per square. The membrane is constructed from several pie shape Kapton sections bonded with double-sided tape. The membrane is secured under tension to an outer support hoop which is mounted inside the Outer Field Cage (OFC) cylinder. There is no mechanical coupling to the IFC, other than a single electrical connection. This design minimizes material and maintains a good flat surface to within 0.5 mm.

Thirty six aluminum stripes have been attached to each side of the CM to provide a low work-function material as the target for the TPC laser calibration system [10,11]. Electrons are photo-ejected when ultraviolet laser photons hit the stripes, and since the position of the narrow stripes are precisely measured, the ejected electrons can be used for spatial calibration.

The field cage cylinders serve the dual purpose of both gas containment and electric field definition. The mechanical design was optimized to reduce mass, minimize track distortions from multiple Coulomb scattering, and reduce background from secondary particle production. Mechanically, the walls of the low mass self-supporting cylinders are effectively a bonded sandwich of two metal layers separated by NOMEX[1] honeycomb (see Fig. 2 for a cutaway view). The metal layers are in fact flexible PC material, Kapton with metal on both sides. The metal is etched to form electrically separated 10 mm strips separated by 1.5 mm. The pattern is offset on the two sides of the Kapton so that the composite structure behaves mechanically more like a continuous metal sheet. The 1.5 mm break is held to the minimum required to maintain the required voltage difference between rings safely. This limits the dielectric exposure in the drift volume thus reducing stray, distorting electric fields due to charge build up on the dielectric surfaces. Minimizing the break has the additional benefit of improving the mechanical strength. Punch-through pins were used to electrically connect the layers on the two sides of the sandwich.

The lay-up and bonding of the field cage sandwich was done on mandrels constructed of wood covered with rigid foam which was turned to form a good cylindrical surface. Commercially available metal-covered Kapton is limited in width to ≈20 cm so the lay-up was done with multiple etched metal-kapton sheets wrapped around the circumference of the mandrel. A laser interferometer optical tool was used to correctly position the sheets maintaining the equi-potential ring alignment to within 50 μm differentially and better than 500 μm, overall. The mandrels were constructed with a double rope layer under the foam. The ropes were unwound to release the mandrel from the field cage cylinder at completion of the lay-up.

A summary of the TPC material thicknesses in the tracking volume are presented in Table 2. The design emphasis was to limit material at the inner radius where multiple coulomb scattering is most important for accurate tracking and accurate momentum reconstruction. For this reason aluminum was used in the IFC, limiting it to only 0.5% radiation length (X_0). To simplify the construction, and electrical connections, copper was used for the OFC. Consequently, the OFC is significantly thicker, 1.3% X_0, but still not much more

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[1] NOMEX, manufactured by DuPont.

Table 2
Material thickness for the inner (IFC) and outer (OFC) electrostatic field cages[a]

Structure	Material	Density (g/cm^3)	X_0 (g/cm^2)	Thickness (cm)	Thickness (%X_0)
Insulating gas	N_2	1.25e-03	37.99	40	0.13
TPC IFC	Al	2.700	24.01	0.004	0.04
TPC IFC	Kapton	1.420	40.30	0.015	0.05
TPC IFC	NOMEX	0.064	40	1.27	0.20
TPC IFC	Adhesive	1.20	40	0.08	0.23
IFC total (w/gas)					0.65
TPC gas	P10	1.56E-03	20.04	150.00	1.17
TPC OFC	Cu	8.96	12.86	0.013	0.91
TPC OFC	Kapton	1.420	40.30	0.015	0.05
TPC OFC	NOMEX	0.064	40	0.953	0.15
OFC	Adhesive	1.20	40	0.05	0.15
OFC total (w/gas)					2.43

[a] Adhesive is only an estimate.

than the detector gas itself. The sandwich structure of the OFC cylinder wall is 10 mm thick while the IFC has a wall thickness of 12.9 mm.

Nitrogen gas or air insulation was used to electrically isolate the field cage from surrounding ground structures. This design choice requires more space than solid insulators, but it has two significant advantages. One advantage is to reduce multiple scattering and secondary particle production. The second advantage is the insulator is not vulnerable to permanent damage. The gas insulator design was chosen after extensive tests showed that the field cage kapton structures and resistors could survive sparks with the stored energy of the full size field cage. The IFC gas insulation is air and it is 40 cm thick without any detectors inside the IFC. It is 18 cm thick with the current suite of inner detectors. The OFC has a nitrogen layer 5.7 cm thick isolating it from the outer shell of the TPC structure. The field cage surfaces facing the gas insulators are metallic potential graded structures which are the same as the surfaces facing the TPC drift volume. In addition to the mechanical advantages of a symmetric structure, this design avoids uncontrolled dielectric surfaces where charge migration can lead to local high fields and surface discharges in the gas insulator volume.

The outermost shell of the TPC is a structure that is a sandwich of material with two aluminum skins separated by an aluminum honeycomb. The skins are a multi-layer wraps of aluminum. The construction was done much like the field cage structures using the same cylindrical mandrel. The innermost layer, facing the OFC, is electrically isolated from the rest of the structure and it is used as a monitor of possible corona discharge across the gas insulator. The outer shell structure is completely covered by aluminum extrusion support rails bonded to the surface. The support rails carry the Central Trigger Barrel (CTB) trays. These extrusions have a central water channel for holding the structure at a fixed temperature. This system intercepts heat from external sources, the CTB modules and the magnet coils, which run at a temperature significantly higher than the TPC. This is just one part of the TPC temperature control system which also provides cooling water for the TPC electronics on the end-caps.

3. The TPC end-caps with the anodes and pad planes

The end-cap readout planes of STAR closely match the designs used in other TPCs such as

PEP4, ALEPH, EOS and NA49 but with some refinements to accommodate the high track density at RHIC and some other minor modifications to improve reliability and simplify construction. The readout planes, MWPC chambers with pad readout, are modular units mounted on aluminum support wheels. The readout modules, or sectors, are arranged as on a clock with 12 sectors around the circle. The modular design with manageable size sectors simplifies construction and maintenance. The sectors are installed on the inside of the spoked support wheel so that there are only 3 mm spaces between the sectors. This reduces the dead area between the chambers, but it is not hermetic like the more complicated ALEPH TPC design [12]. The simpler non-hermetic design was chosen since it is adequate for the physics in the STAR experiment.

The chambers consist of four components; a pad plane and three wire planes (see Fig. 3). The amplification/readout layer is composed of the anode wire plane of small, 20 μm, wires with the pad plane on one side and the ground wire plane on the other. The third wire plane is a gating grid which will be discussed later. Before addressing the details of the amplification region, a word about the chosen wire direction. The direction is set to best determine the momentum of the highest transverse momentum (p_T) particles whose tracks are nearly straight radial lines emanating from the interaction point (the momentum of low p_T particles is well determined without special consideration). The sagitta of the high p_T tracks is accurately determined by setting the anode wires roughly perpendicular to the straight radial tracks because position resolution is best along the direction of the anode wire. In the other direction, the resolution is limited by the quantized spacing of the wires (4 mm between anode wires). The dimensions of the rectangular pads are likewise

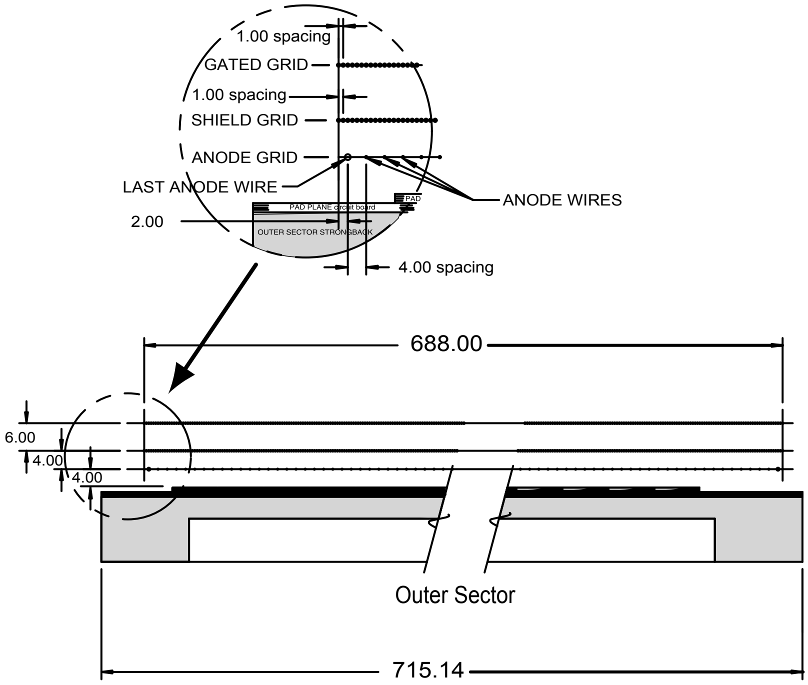

Fig. 3. A cut-away view of an outer subsector pad plane. The cut is taken along a radial line from the center of the TPC to the outer field cage so the center of the detector is to the right. The figure shows the spacing of the anode wires relative to the pad plane, the ground shield grid, and the gated grid. The bubble diagram shows additional detail about the wire spacing. The inner subsector pad plane has the same layout except the spacing around the anode plane is 2 mm instead of the 4 mm shown here. All dimensions are in millimeters.

optimized to give the best position resolution perpendicular to the stiff tracks. The width of the pad along the wire direction is chosen such that the induced charge from an avalanche point on the wire shares most of it's signal with only three pads. This is to say that the optimum pad width is set by the distance from the anode wire to the pad plane. Concentrating the avalanche signal on three pads gives the best centroid reconstruction using either a 3-point Gaussian fit or a weighted mean. Accuracy of the centroid determination depends on signal-to-noise and track angle, but it is typically better than 20% of the narrow pad dimension. There are additional tradeoffs dictating details of the pads' dimensions which will be discussed further in connection with our choice of two different sectors designs, one design for the inner radius where track density is highest and another design covering the outer radius region. Details of the two sector designs can be found in Table 3 and Fig. 4.

The outer radius subsectors have continuous pad coverage to optimize the dE/dx resolution (i.e., no space between pad rows). This is optimal because the full track ionization signal is collected and more ionization electrons improve statistics on

Table 3
Comparison of the inner and outer subsector geometries

Item	Inner subsector	Outer subsector	Comment
Pad size	2.85 mm × 11.5 mm	6.20 mm × 19.5 mm	
Isolation gap between pads	0.5 mm	0.5 mm	
Pad rows	13 (#1-#13)	32 (#14-#45)	
Number of pads	1750	3942	5692 total
Anode wire to pad plane spacing	2 mm	4 mm	
Anode voltage	1170 V	1390 V	20:1 signal:noise
Anode gas gain	3770	1230	

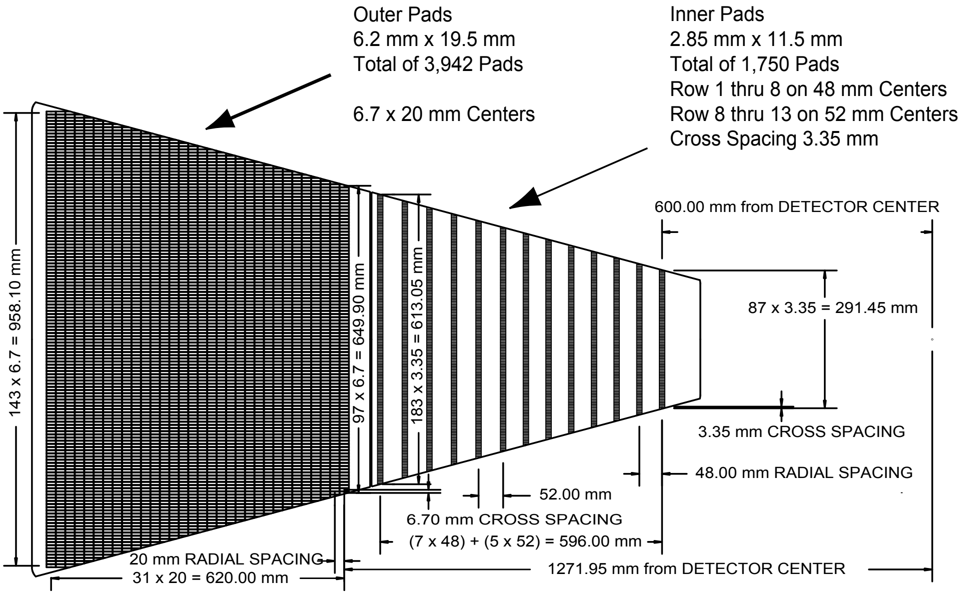

Fig. 4. The anode pad plane with one full sector shown. The inner subsector is on the right and it has small pads arranged in widely spaced rows. The outer subsector is on the left and it is densely packed with larger pads.

the dE/dx measurement. Another modest advantage of full pad coverage is an improvement in tracking resolution due to anti-correlation of errors between pad rows. There is an error in position determination for tracks crossing a pad row at an angle due to granularity in the ionization process (Landau fluctuations). If large clusters of ionization occur at the edge of the pad row they pull the measured centroid away from the true track center. But, there is a partially correcting effect in the adjacent pad row. The large clusters at the edge also induce signal on the adjacent pad row producing an oppositely directed error in the measured position in this adjacent row. This effective cross talk across pad rows, while helpful for tracking precision, causes a small reduction in dE/dx resolution.

On the outer radius subsectors the pads are arranged on a rectangular grid with a pitch of 6.7 mm along the wires and 20.0 mm perpendicular to the wires. The grid is phased with the anode wires so that a wire lies over the center of the pads. There is a 0.5 mm isolation gap between pads. The 6.7 mm pitch and the 4 mm distance between the anode wire plane is consistent with the transverse diffusion width of the electron cloud for tracks that drift the full 2 m distance. More explicitly, with a 4 mm separation between pad plane and anode plane the width of the induced surface charge from a point avalanche is the same as the diffusion width. The pad pitch of 6.7 mm places most of the signal on three pads which gives good centroid determination at minimum gas gain. This matching gives good signal-to-noise without serious compromise to two-track resolution. The pad size in the long direction (20.0 mm pitch) was driven by available electronic packaging density and funding, plus the match to longitudinal diffusion. The z projection of 20.0 mm on $\eta = 1$ tracks matches the longitudinal diffusion spread in z for $\eta = 0$ tracks drifting the full 2 m.

The inner subsectors are in the region of highest track density and thus are optimized for good two-hit resolution. This design uses smaller pads which are 3.35 mm by 12 mm pitch. The pad plane to anode wire spacing is reduced accordingly to 2 mm to match the induced signal width to ≈ 3 pads. The reduction of the induced surface charge width to less than the electron cloud diffusion width improves two-track resolution a small amount for stiff tracks $\sim$ perpendicular to the pad rows at $\eta \approx 0$. The main improvement in two-track resolution, however, is due to shorter pad length (12 mm instead of 20 mm). This is important for lower momentum tracks which cross the pad row at angles far from perpendicular and for tracks with large dip angle. The short pads give shorter projective widths in the r–ϕ direction (the direction along the pad row), and the z direction (the drift direction) for these angled tracks. The compromise inherent in the inner radius subsector design with smaller pads is the use of separate pad rows instead of continuous pad coverage. This constraint imposed by the available packing density of the front end electronics channels means that the inner sector does not contribute significantly to improving the dE/dx resolution. The inner sector only serves to extend the position measurements along the track to small radii thus improving the momentum resolution and the matching to the inner tracking detectors. An additional benefit is detection of particles with lower momentum.

The design choices, pad sizes, and wire-to-pad spacing for the two pad plane sector geometries were verified through simulation and testing with computer models [1,2], but none of the desired attributes: dE/dx resolution, momentum resolution and two-track resolution show a dramatic dependence on the design parameters. This is in part due to the large variation in track qualities such as dip angle, drift distance, and crossing angle. While it is not possible with a TPC to focus the design on a particular condition and optimize performance, a lot is gained through oversampling and averaging. In addition to simulations, prototype pad chambers were built and studied to verify charge-coupling parameters and to test stability at elevated voltages [13].

The anode wire plane has one design feature that is different than in other TPCs. It is a single plane of 20 μm wires on a 4 mm pitch without intervening field wires. The elimination of intervening field wires improves wire chamber stability and essentially eliminates initial voltage conditioning time. This is because in the traditional design both the field wire and the anode wires are captured in a single epoxy bead. The large potential difference on the field and anode wires places significant demands on the insulating condition of the epoxy surface. The surface is much less of a problem in our design where the epoxy bead supports only one potential. This wire chamber design requires a slightly higher voltage on the anode wires to achieve the same electric field at the anode wire surface (i.e., a higher voltage to achieve the same gas gain) but this is not a limitation on stability. Another small advantage in this design is that we can operate the chambers at a lower gas gain (35% lower for the inner sector) [13] since with this design the readout pads pick-up a larger fraction of the total avalanche signal. Like other TPCs, the edge wires on the anode wire plane are larger diameter to prevent the excess gain that would otherwise develop on the last wire.

Most of the anode wires are equipped with amplifiers and discriminators that are used in the trigger to detect tracks passing through the end cap. The discriminators are active before the electrons drift in from tracks in the drift volume.

Another special feature of the anode plane is a larger than normal (1 nF) capacitor to ground on each wire. This reduces the negative cross talk that is always induced on the pads under a wire whenever an avalanche generates charge anywhere along the wire. The negative cross talk comes from capacitive coupling between the wire and the pad. The AC component of the avalanche charge on a wire capacitively couples to the pads proportionally as $C_{\mathrm{p}}/C_{\mathrm{total}}$ where C_{p} is the pad-to-wire capacitance and C_{total} is the total capacitance of the wire to ground. In the high track density at RHIC, there can be multiple avalanches on a wire at any time so it is important to minimize this source of cross-talk and noise. The 1 nF grounding capacitor is a compromise between cross talk reduction and wire damage risk. Our tests showed that the stored energy in larger capacitors can damage the wire in the event of a spark.

The gas gain, controlled by the anode wire voltage, has been set independently for the two sector types to maintain a 20:1 signal to noise for pads intercepting the center of tracks that have drifted the full 2 m. This choice provides minimum gain without significantly impacting the reconstructed position resolution due to electronic noise. The effective gas gain needed to achieve this signal-to-noise is 3770 for the inner sector and 1230 for the outer sector. As discussed in detail in Ref. [14] the required gas gain depends on diffusion size of the electron drift cloud, pad dimensions, amplifier shaping time, the avalanche-to-pad charge-coupling fractions and the electronic noise which for our front end electronics is ≈ 1000 electrons rms.

The ground grid plane of 75 μm wires completes the sector MWPC. The primary purpose of the ground grid is to terminate the field in the avalanche region and provide additional rf shielding for the pads. This grid can also be pulsed to calibrate the pad electronics. A resistive divider at the grid provides 50 Ω termination for the grid and 50 Ω termination for the pulser driver.

The outermost wire plane on the sector structure is the gating grid located 6 mm from the ground grid. This grid is a shutter to control entry of electrons from the TPC drift volume into the MWPC. It also blocks positive ions produced in the MWPC, keeping them from entering the drift volume where they would distort the drift field. The gating grid plane can have different voltages on every other wire. It is transparent to the drift of electrons while the event is being recorded and closed the rest of the time. The grid is 'open' when all of the wires are biased to the same potential (typically 110 V). The grid is 'closed' when the voltages alternate ± 75 V from the nominal value. The positive ions are too slow to escape during the open period and get captured during the closed period. The STAR gating grid design is standard. Its performance is very well described by the usual equations [12]. The gating grid driver has been designed to open and settle rapidly (100 V in 200 ns). Delays in opening the grid shorten the active volume of the TPC because electrons that drift into the grid prior to opening are lost. The combined delay of the trigger plus the opening time for the gating grid is 2.1 μs. This means that the useful length of the active volume is 12 cm less than the physical length of 210 cm. To limit initial data corruption at the opening of the gate, the plus and minus grid driving voltages are well matched in time and amplitude to nearly cancel the induced signal on the pads.

The gating grid establishes the boundary conditions defining the electric field in the TPC drift volume at the ends of the TPC. For this reason the gating wire planes on the inner and outer subsectors are aligned on a plane to preserve the uniform drift field. For the same reason the potential on the gating grid planes must be matched to the potential on the field cage cylinders at the intersection point. Aligning the gating grid plane separates the anode wire planes of the two sector types by 2 mm. The difference in drifting electron arrival time for the two cases is taken into account in the time-to-space position calibration. The time difference is the result of both the 2 mm offset and the different field strengths in the vicinity of the anode wires for the two sector types. The electron drift times near the anode plane was both measured and studied with MAGBOLTZ. The field is nearly uniform and constant from the CM to within 2 mm of the gating grid. We simulated the drift of ionization from 2 mm above the gating grid to the anode wires to estimate the difference between the inner and outer subsector drift times. These MAGBOLTZ simulations find that the drift from the CM to the outer subsectors requires 0.083 μs longer than from the CM to the inner subsectors. Measurement shows a slightly longer average time difference of 0.087 μs.

The construction of the sectors followed techniques developed for earlier TPCs. The pad planes are constructed of bromine-free G10 printed circuit board material bonded to a single-piece backing structure machined from solid aluminum plate. Specialized tooling was developed so that close tolerances could be achieved with minimum setup time. Pad plane flatness was assured by vacuum locking the pad plane to a flat granite work surface while the aluminum backer is bonded with epoxy to the pad plane. Wire placement is held to high tolerance with fixed combs on granite work tables during the assembly step of capturing the wires in epoxy beads on the sector backer. Mechanical details of the wires are given in Table 4. The final wire-placement error is less than 7 μm. Pad location along the plane is controlled to better than 100 μm. The sectors were qualified with overvoltage testing and gas-gain uniformity measurements with an ^{55}Fe source.

Table 4
Properties of the wires in the readout chambers

Wire	Diam. (μm)	Pitch (mm)	Composition	Tension (N)
Anodes	20	4	Au-plated W	0.50
Anodes—last wire	125	4	Au-plated Be–Cu	0.50
Ground plane	75	1	Au-plated Be–Cu	1.20
Gating grid	75	1	Au-plated Be–Cu	1.20

4. Drift gas

P10 (90% argon + 10% methane) is the working gas in the TPC. The gas system (discussed in detail in Ref. [7]) circulates the gas in the TPC and maintains purity, reducing electro-negative impurities such as oxygen and water which capture drifting electrons. To keep the electron absorption to a few percent, the oxygen is held below 100 parts per million and water less than 10 parts per million.

All materials used in the TPC construction that are exposed to the drift gas were tested for outgassing of electron capturing contaminants. This was done with a chamber designed to measure electron attenuation by drifting electrons through a 1 m long gas sample.

The transverse diffusion [8] in P10 is $230\ \mu\text{m}/\sqrt{\text{cm}}$ at 0.5 T or about $\sigma_T = 3.3$ mm after drifting 210 cm. This sets the scale for the wire chamber readout system in the X, Y plane. Similarly, the longitudinal diffusion of a cluster of electrons that drifts the full length of the TPC is $\sigma_L = 5.2$ mm. At a drift velocity of 5.45 cm/μs, the longitudinal diffusion width is equal to a spread in the drift time of about 230 ns full width half maximum (FWHM). This diffusion width sets the scale for the resolution of the tracking system in the drift direction and we have chosen the front-end pad amplifier shaping time and the electronic sampling time accordingly. The shaping time is

180 ns FWHM and the electronic sampling time is 9.4 MHz.

5. Performance of the TPC

This section will discuss the TPC performance using data taken in the RHIC beam in the 2000/2001 run cycle. The TPC performance with cosmic rays without magnetic field has been previously presented [15]. In 2000, the magnetic field was 0.25 T; in 2001 the field was raised to 0.5 T. The TPC performance is strongly affected by the magnetic field because, for example, the transverse diffusion of the electrons that drift through the gas is smaller in higher fields.

The track of an infinite-momentum particle passing through the TPC at mid-rapidity is sampled by 45 pad rows, but a finite momentum track may not cross all 45 rows. It depends on the radius of curvature of the track, the track pseudorapidity, fiducial cuts near sector boundaries, and other details about the particle's trajectory. While the wire chambers are sensitive to almost 100% of the secondary electrons arriving at the end-cap, the overall tracking efficiency is lower (80–90%) due to the fiducial cuts, track merging, and to lesser extent bad pads and dead channels. There are at most a few percent dead channels in any one run cycle.

The track of a primary particle passing through the TPC is reconstructed by finding ionization clusters along the track. The clusters are found separately in x, y and in z space. (The local x-axis is along the direction of the pad row, while the local y-axis extends from the beamline outward through the middle of, and perpendicular to, the pad rows. The z-axis lies along the beam line.) For example, the x-position cluster finder looks for ionization on adjacent pads, within a pad row, but with comparable drift times. And, for simple clusters, the energy from all pads is summed to give the total ionization in the cluster. If two-tracks are too close together, the ionization clusters will overlap. These complex clusters are split using an algorithm that looks for peaks with a valley between them and then the ionization is divided between the two tracks. These merged clusters are used only for tracking and not for $\mathrm{d}E/\mathrm{d}x$ determination because of the uncertainty in the partitioning between the tracks. In central Au–Au events at 200 GeV, about 30% of the clusters are overlapping.

5.1. Reconstruction of the x, y position

The x and y coordinates of a cluster are determined by the charge measured on adjacent pads in a single pad row. Assuming that the signal distribution on the pads (pad response function) is Gaussian, the local x is given by a fit, where h_1, h_2 and h_3 are the amplitudes on three adjacent pads, with pad h_2 centered at $y = 0$:

$$x = \frac{\sigma^2}{2w} \ln\left(\frac{h_3}{h_1}\right) \tag{1}$$

where the width of the signal, σ, is given by

$$\sigma^2 = \frac{w^2}{\ln(h_2^2/h_1 h_3)} \tag{2}$$

and w is the pad width. The position uncertainty due to electronics noise may be fairly easily computed in this approach:

$$\Delta x = \frac{\Delta h}{h_c}\frac{\sigma^2}{2w}\sqrt{\left(1-\frac{2x}{w}\right)^2 \exp\left(\frac{-(x+w)^2}{\sigma^2}\right) + \frac{16x^2}{w^2}\exp\left(\frac{-x^2}{w^2}\right) + \left(1+\frac{2x}{w}\right)^2 \exp\left(\frac{-(x-w)^2}{\sigma^2}\right)}. \tag{3}$$

Here, Δh is the noise, h_c is the signal amplitude under a centered pad ($h_c = 0$), and the three terms in the root correspond to the errors on h_1, h_2, and h_3 respectively. For $\Delta h < 0.05h$ (a 20:1 signal-to-noise ratio), the noise contribution is small. The total signal is summed over all above-threshold time buckets. This equation is slightly different from the results in [16] because it includes the error in the σ determination.

The Gaussian approximation has some short comings. First, it does not exactly match onto the tails the true pad response function which introduces an x-dependent bias of a few hundred μm. More importantly, the algorithm deteriorates at large crossing angles. When a track crosses the pad row at large angles, it deposits ionization on many pads and any three adjacent pads will have similar amplitude signals. In this case, a weighted mean algorithm, using all of the pads above a certain threshold is much more effective.

Figs. 5a and c show the position resolution along the pad rows (local x) for both field settings of the magnet. The sigma is extracted by fitting a Gaussian to the residual distribution, i.e., the distance between the hit position and the track extrapolation.

5.2. Reconstruction of the z position in the TPC

The z coordinate of a point inside the TPC is determined by measuring the time of drift of a cluster of secondary electrons from the point of origin to the anodes on the endcap and dividing by the average drift velocity. The arrival time of the cluster is calculated by measuring the time of arrival of the electrons in "time buckets" and weighting the average by the amount of charge collected in each bucket. (Each time bucket is approximately 100 ns long.) The signal from a typical cluster covers several time buckets because of three phenomena: the longitudinal diffusion of the drifting electrons, the shaping of the signal by

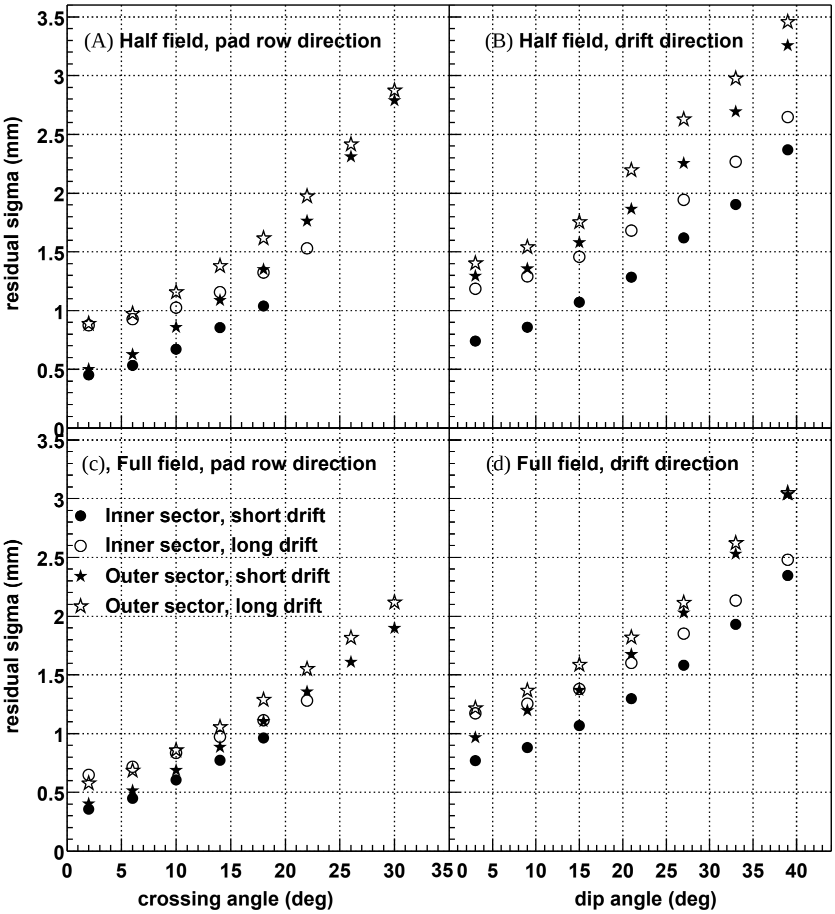

Fig. 5. Position resolution across the pad rows and along the z-axis of the TPC. The crossing angle is the angle between the particle momentum and the pad row direction. The dip angle is the angle between the particle momentum and the drift direction, $\theta = \cos^{-1}(p_z/p)$.

the preamplifier electronics, and the track dip angle. The preamplifier shaping time is chosen to correspond to the size of the electron cloud for particles drifting and diffusing the entire length of the TPC [29]. This setting smooths out the random fluctuations of the average cluster positions introduced by statistics and diffusion. The amplifier also has cancellation circuitry to remove the long current tail characteristic of MWPCs [17].

The length of the signal reaching a pad depends on the dip angle, θ, which is the angle between the particle momentum and the drift direction. The ionization electrons are spread over a distance d along the beam axis, with $d = L/\tan(\theta)$ and L is the length of the pad.

The drift velocity for the electrons in the gas must be known with a precision of 0.1% in order to convert the measured time into a position with sufficient accuracy. But the drift velocity will change with atmospheric pressure because the TPC is regulated and fixed at 2 mbar above atmospheric pressure. Velocity changes can also occur from small changes in gas composition. We minimize the effect of these variations in two ways. First, we set the cathode voltage so the electric field in the TPC corresponds to the peak in the drift velocity curve (i.e., velocity vs. electric field/pressure). The peak is broad and flat and small pressure changes do not have a large effect on the drift velocity at the peak. Second, we measure the drift velocity independently every few hours using artificial tracks created by lasers beams [10,11]. Table 1 gives the typical drift velocities and cathode potentials.

The conversion from time to position also depends on the timing of the first time bucket with respect to the collision time. This time offset has several origins: trigger delay, the time spent by the electron drifting from the gating grid to the anode wires, and shaping of the signal in the front end electronics. The delay is constant over the full volume of the TPC and so the timing offset can be adjusted, together with the drift velocity, by reconstructing the interaction vertex using data from one side of the TPC only and later matching it to the vertex found with data from the other side of the TPC. Local variations of the time offset can appear due to differences between different electronic channels and differences in geometry between the inner and outer sector pad planes. These electronic variations are measured and corrected for by applying a calibrated pulse on the ground plane. Fluctuations on the order of 0.2 time buckets are observed between different channels.

Figs. 5b and d show the position resolution along the z-axis of the TPC in 0.25 and 0.5 T magnetic fields, respectively. The resolution is best for short drift distances and small dip angles. The position resolution depends on the drift distance but the dependence is weak because of the large shaping time in the electronics, which when multiplied by the drift velocity (≈ 1 cm), is comparable to or greater than the longitudinal diffusion width (≈ 0.5 cm). The position resolution for the two magnetic field settings is similar. The resolution deteriorates, however, with increasing dip angle because the length of path received by a pad is greater than the shaping time of the electronics (times drift velocity) and the ionization fluctuations along the particle path are not fully integrated out of the problem.

5.3. Distortions

The position of a secondary electron at the pad plane can be distorted by non-uniformities and global misalignments in the electric and magnetic fields of the TPC. The non-uniformities in the fields lead to a non-uniform drift of the electrons from the point of origin to the pad plane. In the STAR TPC, the electric and magnetic fields are parallel and nearly uniform in r and z. The deviations from these ideal conditions are small and a typical distortion along the pad row is $\leqslant 1$ mm before applying corrections.

Millimeter-scale distortions in the direction transverse to the path of a particle, however, are important because they affect the transverse momentum determination for particles at high p_T. In order to understand these distortions, and correct for them, the magnetic field was carefully mapped with Hall probes and an NMR probe before the TPC was installed in the magnet [6]. It was not possible to measure the electric fields and so we calculated them from the known geometry

Table 5
The distortion corrections applied to STAR data; their cause, and the magnitude of their effect on the data

Cause of the distortion	Magnitude of the imperfection	Magnitude of the correction
Non-uniform B field	± 0.0040 T	0.10 cm
Geometrical effect between the inner and outer subsectors	Exact calculation based on geometry	0.05 cm (near pad row 13)
Cathode—non-flat shape and tilt	0.1 cm	0.04 cm
The angular offset between E and B field	0.2 mr	0.03 cm
TPC endcaps—non-flat shape and tilt	0.1 cm	0.03 cm
Misalignment between IFC and OFC	0.1 cm	0.03 cm
Space charge build up in the TPC	$0.001\ \mathrm{C}/\varepsilon_0$	0.03 cm average over volume

of the TPC. With the fields known, we correct the hit positions along the pad rows using the distortion equations for nearly parallel electric and magnetic fields [12].

$$\delta_x = \int \frac{-\omega\tau B_y + \omega^2\tau^2 B_x}{(1+\omega^2\tau^2)B_z}\,\mathrm{d}z + \int \frac{E_x + \omega\tau E_y}{(1+\omega^2\tau^2)E_z}\,\mathrm{d}z \qquad (4)$$

$$\delta_y = \int \frac{\omega\tau B_x + \omega^2\tau^2 B_y}{(1+\omega^2\tau^2)B_z}\,\mathrm{d}z + \int \frac{E_y - \omega\tau E_x}{(1+\omega^2\tau^2)E_z}\,\mathrm{d}z \qquad (5)$$

where δ_x is the distortion in the x direction, $\vec{E}$ and $\vec{B}$ are the electric and magnetic fields, ω is the signed cyclotron frequency, and τ is the characteristic time between collisions as the electron diffuses through the gas.

These are precisely the equations in Blum and Rolandi [12], except that they are valid for any $\vec{E}$ field or $\vec{B}$ field configuration while the equations in Blum and Rolandi are *not* valid for all orientations of $\vec{E}$ and $\vec{B}$. Our equations differ from Blum and Rolandi in the definition of $\omega\tau$. In Blum and Rolandi, $\omega\tau$ is always positive. Here, $\omega\tau$ is signed, with the sign depending on the directions of B_z, E_z and the drift velocity u_z:

$$\omega\tau = k\frac{u_z(\mathrm{cm}/\mu\mathrm{s})}{E_z(\mathrm{V/cm})}B_z(T) \qquad (6)$$

where k is a constant. The negative charge of the drifting electrons is included in the sign of u_z. For example, the STAR electric field always points towards the central membrane and electrons always drift away from it, while B_z can point in either direction. Here, $k \approx 100$ and it depends on microscopic physics that is not represented in Eqs. (4) and (5). For precise work, k must be determined by measuring $\omega\tau$ directly [12,18]. In STAR, $k = 110$ and so $|\omega\tau| = 1.15$ at 0.25 T, rising to $|\omega\tau| = 2.30$ at 0.5 T. The magnitude of the distortion corrections are given in Table 5.

Fig. 6 shows the sum of the distortion corrections as a function of radius and z inside the active volume of the TPC. With these distortion corrections applied, the relative error between a point and the track-model fit is 50 μm while the absolute error for any one point is about 500 μm.

5.4. Two hit resolution

The inner and outer subsectors have different size pads and so their two-hit resolutions are different. Fig. 7 shows the efficiency of finding two hits as a function of the distance separating them. The efficiency depends on whether the track segment is observed in the inner or the outer subsectors. The efficiency is the ratio of the distributions of the distance separating two hits from the same event and two hits from different events. Two hits can be completely resolved when they are separated in the padrow direction (i.e., along the local x-axis) by at least 0.8 cm in the inner sector and 1.3 cm in the outer sector. Similarly, two hits are completely resolved when they are separated in the drift direction (i.e., along the z-axis) by 2.7 cm in the inner sector and 3.2 cm in the outer sector.

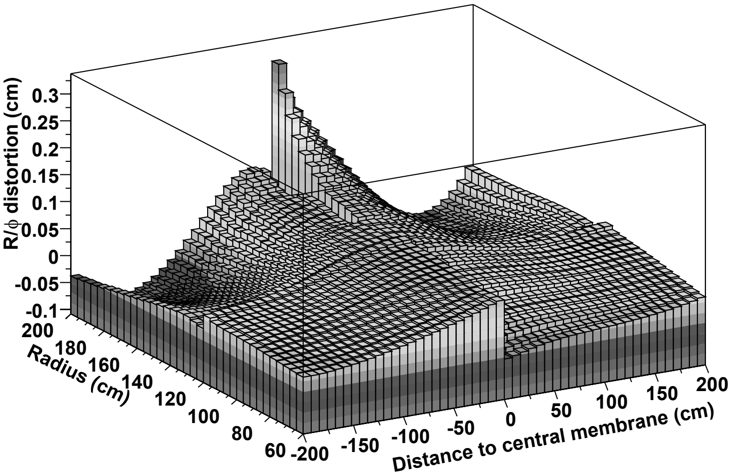

Fig. 6. The sum of all distortion corrections. The sum includes the distortions caused by the magnetic field non-uniformities, misalignment between the axis of the magnetic and electric fields, the effects of a tilted central membrane, non-flat end-caps, and local electric field imperfections at the junction of the inner and outer sectors at $R \approx 120$ cm.

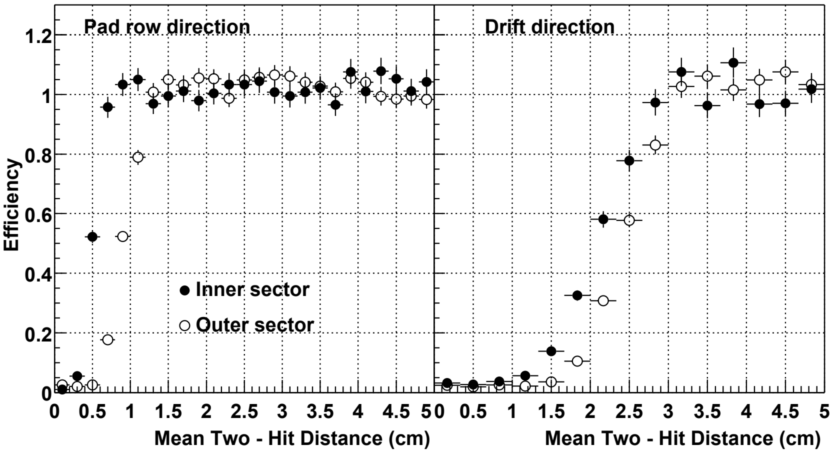

Fig. 7. Two-hit resolution in the STAR TPC. The drift direction is along the z-axis and the pad row direction is along the local x-axis.

5.5. Tracking efficiency

The tracking software performs two distinct tasks. First, the algorithms associate space points to form tracks and, second, they fit the points on a track with a track model to extract information such as the momentum of the particle. The track model is, to first order, a helix. Second-order effects include the energy lost in the gas which causes a particle trajectory to deviate slightly from the helix. In this section, we will discuss the efficiency of finding tracks with the software.

The tracking efficiency depends on the acceptance of the detector, the electronics detection efficiency, as well as the two-hit separation capability of the system. The acceptance of the TPC is 96% for high momentum tracks traveling perpendicular the beamline. The 4% inefficiency is caused by the spaces between the sectors which are required to mount the wires on the sectors. The software also ignores any space points that fall on the last two pads of a pad row. This fiducial cut is applied to avoid position errors that result from tracks not having symmetric pad coverage on both sides of the track. It also avoids possible local distortions in the drift field. This fiducial cut reduces the total acceptance to 94%.

The detection efficiency of the electronics is essentially 100% except for dead channels and the dead channel count is usually below 1% of the total. However, the system cannot always separate one hit from two hits on adjacent pads and this merging of hits reduces the tracking efficiency. The software also applies cuts to the data. For example, a track is required to have hits on at least 10 pad rows because shorter tracks are too likely to be broken track fragments. But this cut can also remove tracks traveling at a small angle with respect to the beamline and low momentum particles that curl up in the magnetic field. Since the merging and minimum pad rows effects are non-linear, we cannot do a simple calculation to estimate their effects on the data. We can simulate them, however.

In order to estimate the tracking efficiency, we embed simulated tracks inside real events and then count the number of simulated tracks that are in the data after the track reconstruction software has done its job. The technique allows us to account for detector effects and especially the losses related to a high density of tracks. The simulated tracks are very similar to the real tracks and the simulator tries to take into account all the processes that lead to the detection of particles including: ionization, electron drift, gas gain, signal collection, electronic amplification, electronic noise, and dead channels. The results of the embedding studies indicate that the systematic error on the tracking efficiency is about 6%.

Fig. 8 shows the pion reconstruction efficiency in Au + Au collisions with different multiplicities as a function of the transverse momentum of the primary particle [19]. In high multiplicity events it reaches a plateau of 80% for high p_T particles. Below 300 MeV/c the efficiency drops rapidly because the primary particles spiral up inside the TPC and do not reach the outer field cage. In addition, these low momentum particles interact with the beam pipe and the inner field cage before entering the tracking volume of the TPC. As a function of mulitplicity, the efficiency goes up to the geometrical limit, minus software cuts, for low multiplicity events.

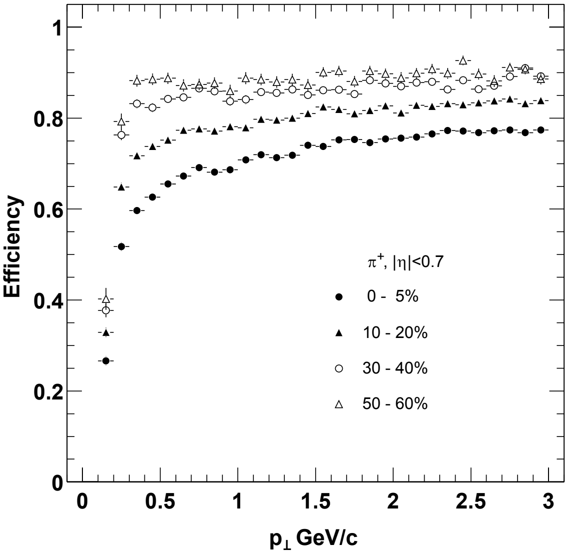

Fig. 8. The pion tracking efficiency in STAR for central Au + Au events at RHIC. Tracks with $|y| < 0.7$ were used to generate the figure and the magnetic field was set to 0.25 T. The data are binned by centrality. The most central collisions are the highest multiplicity data, they are shown as black dots. The lowest multiplicity data are shown as open triangles.

5.6. Vertex resolution

The primary vertex can used to improve the momentum resolution of the tracks and the secondary vertices can be separated from the primary vertices if the vertex resolution is good enough. Many of the strange particles produced in heavy ion collisions can be identified this way.

The primary vertex is found by considering all of the tracks reconstructed in the TPC and then extrapolating them back to the origin. The global average is the vertex position. The primary vertex resolution is shown in Fig. 9. It is calculated by comparing the position of the vertices that are reconstructed using each side of the TPC, separately. As expected, the resolution decreases as the square root of the number of tracks used in the

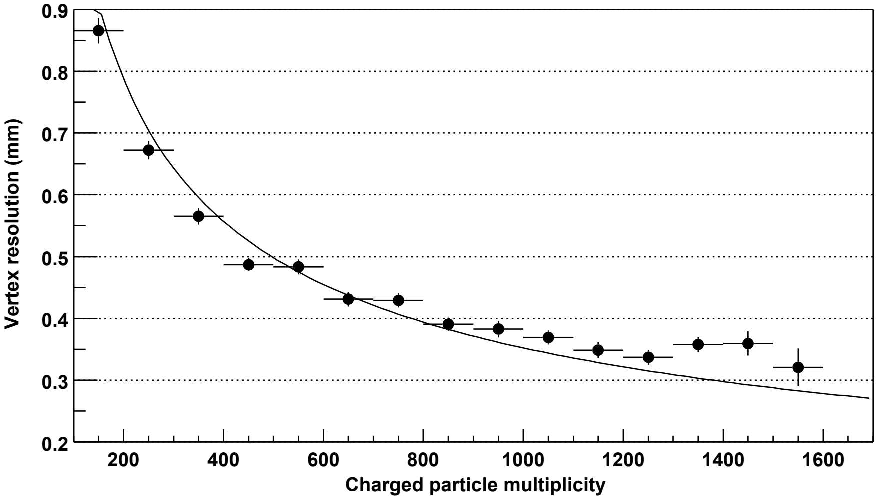

Fig. 9. Primary vertex resolution in the transverse plane.

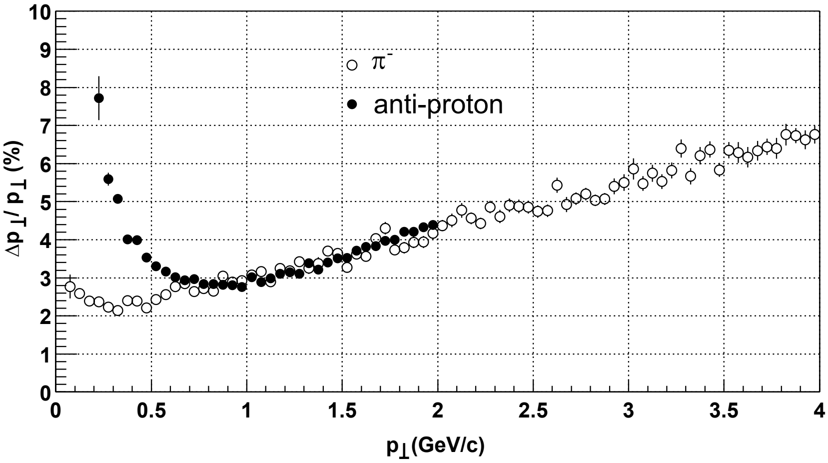

Fig. 10. Transverse momentum resolution of the STAR TPC for π^- and anti-protons in the 0.25 T magnetic field. Tracks are required to be formed by more than 15 hits. Tracks are embedded in minimum bias events. The momentum resolution is calculated as the Gaussian *sigma*.

calculation. A resolution of 350 μm is achieved when there are more than 1000 tracks.

5.7. Momentum resolution

The transverse momentum, p_T, of a track is determined by fitting a circle through the x, y coordinates of the vertex and the points along the track. The total momentum is calculated using this radius of curvature and the angle that the track makes with respect to the z-axis of the TPC. This procedure works for all primary particles coming from the vertex, but for secondary decays, such as Λ or K_s, the circle fit must be done without reference to the primary vertex.

In order to estimate the momentum resolution we use the embedding technique discussed above. The track simulator was used to create a track with a known momentum. The track was then embedded in a real event in order to simulate the momentum smearing effects of working in a high track density environment. Fig. 10

shows the p_T resolution for π^- and anti-protons in STAR. The figure shows two regimes: at low momentum, where multiple Coulomb scattering dominates (i.e., $p_T < 400$ MeV/c for pions, and $p_T < 800$ MeV/c for anti-protons), and at higher momentum where the momentum resolution is limited by the strength of the magnet field and the TPC spatial resolution. The best relative momentum resolution falls between these two extremes and it is 2% for pions.

5.8. *Particle identification using* dE/dx

Energy lost in the TPC gas is a valuable tool for identifying particle species. It works especially well for low momentum particles but as the particle energy rises, the energy loss becomes less mass dependent and it is hard to separate particles with velocities $v > 0.7c$. STAR was designed to be able to separate pions and protons up to 1.2 GeV/c. This requires a relative dE/dx resolution of 7%. The challenge, then, is to calibrate the TPC and understand the signal and gain variations well enough to be able to achieve this goal.

The measured dE/dx resolution depends on the gas gain which itself depends on the pressure in the TPC. Since the TPC is kept at a constant 2 mbar above atmospheric pressure, the TPC pressure varies with time. We monitor the gas gain with a wire chamber that operates in the TPC gas return line. It measures the gain from an ^{55}Fe source. It will be used to calibrate the 2001 data, but for the 2000 run, this chamber was not installed and so we monitored the gain by averaging the signal for tracks over the entire volume of the detector and we have done a relative calibration on each sector based on the global average. Local gas gain variations are calibrated by calculating the average signal measured on one row of pads on the pad plane and assuming that all pad-rows measure the same signal. The correction is done on the pad-row level because the anode wires lie on top of, and run the full length of, the pad rows.

The readout electronics also introduce uncertainties in the dE/dx signals. There are small variations between pads, and groups of pads, due to the different response of each readout board. These variations are monitored by pulsing the ground plane of the anode and pad plane read-out

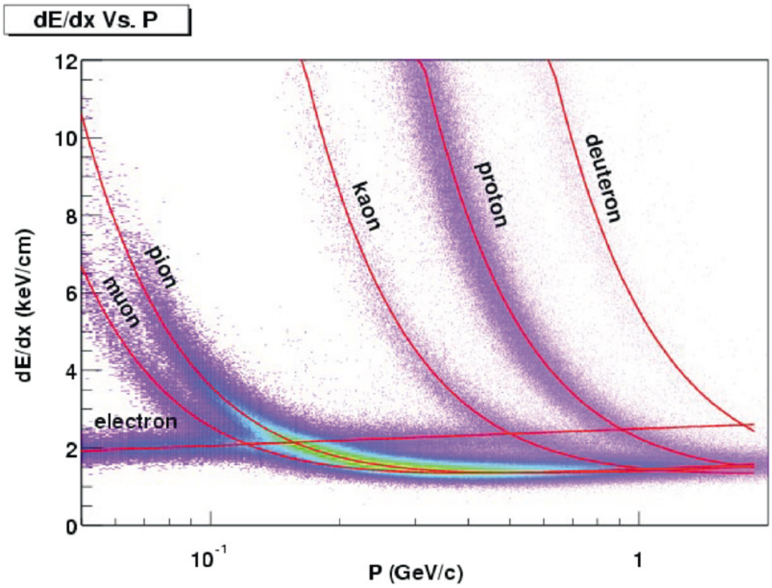

Fig. 11. The energy loss distribution for primary and secondary particles in the STAR TPC as a function of the p_T of the primary particle. The magnetic field was 0.25 T.

system and then assuming that the response will be the same on every pad.

The dE/dx is extracted from the energy loss measured on up to 45 padrows. The length over which the particle energy loss is measured (pad length modulo the crossing and dip angles) is too short to average out ionizations fluctuations. Indeed, particles lose energy going through the gas in frequent collisions with atoms where a few tens of eV are released, as well as, rare collisions where hundreds of eV are released [20]. Thus, it is not possible to accurately measure the average dE/dx. Instead, the most probable energy loss is measured. We do this by removing the largest ionization clusters. The truncated mean where a given fraction (typically 30%) of the clusters having the largest signal are removed, is an efficient tool to measure the most probable dE/dx. However, fitting the dE/dx distribution including all clusters associated to a given track was found to be more effective. It also allows us to account for the variation of the most probable energy loss with the length of the ionization samples (dx) [21].

Fig. 11 shows the energy loss for particles in the TPC as a function of the particle momentum. The data have been corrected for signal and gain variations and the data are plotted using a 70% truncated mean. The magnetic field setting is 0.25 T. The resolution is 8% for a track that crosses 40 pad-rows. At 0.5 T, the dE/dx resolution improves because the transverse diffusion is smaller, and this improves the signal-to-noise ratio for each cluster. Fig. 11 includes both primary and secondary particles. The prominent proton, deuteron, and muon bands come from secondary interactions in the beam pipe and IFC, and from pion and kaon decays. Pions and protons can be separated from each other up to 1 GeV/c.

6. Conclusions

The STAR TPC is up and running at RHIC. The detector finished its second year of operation on January 25, 2002 and the operation of the TPC was stable and reliable throughout both run cycles. Its performance is very close to the original design requirements in terms of tracking efficiency, momentum resolution, and energy-loss measurements. Many results from the 2000/2001 data have already been published and they demonstrate that the physics at RHIC is exciting and rich. We invite you to examine these papers [22–28].

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NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH
Section A

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STAR TPC gas system

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Abstract

The STAR TPC (Time Projection Chamber) Gas System supplies either of two mixtures, P10 (Ar 90% + CH_4 10%) or C_2H_6 50% + He 50%, to the STAR TPC (STAR Project, Brookhaven, USA) at a controlled pressure. This system regulates the pressure and composition of the gas while monitoring gas temperature, O_2 and H_2O. A computer data acquisition system collects and logs the gas system parameters, controls the purification of the recirculating mixture. A separate alarm and interlock system prevents the TPC from operating under unsafe conditions.

1. Description of STAR TPC gas system

The primary purpose of the STAR TPC [1] Gas System (Fig. 1) is to provide either of two pure gas mixtures, P10 or He + 50% C_2H_6, to the TPC at the correct temperature and pressure. Performance of the system is shown in Table 1.

A secondary function of the system is to cool the outer field cage resistor strings located in two channels at the top of the drift volume. The system operates nominally as a closed circuit gas system with the majority of gas recirculating through the TPC and delivery system. During normal operation a small amount of fresh mixture is added and an equivalent quantity (including TPC leakage) of the existing mixture is vented. The gas system can be operated in an open system configuration for purging.

The gas circulation rate is 36,000 l/h which, given the 50,000 l volume of the TPC, is one volume change every 1.4 h. The gas system contains two Rietschel's compressors, one active and one spare, each capable of 60,000 l/h at 100 mbar gauge. The 100 mbar output pressure from the compressor is reduced to 30 mbar by the first pressure regulator (PCV-1) and then to 2.4 mbar by the second one (PCV-4) upstream of the TPC. A water-cooled heat exchanger downstream of the compressors is used to remove the compression heat. The return gas manifold is maintained at 0.5–1.6 mbar above atmospheric pressure by a differential Dwyer's pressure transmitter (PT-6) and electropneumatic microprocessor (PID) controller that operates a bypass valve. The bypass shunts flow from the compressor discharge line directly back to the compressor's

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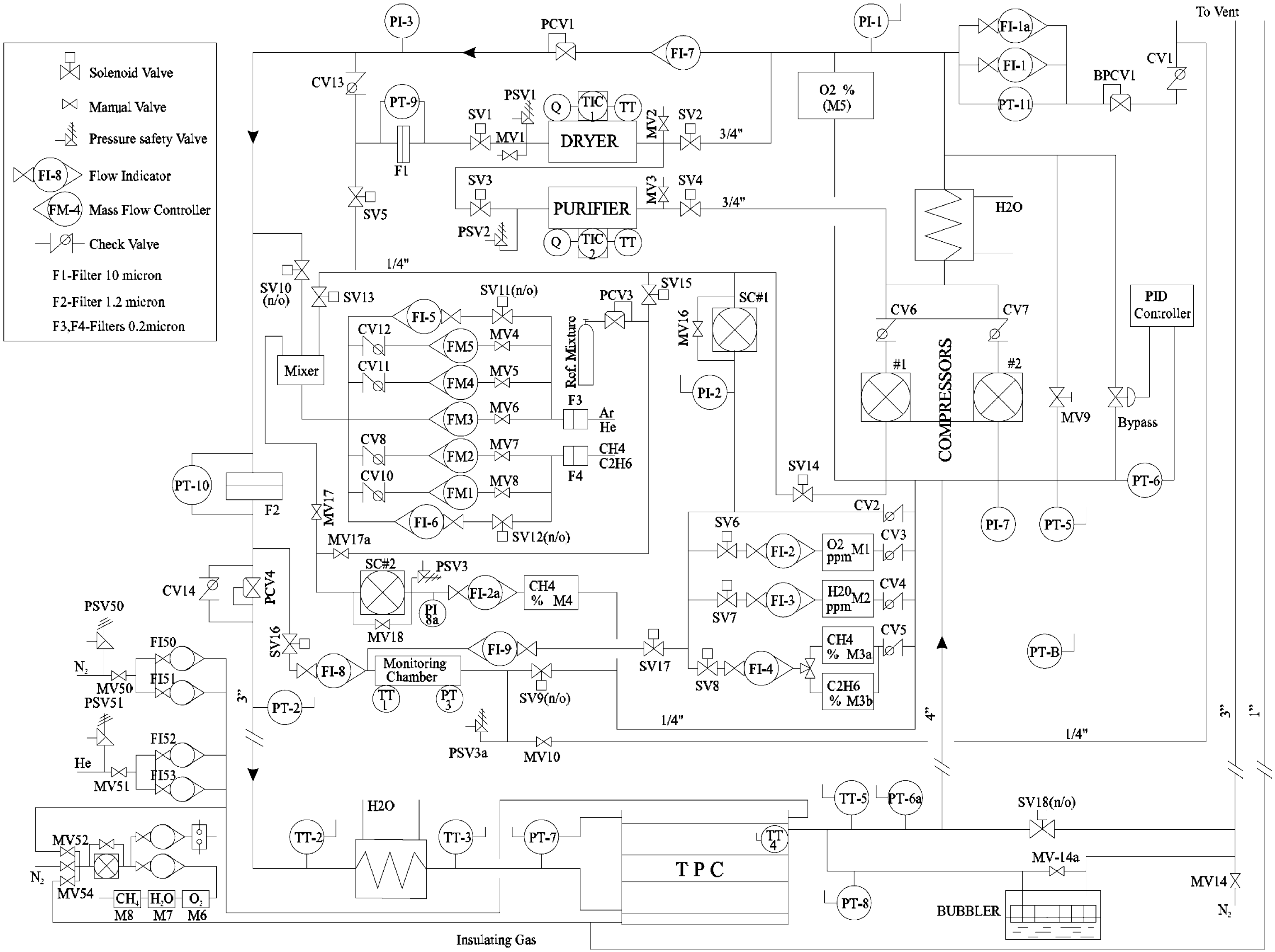

Fig. 1. STAR TPC gas system.

intake. A second bypass valve (MV-9) is manually adjusted to enable the automatic control loop to be used within its optimum range.

The purity and composition of the TPC mixture is monitored using O_2, CH_4 (C_2H_6) and H_2O analyzers. An additional CH_4 analyzer is installed to constantly measure the CH_4 content of the fresh mixture. A fraction of the recirculating mixture can be passed through a dryer and purifier to remove H_2O and contaminants as needed. Fresh gas is provided by the Gas Storage/Supply System.

A computer driven data acquisition/control system (Fig. 2) monitors all of the process variables. The computer system flags quantities that fall outside of predefined limits and initiates corrective action. However, where the safety of equipment or personnel are concerned, a relay-based, hard-wired interlock system connected to a redundant set of sensors controls the action of all key valves. The relay-based controls will bring the gas system to a safe state in the event the computer-based controls fail.

It is imperative, for the safety of the TPC, that the TPC pressure accurately tracks ambient pressure. A rapid change in atmospheric pressure is typical preceding storms and hurricanes, not uncommon in the Long Island area. To assure that the TPC follows a fast rise in ambient pressure, a relatively large flow of inert gas will be admitted into the vessel if normal pressure controls fail to keep up with falling external pressure. The vent lines and associated valves are sized to allow for rapid venting of the TPC gas to prevent a high internal pressure should the external ambient pressure fall faster than the closed system controls can accommodate. A large valve (SV-18) is opened if rapid venting is required and a bubbler connected to the TPC exhaust manifold will vent in the event that all other measures fail. The SV-18 valve is a “normally open” solenoid valve, so it

Table 1
Gas system parameters

TPC Volume	50,000 l
Mixture	($10\pm0.1\%$) CH_4 in Ar, ($50\pm0.1\%$) C_2H_6 in He
Compressor pressure	90–120 mbar
Supply pressure	2.2–2.4 mbar
Return pressure	0.5–1.6 mbar
Internal TPC pressure	2.0 ± 0.03 mbar
Recirculation flow	36, 000 l/h
Purge flow	12, 000 l/h
Make-up gas flow	3.0–33 l/h
Oxygen content	<25 ppm
Water content	<20 ppm

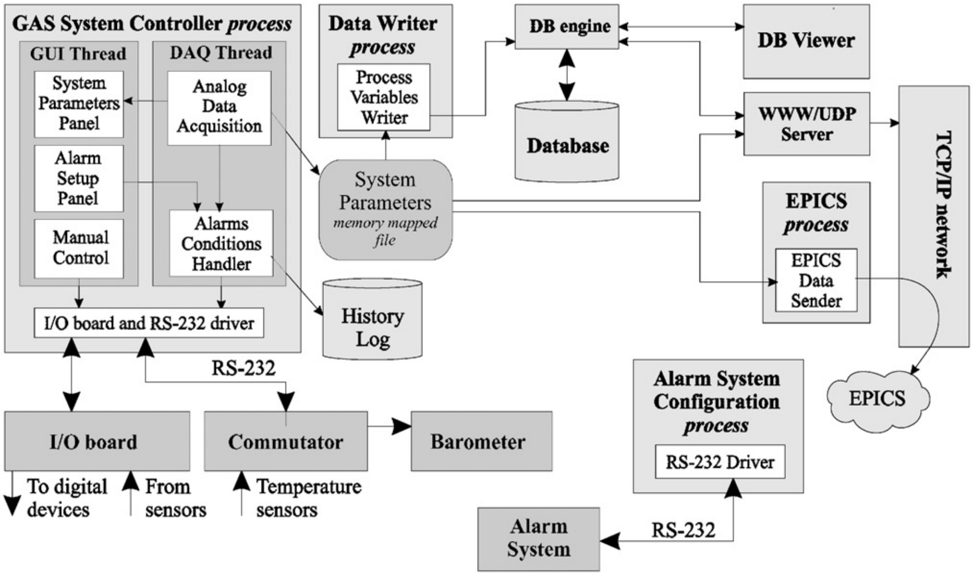

Fig. 2. DAQ and control diagram.

opens automatically when there is a power failure. A restrictive orifice has been placed upstream of the high-pressure regulators to assure that the TPC and vent piping is not overwhelmed by a high intake flow.

1.1. Pressure control

There are two sources of pressure in the gas system. The first is the compressor located at the exit of the TPC. The second is the flow of fresh gas through the mixing manifold. Normally the pressure within the TPC is controlled by maintaining a constant pressure downstream of the TPC by regulating the amount of gas shunted from the compressor output to intake.

As mentioned above, the output from the compressor is 60, 000 l/h at 100 mbar. The back pressure regulator (BPCV-1) in the outlet line maintains the 100 mbar pressure independent of compressor output and provides an exhaust to make up for the influx of fresh gas. Two pressure levels of 30 mbar and 2.4 mbar are controlled by the pressure regulators PCV-1 and PCV-4 upstream of the TPC. The TPC exhaust pressure, measured at the return gas manifold may be maintained in the range of 0.5–1.6 mbar by a Tescom electropneumatic microprocessor PID controller (ER2000). A Dwyer 0–2.5 mbar differential pressure transmitter (PT-6) produces a 4–20 mA output that the PID controller compares to a set point value. If the transmitter signal is different from the set point, the controller sends a pneumatic output signal to the bypass control valve. The bypass shunts flow from the compressor discharge line directly back to the compressor intake. Opening the bypass valve causes the TPC's exhaust pressure to rise and closing it makes the pressure fall. A second bypass valve (MV-9), manually adjusted during the initial system set-up, enables this automatic control loop to be used within its optimum range. Using PT-6a pressure transmitter, setting on the TPC instead of PT-6 permits to have more high TPC pressure stability.

There are additional levels of control in the event the primary pressure control loop fails or is insufficient to keep up with external pressure changes. When the internal TPC pressure, as measured by PT-5 and PI-7, is more than 2.0 mbar above ambient, the gas control system will close the solenoid valves SV-10, SV-20 and SV-21 in the gas supply lines and open the vent valve SV-18 allowing the TPC to vent directly to the atmosphere. If the pressure exceeds 3.0 mbar, the excess TPC mixture will vent to the atmosphere through the bubbler as well. This system of backups protects the TPC from over pressure due to mass flowmeter malfunction, rapidly dropping atmospheric pressure and a failure of the back-pressure regulator.

The TPC is also protected from under pressure. If there is a rapid rise in atmospheric pressure or, effectively, a fast drop in the TPC's internal pressure, the dual set point Dwyer differential pressure transmitter (PT-5) in the return manifold will trip as the pressure falls below 0.5 mbar, causing an audible and visual alarm. If the pressure at PT-5 falls further, to 0.3 mbar, a second set point trips and the computer control system will stop the compressor, shut-off the flow of flammable gas closing SV-21, 21a (Fig. 3) and pass inert gas through the CH_4 (C_2H_6) mass flowmeters by opening valves SV-22, SV-12, SV11 and maintain SV-10 in the open position to supply an additional 300 l/min of inert gas. This system can keep up with a rate of increase of atmospheric pressure of up to 6 mbar/min. An added level of protection against TPC under pressure is provided by another pressure-indicating switch (PI-7) with dual set points installed in the return manifold. This switch is not connected to the computer control system, but, instead, is hardwired to perform the same functions as the computer control system in the event of falling TPC pressure.

To protect TPC cylindrical case from the damage in the case of the overpressure inside the TPC insulation gap, PT7 measures differential pressure. If this pressure is less 0.0 mbar, SV23 will be closed by the control system.

The TPC is also protected from pressure extremes in case of power failure. A power failure will cause solenoid valves, SV-10, 11, 12, 19, 20 and 22 to open or remain open and will cause SV-21, 21a to close, causing 60 l/min of inert gas to flow through the TPC. This flow rate is adequate

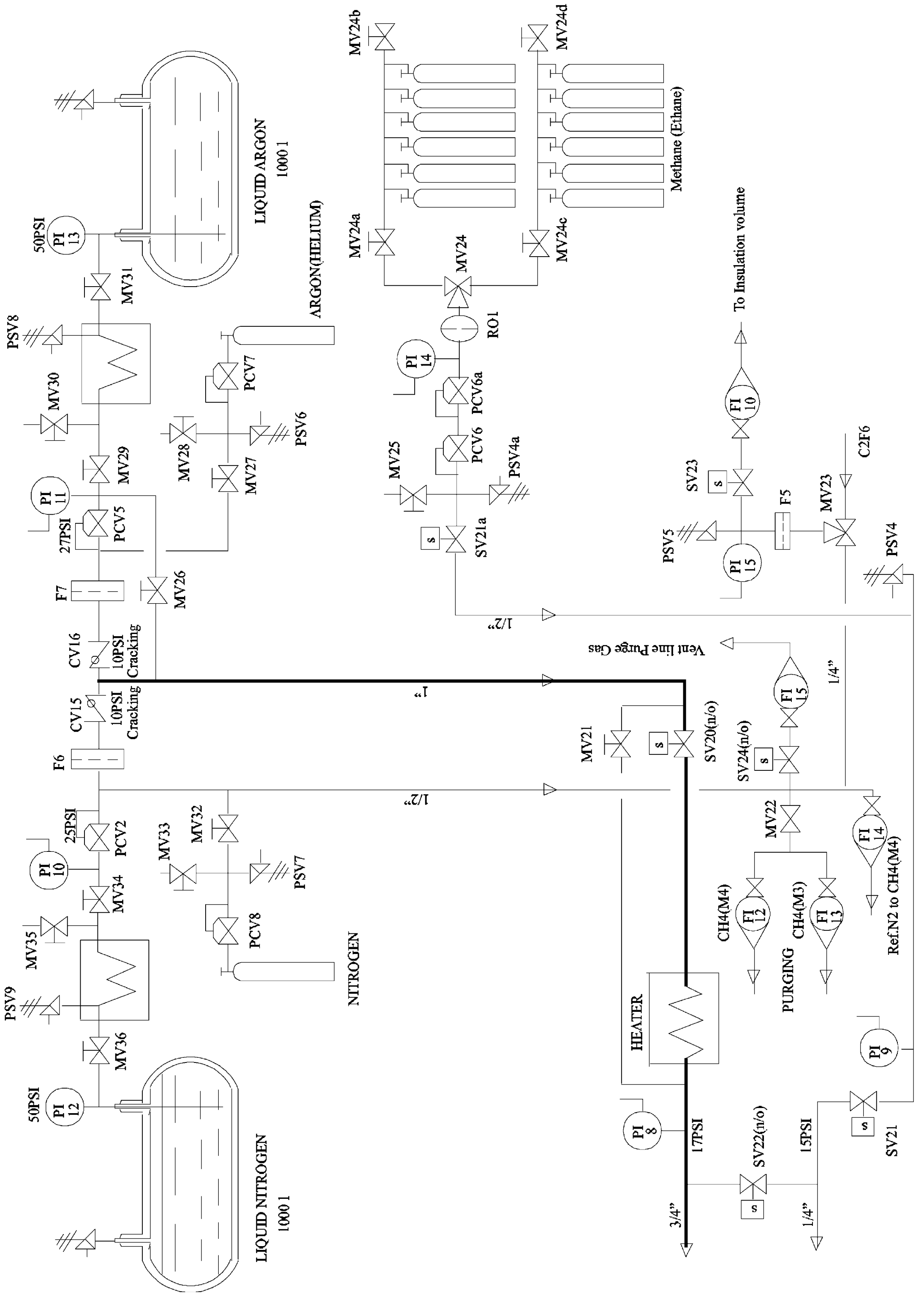

Fig. 3. STAR TPC gas storage/supply system.

to assure that fluctuations in the atmospheric pressure will not result in an excessive external pressure in the field cage and the TPC gas will not be contaminated by air being drawn back in through the exhaust vent. In the event that the Ar (He) supply is exhausted before power is restored, N_2 will automatically flow into the system to assure an adequate purge of all flammable mixtures. This N_2 back up of the Ar (or He) is provided by a completely passive system, see Fig. 3, where the supply of N_2 is maintained at a lower pressure than the Ar (or He) supply. As the primary gas runs out and the pressure falls, the N_2 begins to flow when the pressure exceeds the sum of the primary gas pressure and the check valve-cracking pressure. The check valves (CV-15, CV-16) cracking and reseal pressures were selected in conjunction with the delivery pressure of the primary (Ar or He) gas and N_2 to assure that back flow of either gas does not occur.

1.2. Mixture control

The gas mixture is controlled with mass flow meters, which feed fresh gas into the circulation loop between pressure regulators PCV-1 and PCV-4. The fresh gas mixing ratio is controlled for two different flow ranges by using different sets of flow meters. To rapidly purge the TPC, mass flow meters FM-2 and FM-3 are used to deliver fresh gas mixture at up to 200 l/min. Mass flow meters FM-1, FM-2, FM-3 and FM-4 are used for long term stable delivery at a reduced flow rate of 3.0–33 l/min for Ar–CH_4 or up to 50 l/min for the He–C_2H_6 mixture. The flow meters are operated as master-slave with FM-1 slaved to FM-4 and FM-2 slaved to FM-3. The masters are normally remotely controlled by computer but may be controlled locally if necessary.

1.3. Temperature measurement, drift and gas gain monitoring

Four temperature transmitters (TT-2, TT-3, TT-4 and TT-5) are used to measure the mixture temperature within the TPC. A fifth temperature transmitter, TT-1, measures the mixture temperature within the monitoring chamber. The temperature control of the TPC is a function of the cooling system and is independent of the gas system. The measured temperatures in the TPC are logged in a database.

Drift and Gas Gain measurements are provided by a separate, specially constructed chamber built and tested by Purdue University, for use in this application. Output from this chamber is read and evaluated by a separate data acquisition unit and archived for future reference.

1.4. Mixture sampling

The gas system is equipped with O_2, H_2O and CH_4 (or C_2H_6) monitors plumbed such that each section of the gas system can be selected separately for evaluation. Since some sample points are at low pressure, a small membrane compressor is used to maintain gas flow through the analyzers.

In the interest of safety, a second O_2 monitor upstream of the 30 mbar pressure regulator (PCV-1) provides a continuous monitor of the recirculating gas mixture. If the O_2 content exceeds the 0.1% set point, the flow of flammable gas will be shut off and inert gas will flow in its place. As an added precaution, during P10 running, a dedicated gas monitor at the output of the mixing manifold continuously measures the CH_4 content of the incoming mixture. In the event that the CH_4 content exceeds 11%, the monitor will trip and shut off the flow of CH_4 to the system. All analyzers are read and archived with the computer-based Data Acquisition System.

1.5. Purification

O_2 and H_2O contamination is controlled with a dryer and purifier which withdraw a portion, about 40–45 l/min, of the flow upstream of the 30 mbar regulator and deliver the conditioned mixture to the recirculating flow upstream of the 2.4 mbar regulator. This loop is controlled by the computer control system and used only as needed to maintain low O_2 and H_2O levels.

The dryer is made from a stainless steel tube containing 10 lbs (4.5 kg) of molecular sieve (Zeolite 13X) adsorbent. This amount permits the removal of about 3 lbs (1.4 kg) of water vapor to a level of 2–5 ppm at room temperature. Filters are installed upstream and downstream of the adsorbent to prevent Zeolite dust contamination of the rest of the system. The absorbent column is equipped with a heater coil and insulating jacket for regenerating the absorbent. The dryer is regenerated by heating to 350–400°C while purging with Ar or He gas. The purge gas enters at the top of the dryer and exits at the bottom, carrying with it the water vapor. A temperature transmitter fixed on the outside of the tube and connected to a Dwyer controller (TIC-1) regulates the coil temperature. Solenoid valves installed at the intake and outlet of the dryer isolate the unit from the main circuit when it's not in use. A H_2O analyzer is used to measure the quantity of H_2O in the circuit before and after the dryer to determine when the adsorbent is saturated.

The purifier is similar in mechanical construction to the dryer, but it is filled with a catalyzer that permits the oxidization of CH_4 (C_2H_6) by O_2, present as an impurity, to form alcohol. The dryer subsequently removes the alcohol. The catalyzed oxidization process takes place at 210–220°C. This purifier does not require regeneration but must work in conjunction with the dryer. The dryer can be used separately as required. Initial tests with the TPC show that the catalyzer must be used continuously to maintain an acceptable 19–22 ppm O_2 level with a gas refresh rate of 15 l/min. The equilibrium O_2 level is 60 ppm without the catalyzer.

Two safety valves, PSV-1 and PSV-2, prevent accidental over pressure of the dryer and purifier during purging. A 10-μm filter is installed after the purifier/dryer prevents dust from passing into the main mixture supply line. Dust buildup in the filter is monitored with a Dwyer's differential pressure transmitter (PT-9).

2. TPC gas system control and data acquisition

2.1. Alarm and interlock system

The alarm/interlock system provides warnings, prevents fault conditions and takes corrective action automatically if specified parameter limits are exceeded. These actions include stopping the gas system compressor and shutting off ignition sources in the TPC and turning off flammable gas at the source. The alarm/interlock system design is based on solid-state relays. This system operates in parallel with the computer control system and in many cases provides redundant control. A block scheme of the Alarm system is shown in Fig. 4. A list of fault conditions and the system's response is contained in Table 2.

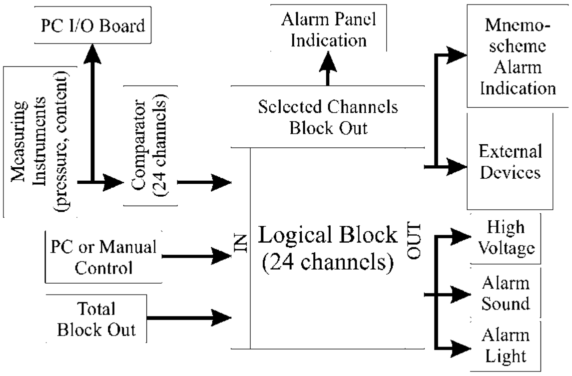

Fig. 4. Block diagram of alarm/interlock subsystem.

2.2. Data acquisition and control

The gas system is controlled by a PC-based DAQ subsystem (Fig. 2) that consists of three separate devices. The first one is a barometer for measuring the atmospheric pressure [3]. The second is a commutator for temperature measurements at multiple points. Each of these two devices is based on an Intel 8031 microcontroller and is connected to the main computer with a standard RS-232 interface. The third device is a custom I/O board, which was developed for the Gas System. This I/O board has 32 analog input channels, 8 analog output channels, 32 digital output channels and, optionally, 8 digital input channels. There are 32 sensors connected to this board: 10 pressure transmitters, 6 pressure indicators, 5 flowmeters, 2 flow indicators and 9 content analyzers. The board also controls 22 solenoid valves, 3 compressors, 2 alarm indicators and an interlock for ignition sources in the TPC. Analog output channels are used to control flowmeters. Each analog input

Table 2
List of fault conditions

Condition	Description	Action
PT1 $<$ 50 mbar	Output of compressor—input of PCV1	Alarm
PT7 $<$ 0.0 mbar	TPC Volume-TPC Gap	Alarm
PT5 $<$ 0.3 mbar	Output of TPC—input of compressor	Alarm, stop compressor & HV, Purge
PT1 $>$ 2.5 mbar	Output of TPC—input of compressor	Alarm, stop HV, Fresh Gas, Open SV18 (Vent)
$CH_4 < 9.0\%$	M3a Methane return gas	Alarm, Stop HV
$CH_4 > 11.0\%$	M3a Methane return gas	Alarm, Stop HV & Methane In
$C_2H_6 < 49.6\%$	M3b Ethane return gas	Alarm, Stop HV
$C_2H_6 > 50.4\%$	M3b Ethane return gas	Alarm, Stop HV & Ethane In
$O_2 > 80$ ppm	M1 Oxygen content of return gas	Alarm, Stop HV & Compressor
$H_2O > 80$ ppm	M2 Water content of return gas	Alarm, Stop HV & Compressor
PT9 $>$ 80 mbar	Pressure across dryer filter	Alarm
PT10 $>$ 12 mbar	Pressure across main filter	Alarm
PS1 $<$ 0.5 mbar	Small compressor	Alarm
$CH_4 > 11.0\%$	M4 Fresh methane	Alarm
PI8 $<$ 0.5 bar	Argon supply Rack 3	Alarm
PI9 $<$ 0.5 bar	Methane supply Rack 3	Alarm
PI13 $<$ 0.5 bar	Argon supply on pad	Alarm
PI14 $<$ 0.5 bar	Methane supply on pad	Alarm
PI15 $<$ 0.5 bar	Nitrogen supply Rack 3	Alarm
PT2 $>$ 2.5 mbar	TPC Inlet pressure	Alarm
$O_2 > 0.1\%$	M5 Oxygen meter	Alarm

channel has overvoltage protection and uses signal averaging (0.2 mV accuracy in 0.7 s) to reduce the noise effect in the cables.

The software for microcontroller devices was written in 8051 assembly code. The barometer software reads out the pressure sensor, shows pressure in one of the three allowed units (mbar, mmHg and kPa) on a LCD indicator and responds to the main computer requests for pressure values. The commutator software provides reading of up to 16 temperature sensors connected in a four-wire scheme. The commutator code also handles four RS-232 ports, one master port for main computer and three slave ports for other devices. One of the slave ports is connected to the barometer. The software accepts requests from the main computer to establish a "transparent" connection to one of the slave ports or to send all the temperature values.

The main computer software (Fig. 2) has been developed with Borland Delphi 5 [2] for Windows 2000. It provides reliable data acquisition, alarm conditions handling and manual control of the Gas System. The software also logs all events and process variables, transfers data to EPICS [4] and publishes all the process variables on the World Wide Web. All these tasks are distributed between multiple processes that communicate making use of special operating system kernel objects.

Gas System Controller is the heart of the DAQ software. In order to make DAQ more reliable it has been divided into two threads: one for the Graphical User Interface (GUI) and one for the data acquisition. The GUI thread is composed of three windows: manual control window, system parameters window that shows process variables, and configuration window for all preferences and settings. The DAQ thread acquires all the process variables, writes them into shared memory and checks alarm conditions. Every alarm settings contains alarm threshold, alarm message and control template, which indicates alarm set and release action for every controlled device, e.g. valve or compressor. This allows user to have a very flexible configuration of system behavior.

The Data Writer reads current process variables acquired by the main process and writes them to the MS Access database. Using a separate process for this critical operation improves overall software stability and decreases response time for gas system events. The EPICS process is very similar. It just sends all process variables to EPICS software through a TCP/IP network [5]. There are two ways for the data—it can be either saved to a remote disk on a Unix machine or sent directly to the EPICS database making use EZCA library for Win32 platform.

All data from the TPC gas system are kept in MS Access database, giving one a possibility to use native MS Access tools for converting and analyzing these data. Besides, this simplifies dramatically access to the certain data in a huge database (for example, 3.5 month database has approximately 200 thousands of records). Sometimes it is useful to get fast results and charts from the database during the gas system operation. A special tool for working with the database has been developed. This program (DB Viewer) provides visualization of the data from any system sensor at any given date for one of three periods (day, week or month). It also allows user to convert data from the database to tab-delimited text file for external analysis. Web server for the gas system was built with Delphi and provides remote access to the database and current system parameters. It also works as a server for the special client using XDR-based UDP protocol.

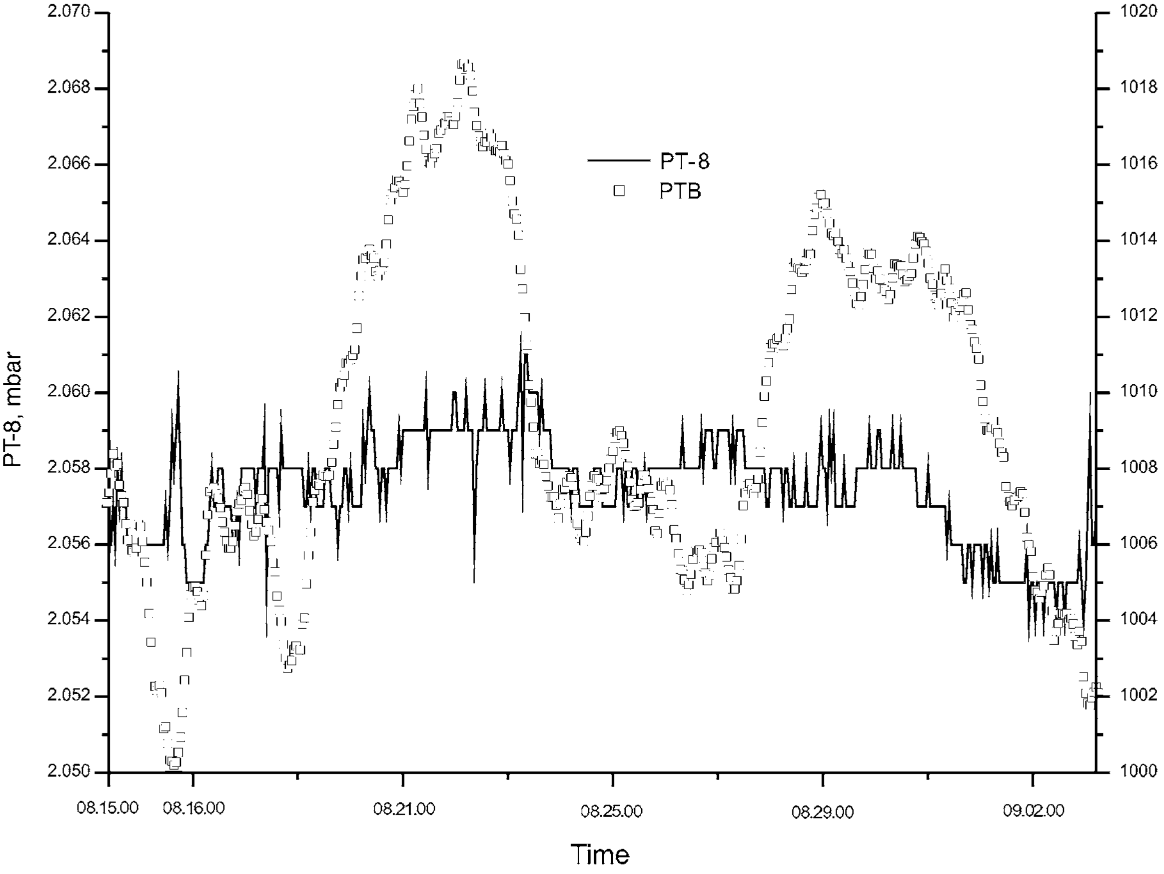

Fig. 5. TPC Pressure stability test. Rectangles correspond to barometric pressure (PTB), TPC internal pressure (PT-8) is shown as a solid line.

3. TPC gas system experimental pressure stability

The STAR TPC Gas System was tested at Lawrence Berkeley National Laboratory and Brookhaven National Laboratory.

The results of the pressure stability test with the full TPC volume are shown in Fig. 5, along with the barometric pressure. In this test the PT-6a pressure transmitter signal was used as the feedback signal by PID Controller. The pressure was measured with PT-8 pressure transmitter setting on the TPC. Although the barometric pressure varied in the range of ±9.3 mbar during the testing period, the inside TPC pressure was stable at 2.057 mbar within the range of ±0.0035 mbar. This shows that the TPC Gas System can support a constant pressure difference between the inside pressure and the outside barometric pressure with a stability of ±0.004 mbar.

Using the PT-6 pressure transmitter as the feedback PID Controller signal gives ±0.03 mbar internal TPC pressure stability.

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NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH Section A

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The laser system for the STAR time projection chamber

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Abstract

The Time Projection Chamber (TPC) is the core tracking detector for the STAR experiment at RHIC. To determine spatial distortions, calibrate and monitor the TPC, a laser calibration system has been built. We developed a novel design to produce ~500 thin laser beams simulating straight particle tracks in the TPC volume. The new approach is significantly simpler than the traditional ones, and provides a higher TPC coverage at a reduced cost. During RHIC 2000 and 2001 runs the laser system was used to monitor the TPC performance and measure drift velocity with ~0.02% accuracy. Additional runs were recorded with and without magnetic field to check $\mathbf{E} \times \mathbf{B}$ corrections.

PACS: 29.40.−n; 29.40.Gx

Keywords: Detectors; Laser; Time Projection Chamber; Calibration; Heavy ions

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1. Introduction

Gas detectors in many modern experiments are large and complex. Assembling, testing, calibrating and monitoring during accelerator runs becomes a difficult task. The introduction of narrow ultraviolet (UV) laser beams to imitate straight charged particle tracks simplifies operating procedures [1]. If the laser beam position and time of appearance is known with high accuracy, repeated measurements provide precise calibration. Laser tracks have no multiple scattering and are not sensitive to magnetic fields. A comprehensive review of detector calibration by laser beams is presented in Ref. [2]. Experiments with gaseous detectors being proposed for new accelerators with much higher particle multiplicity foresee problems with two-particle resolution and distortion due to charge accumulation in the sensitive volume [3]. This becomes especially important at accelerators with high energy, heavy ion beams, where particle multiplicity could reach $dN/dy \sim 2000$–5000. To monitor these distortions, more calibration tracks are required. In this article we briefly describe the laser system for the Time Projection Chamber (TPC) in the STAR experiment at the heavy ion collider, RHIC [4].

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2. Laser system requirements

The main tracking detector in the STAR experiment is a TPC [5]. The task of the TPC is to provide track reconstruction, momentum measurement and particle identification. The STAR TPC is a cylinder 4 m in diameter and 4.2 m long, with a 0.5 T axial magnetic field. The TPC volume is bounded by coaxial inner and outer field cages (IFC, OFC) connected to end cap wheels with multiwire proportional chambers (MWPC) on the end wheels. The working gas for the MWPC is 90% argon and 10% methane (P-10). A high voltage membrane at the TPC center with resistor chains on the field cages creates a uniform electric field along the Z-axis (parallel to the magnetic field) in which electrons produced by charged particles drift to the end cap MWPCs. Measured drift time and the drift velocity provides the coordinate along Z, while induced signals on the pad rows provides spatial coordinates in the MWPC plane.

Physics goals for the STAR experiment impose 10% momentum resolution for a particle with a transverse momentum of 10 GeV/c. This requires an accuracy ~200 μm in the sagitta measurement of the curved particle trajectory. The errors in the Z coordinate must be well under 1 mm. There are several sources of uncertainty in track coordinate measurements:

1. Variation in drift velocity caused by gas mixture, temperature, pressure and electric field variation.
2. TPC misalignment in the magnet and existence of the global $\mathbf{E} \times \mathbf{B}$ effect.
3. Radial inhomogenities of magnetic and electric field.
4. Space charge buildup due to high multiplicity in Au–Au collisions.
5. TPC endcap wheel displacement and inclination.

At maximum RHIC energy, Au–Au collisions create ~2000 charged particles in the TPC volume which could produce charge accumulation and track distortions [6], especially near the IFC region at ~0.6 m radius. These distortions varied significantly along the Z-axis in the TPC [3,6]. To see all spatial variations throughout the TPC volume it is desirable to increase the number of laser beams up to 100–400 for one-half TPC. Considering these issues we specified for the STAR laser system:

1. Number of laser tracks ~100–400 in each half of the TPC.
2. Laser beams should fill the TPC volume uniformly.
3. Electron density along the laser beam in any point must be higher than ionization from relativistic particles.
4. The accuracy of the position and stability during operation of each laser beam at any point must be smaller than ~200 μm in azimuthal and radial directions and smaller than ~700 μm in axial direction.
5. Synchronization of the time of the laser beams appearance in the TPC volume to the RHIC clock within ~5 ns error to provide ~0.01% accuracy in drift velocity measurements.
6. Laser system must provide alignment, steering and stable position of laser beams with the accuracy specified above.

3. Laser system description

As shown in many investigations [2,7], UV-laser beams produce ionization in gaseous detectors via a two-photon ionization process of organic substances, which are commonly present in the detector volume at ~ppb level. A Nd-YAG frequency-quadrupled laser ($\lambda = 266$ nm) with energy density about 1–20 μJ/mm^2 can produce ionization equivalent to a relativistic particle (mip) in common gases without special additives.

There are two optics designs widely used to produce multiple narrow laser beams. In the first design a powerful laser beam is focused by a demagnification telescope to ~1 mm diameter beam with the smallest waist positioned in the detector center. This beam is split by semitransparent mirrors, installed on an inner surface of the detector (ALEPH TPC [8]), or on a separate optical bench near the detector (EOS TPC [9]). There are several difficulties in this design. The number of narrow beams is limited by mirror coating resistance to laser radiation. The safe energy level for dielectric coating and UV radiation is $\sim 0.1\,\mathrm{J/cm^2}$ [10], so only ~100 laser beams could be formed by one laser. It is also difficult to produce approximately equal beam intensity by splitting a single laser beam through multiple mirror stacks. In a second design a low power laser beam is focused by the previous method. This beam is then directed by steering mirrors into the TPC volume in different directions. The difficulty with power density is replaced by stringent requirements on stability and repeatability of mechanical drivers for the steering mirrors. For a detector with the size ~5 m and laser beam stability on the level of $\sim 100\,\mu\mathrm{m}$, the angular movement of the mirror must be controlled to $< 10^{-5}$ rad. This approach also significantly increases the time required to provide full chamber calibration. This kind of laser system was used in the OPAL jet chamber [11], the NA49 TPC [12] and the CERES TPC.

We proposed a novel design to produce a large number of narrow laser beams by splitting a wide laser beam with a diameter ~20–30 mm by many small diameter mirrors, installed in a region of approximately equal intensity. Small mirrors are made from glass rods, cut at 45°, polished and covered by dielectric coating with 100% reflectivity (Fig. 1). More effective use of the wide laser beam is accomplished by gathering the small mirrors in bundles; in our design there are 7 small mirrors in each bundle. Each mirror in a bundle is rotated to create different directions for the calibration beams in the TPC volume.

The creation of a thin beam by each small mirror is the same as the diffraction of the plane wave through a small circular aperture [13]. The spread and size of the diffraction pattern is defined by the Fresnel number $N = a^2/\lambda z$, where a is the aperture radius, λ the wavelength of the laser light and z is the distance from the aperture to the viewer. For $N < 1$ the so-called Airy-disc diffraction pattern is created. For 0.5 mm radius and $\lambda = 266\,\mathrm{nm}$, $N < 1$ if $z > 1\,\mathrm{m}$. The divergence of the Airy disc, $\theta = 1.22\lambda/2a$, is comparable with divergence of the beam from focusing telescopes, $\theta = \lambda/\pi a$ (~0.17 mrad for $a = 0.5\,\mathrm{mm}$). In the near field region, when the Fresnel number $N = d^2/4\lambda z > 1$ ($z < 1\,\mathrm{m}$) the laser beam is confined in a ~1 mm diameter cylinder.

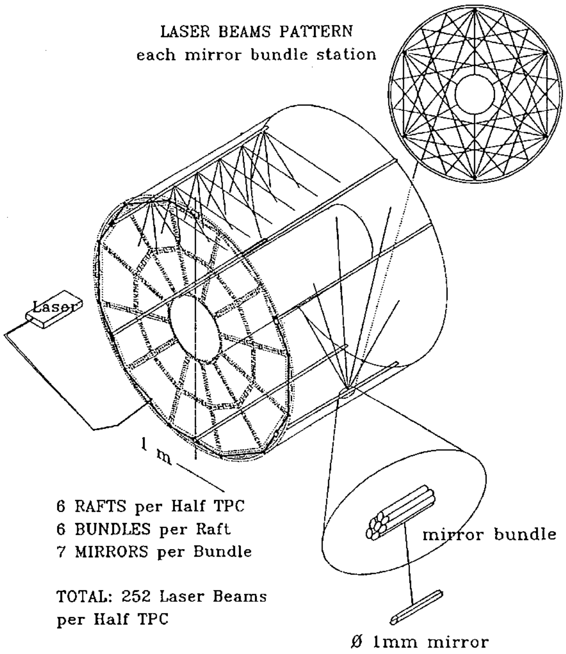

Fig. 1. Conceptual design of the laser system.

The production of thin laser beams by single small mirrors installed in wide laser beam was used in the laser calibration system for the 1.5 m streamer chamber of the magnetic spectrometer SCAP (IHEP) [14].

The advantage of the design is that the initial point in space of each thin laser beam is completely defined by the position of the small mirror and only deflection of the wide beam could change the direction of the thin beam. One half of the laser system is presented schematically in Fig. 2. The Nd:YAG laser GCR-130-10 [15] operates in Q-switched mode to obtain high power laser pulses of ~3–4 ns duration. A Glan-laser polarizer and rotating half-wave plate are used to change the laser power over a wide range to produce calibration beams with different ionization. The laser beam is expanded by a telescope to ~30 mm diameter and directed to the TPC endcap wheel through a hole in the magnet steel. On the TPC outer radius a system of dielectric splitters

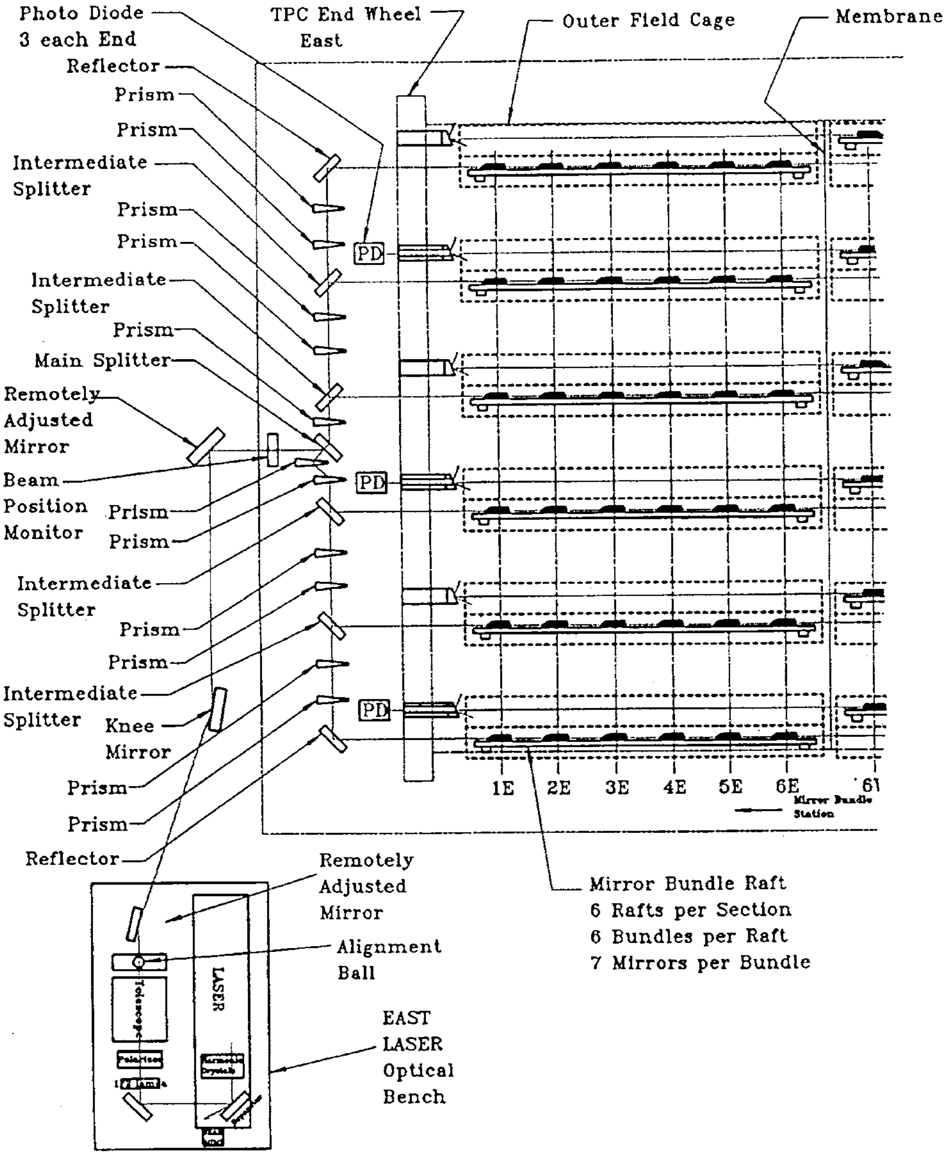

Fig. 2. Optical scheme for one-half TPC.

and prisms are installed to rotate and split the wide beam into 6 beams with equal intensity. These beams are directed to positions 60° apart along the inner surface of the OFC parallel to the Z-axis of the TPC. There are 6 rafts installed parallel to the laser beams. Square glass tubes $\sim 1500\,\text{mm}$ length were used for the raft as a rigid and stable support for mirror bundles. Three-ball supports are glued to each raft to decrease the influence of OFC distortions. Six bundles are installed on each raft $\sim 300\,\text{mm}$ apart and uniformly occupy the wide beam. These bundles produce seven different directions of thin laser beams, covering approximately uniformly the whole TPC volume. This design provides $(6 \times 6 \times 7 = 252)$ laser calibration beams for each half of the TPC. In addition, the residual beam, which survives after passing through the raft, is directed through a slot in the central membrane towards diffuse reflectors, installed on the opposite TPC wheel. Reflected from these diffusers, UV light illuminates the central membrane, which is made from carbonized kapton with a pattern of 3 mm wide aluminum stripes glued on. Electron clouds emitted from the stripes by a one-photon ionization process provide signals similar to the laser beams in the TPC volume. The membrane pattern covers all the TPC sectors at the maximum drift distance and was used to align TPC sectors.

4. Laser subsystems

4.1. Bundle production

The main element in this system is the bundle of small mirrors. We produced small mirrors with different diameters (Fig. 3) to determine beam formation, technology and assembly procedures. A mirror smaller than 1 mm diameter creates significant divergence, and difficulties with production and alignment. Bigger diameter required wider beams, increased laser power and optics sizes. We therefore chose 1 mm as the basic diameter for mirrors to produce thin beams with good quality up to 4 m. A support was designed to install and adjust the position and angle of each 1 mm mirror in a bundle. The mirrors were then glued together in a metal collar. Two sets of mirror angles were used to provide more uniform TPC coverage. The relative mirror position in each bundle was measured with an accuracy ~30 μm. A special installation was developed to measure all angles between mirror faces. A vertically aligned wide laser beam shines on the bundle, installed on the top of a theodolite. Reflected thin laser beams are directed to a quadrant detector, installed on a vertical stage. The position of the beam was determined with ~100 μm accuracy at 4 m distance from the theodolite, and an accuracy of ~0.025 mrad for the horizontal angle was achieved, while the vertical angle was measured by the stage with an accuracy ~0.12 mrad. After these measurements, the bundles were assembled on the raft, the position of each bundle was measured with ~100 μm accuracy and 12 rafts with bundles were aligned inside the TPC volume. Finally, the position of each mirror in the TPC coordinate system was measured with ~200 μm accuracy.

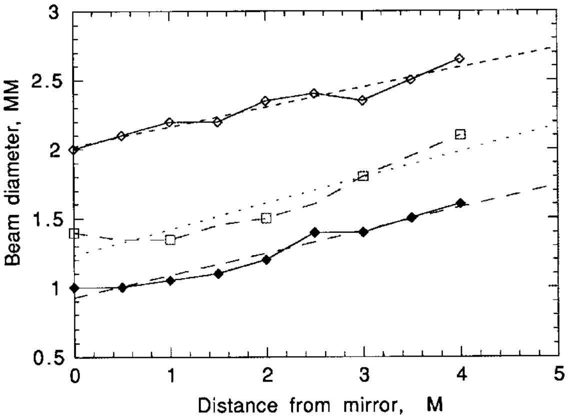

Fig. 3. The formation of thin laser beams by small mirrors.

4.2. Laser beam characteristics

Linear electron density along the laser beam was measured by a drift chamber filled by P-10 gas with a 2 cm sensitive region along the anode wire.

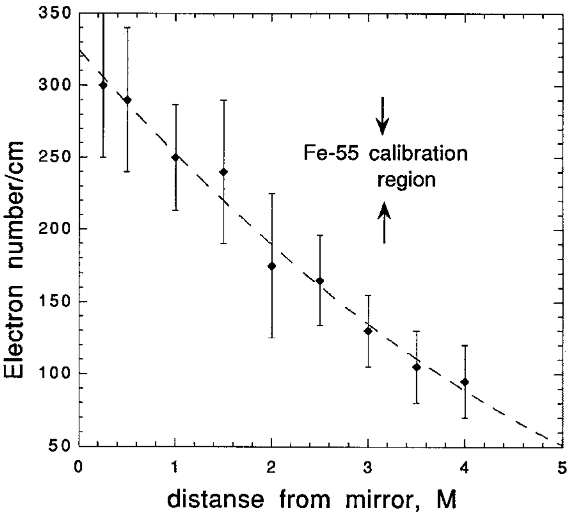

Fig. 4. Linear electron density from a laser beam created by a 1 mm mirror.

The laser beam was directed parallel to the anode wire, entering the drift volume through a quartz window. The linear electron density at distances up to 4 m from the 1 mm diameter mirror is shown in Fig. 4. A laser power density of ~1–2 μJ/mm^2 was enough to produce ionization close to mip. Due to the quadratic dependence of two-photon ionization on the power density we can estimate the "electron" divergence of a laser beam in a drift chamber assuming uniform power density across the laser beam. Assume N_p is the number of photons in a laser beam with diameter $d = d_0 + \alpha M$, N_e is the linear electron density and M is the distance from the drift chamber to the small mirror. Then $N_e = N_p^2/S$, where S is the beam area, $S = \pi d^2/4$, and for N_p-const, $N_e \sim 1/(d_0 + \alpha M)^2$. A fit from experimental data yields an "electron" divergence $\alpha = (0.16 \pm 0.04)$ mrad, which is close to the optical divergence, $\theta = 2\lambda/\pi d$ ($\sim$0.17 mrad for $d = 1$ mm).

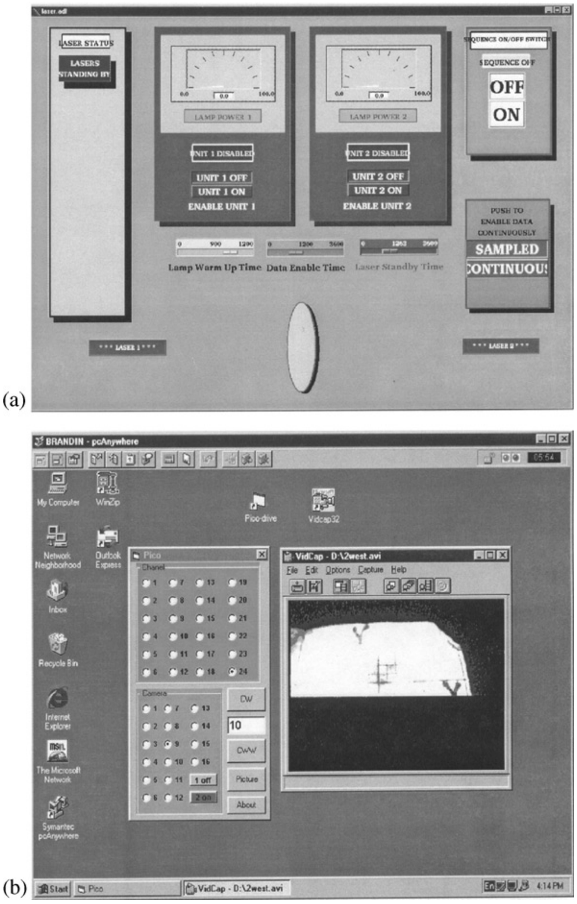

Fig. 5. Remote computer windows to operate the laser system: (a) control window for laser operation, (b) window to align and monitor laser beams.

The total number of laser beams is determined by the wide laser beam area and the number of bundles occupying it. Bundles are installed along the Z-axis about 30 cm apart. Diffraction from the bundle supports could distort the uniformity of the wide laser beam, so we investigated the influence of the transverse distance between bundles on a raft on the thin laser beam position and electron density. For distances smaller than 0.5 mm, linear electron density starts to decrease. For reliability and ease of adjustment a 1 mm radial distance between bundles was chosen. At this distance no laser beam disturbance was observed.

4.3. Monitoring and beam steering

Remote laser operation used the global TPC operations slow control infrastructure. A graphical user interface (GUI), accessible on a PC in the STAR control room using EPICS [21] (Fig. 5a) provides start–stop procedures for the selected laser and defines run time. The Poisson line reference method [16] was chosen to perform positioning and steering of the wide laser beam. After the expanding telescope a 3 mm ball is installed in the center of the wide laser beam

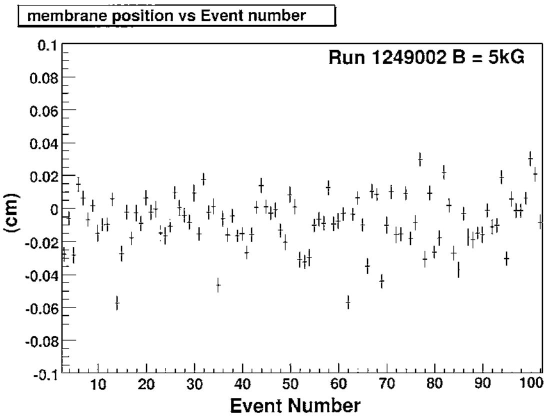

Fig. 6. The membrane position stability using a trigger synchronized with the RHIC clock.

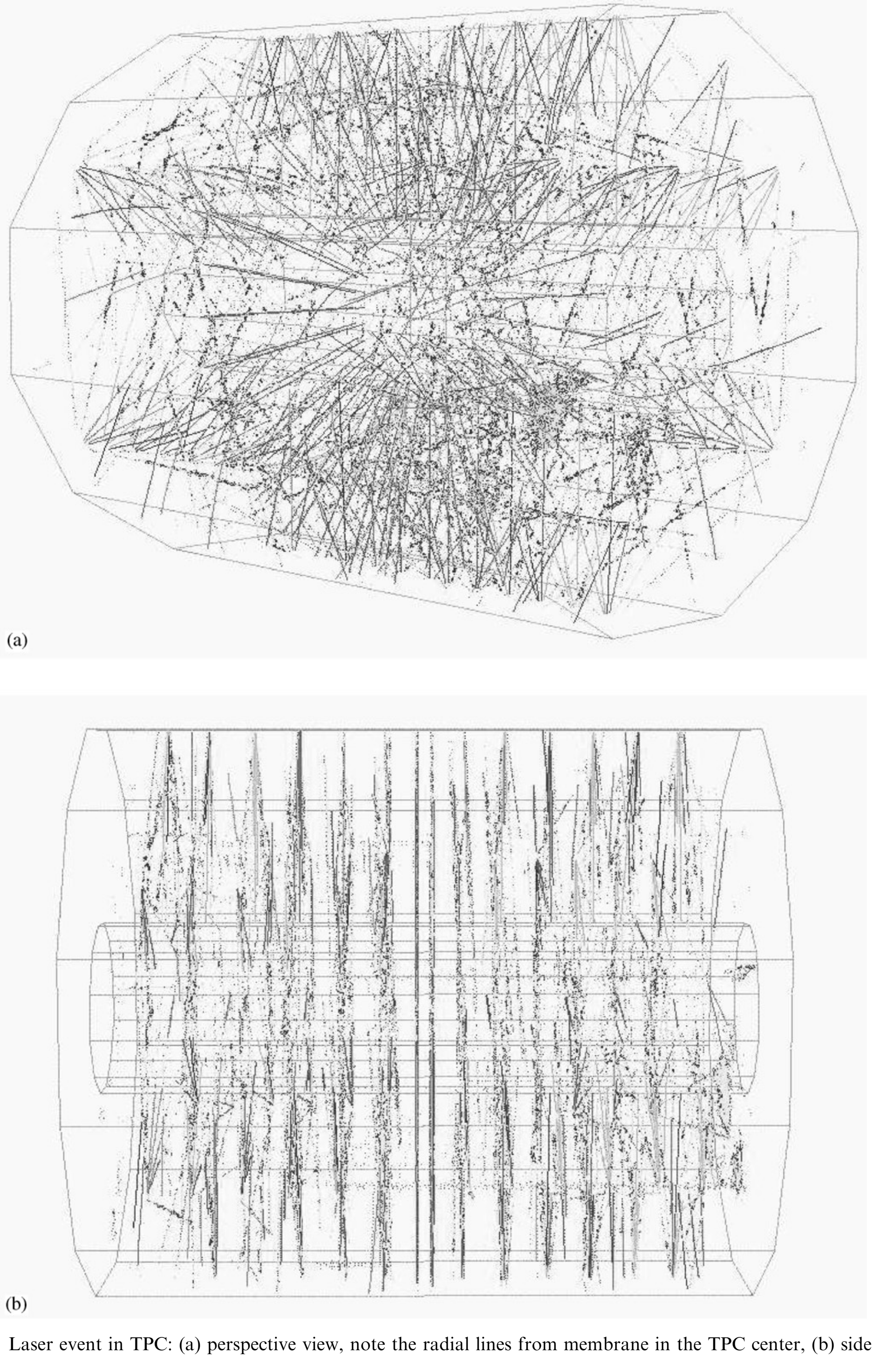

Fig. 7. Laser event in TPC: (a) perspective view, note the radial lines from membrane in the TPC center, (b) side view.

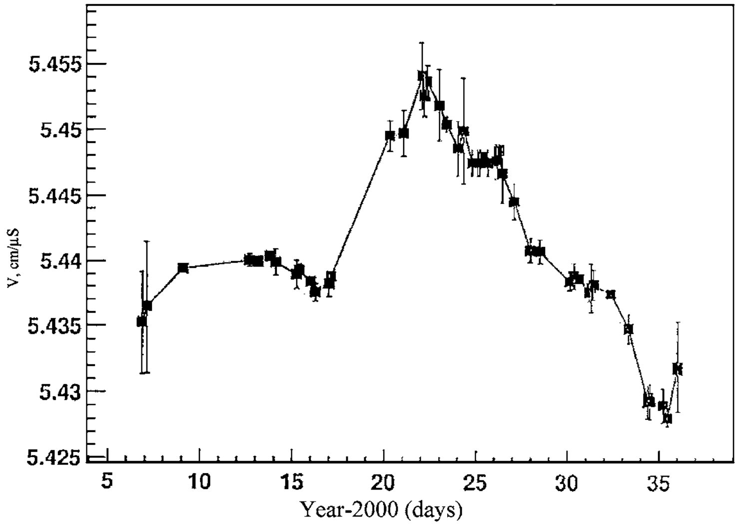

Fig. 8. Laser drift velocity measurement over one month during year 2000.

(Fig. 2). In the center of the dark shadow a bright spot appears, and a very thin "Poisson beam" is created. The divergence of this "Poisson beam" is extremely small, ~0.05 mrad at 266 nm wavelength. A quadrant detector or CCD camera could easily monitor this beam. The quadrant detector is workable only with an additional diaphragm, cutting the bright field of wide beam, and this circumstance decreases the region of steering operation for wide beam by ~1 mm. A miniature CMOS CCD camera (type MC-MRB-4 [17]) with lens and fluorescence screen ~20 mm diameter was chosen to pick up the laser beam image. This camera could work in 1.0 T magnetic field. The screen has a mm scale grid, so viewing and alignment of the laser beam becomes a convenient procedure. Compact piezoelectric picomotor drivers were chosen [18] to provide mirror adjustment. The driver has a resolution <0.1 µm, minimum backlash and insensitivity to magnetic field. Remote control over the piezodrives and CCD cameras was installed on a PC computer. Another GUI (Fig. 5b) was used to provide observation of the laser beam through the set of four CCD cameras installed on the TPC and operation of 24 piezodrivers to monitor and align the laser beam with ~200 µm accuracy. This system was used to correct shifts of the laser beam position due to magnetic forces. From zero to full field the position of laser beam at the TPC entrance shifted up to 3 mm.

4.4. Laser trigger

The laser operation frequency is (10 ± 0.5) Hz. A TTL pulse triggers the xenon lamps to pump the YAG crystal and after ~180 µs a second TTL pulse provides Q-switch opening. After ~30–40 ns an UV pulse is emitted from the laser. A signal from a photodiode is used as a start signal for TPC readout. STAR detectors were synchronized with the RHIC clock (~10 MHz). The laser trigger board accepts an external RHIC clock signal and provides, simultaneously for both lasers, a trigger for the lamp and Q-switch synchronized with the RHIC clock with a jitter ~5–6 ns. In Fig. 6 the mean position of the central membrane, measured by electrons from the Al stripes, for the synchronized laser is presented. We achieved an accuracy ~200 µm in determining Z-coordinates, which affects the error in drift velocity measurement.

5. RHIC runs results

The laser calibration system was used extensively during TPC test runs with cosmic rays starting in 1997. Reconstruction of the laser events

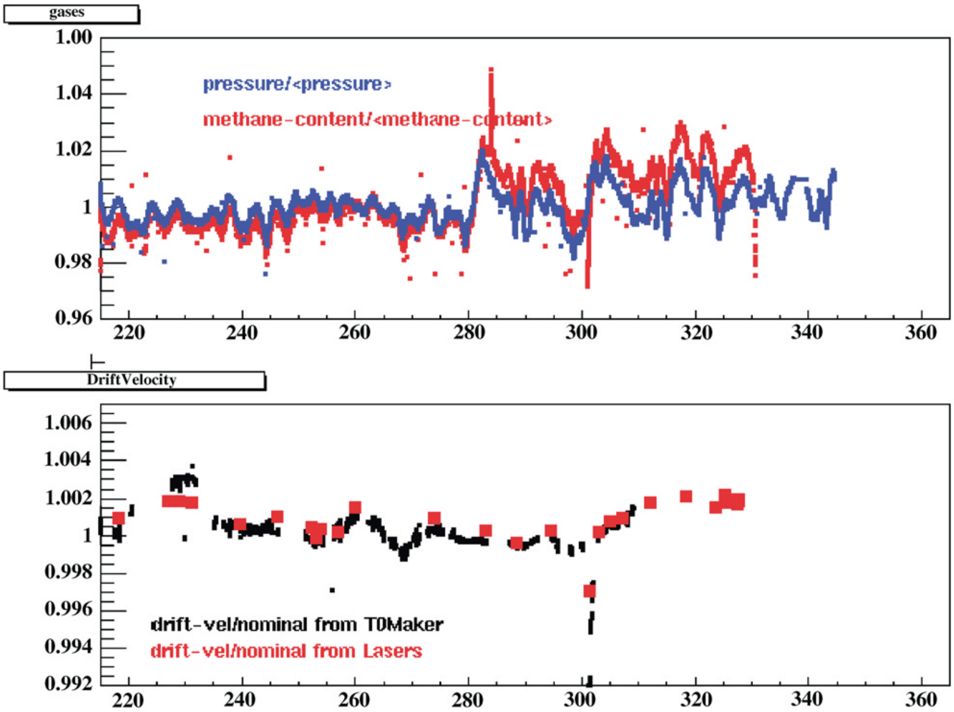

Fig. 9. A comparison of laser drift velocity measurements for year 2001–02 using the laser system and by matching TPC vertices from each half (T0Maker). The top panel shows the variations of the TPC pressure and methane content for the same period.

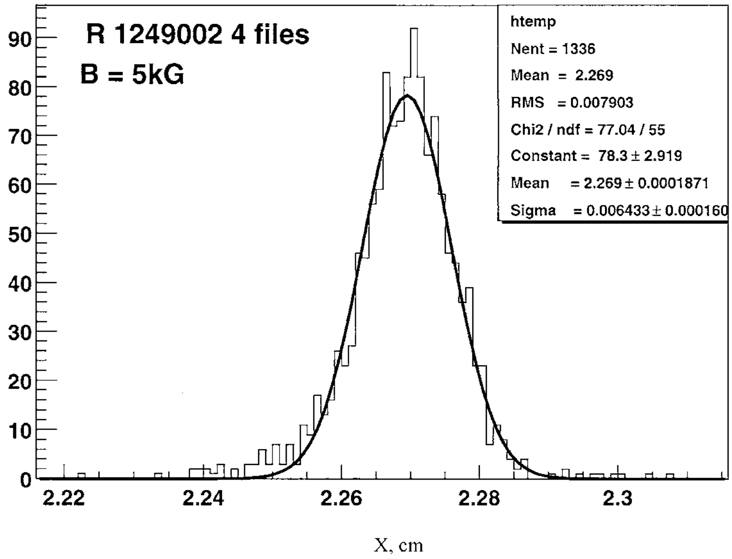

Fig. 10. Pointing stability of laser tracks.

helped to recognize errors in tracking code, wrong cabling and non-functioning readout electronics. Laser data were used to align the inner and outer sectors. Also lasers were used to check the clock frequency by matching the membrane image for both TPC halves.

During the summer of 2000 about 80 laser calibration runs were recorded. Precise drift velocity measurement is crucial for physics analysis and to match tracks across TPC halves. For each physics run a laser calibration run was recorded, containing ~500 events. A typical laser event with different projection views is presented in Fig. 7. Approximately 450 laser tracks are recorded in a single event. Radial lines in the TPC center are the image of the Al stripes on the central membrane. For analysis of this event a time offset of ~500 ns was used to separate the central membrane images for display.

A drift velocity was determined using the Z position difference of the mirror positions for the sets of laser tracks closest to and furthest from the pad plane. Tracks were extrapolated to the mirror's X, Y position and the ratio of the measured dZ and the survey dZ was used to scale the input velocity. In Fig. 8 the laser-measured drift velocity monitored over a one month period is shown. There are several parameters affecting drift velocity: barometric pressure, cathode voltage, temperature, clock frequency, methane concentration and unknown additives in TPC gas. We estimate that the most influential parameter is methane concentration. To check systematic error in our data the ratio $R = W(\text{east})/W(\text{west})$ was calculated, where W(east) and W(west) are data for two TPC halves. For all laser runs $R = 0.999991 \pm 0.000225$.

In addition to using the laser system, the drift velocity in TPC could be calibrated by matching the primary vertices reconstructed independently in each half of the TPC. This method works best for high multiplicity events and is not usable for low multiplicity events such as p + p collisions. For p + p runs, the laser drift velocity calibration was used exclusively. During RHIC 2001–02 run, a special trigger was implemented to interleave laser events in a physics run, and a comparison of the two methods of drift velocity determination is shown in Fig. 9. On-line software provides a fast calculation of drift velocity using the laser triggers, and these results are monitored to look for problems with TPC gas. The dip in the drift velocity near day 300 caused by a temporary methane loss in the gas system.

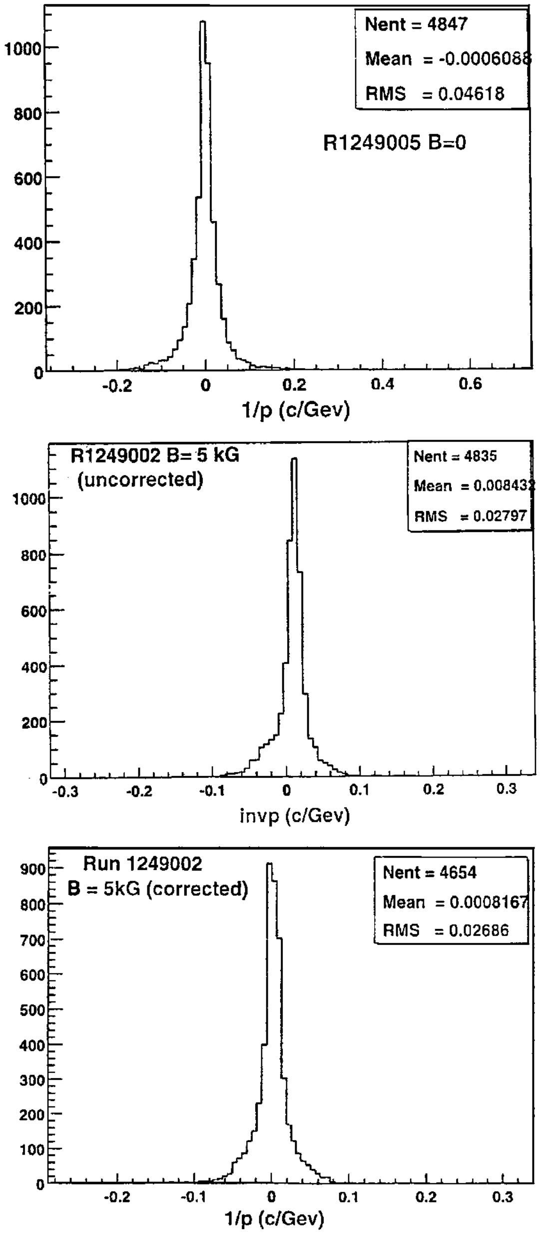

Fig. 11. Histograms of inverse momentum distribution for radial laser tracks: $B = 0$, $B = 0.5\,\text{T}$ (no $\mathbf{E} \times \mathbf{B}$ corrections), $B = 0.5\,\text{T}$ (corrected for $\mathbf{E} \times \mathbf{B}$ distortion).

We measured the position stability of laser beams to understand the limits of accuracy of the system. Fig. 10 shows a histogram of transverse position for a powerful laser beam with ionization ~10 mip. The error (sigma) on the level of ~64 μm confirms our expectations about laser track stability. For a laser with ionization ~1–2 mip, stability is ~150–200 μm.

The momentum resolution of the TPC is defined by accuracy in sagitta measurement and multiple scattering. For high momentum tracks the influence of multiple scattering is negligible. For high momentum the resolution is $dp/p = Ap/B$ [19], where p is the particle transverse momentum, B-the magnetic field and A is the error in sagitta measurement. There are several factors affecting A: the track length, the accuracy in point measurement on the particle trajectory and the number and the position of these points. Laser tracks, which could be represented as particles with infinite momentum, are an excellent tool to determine all these errors. Distribution of inverse momentum $f = 1/p$ for radial laser tracks provides systematic effects, a limit in determining particle momentum and TPC momentum resolution. The width of the histogram f, $df = (dp/p)1/p$ provides a direct value of A. Data without B field represents systematic error in global reconstruction. Although extensive and detailed $\mathbf{E} \times \mathbf{B}$ corrections were made with particles from central Au–Au collisions, it is useful to check these corrections with laser tracks. Fig. 11 shows corrected and uncorrected f-distributions. The data shows small systematic errors and the ability to measure particle momentum with designed accuracy.

An upgrade for the laser system foreseen in the near future is a fully automated system to monitor and align lasers for the TPC and a calibration procedure for another tracking detector in STAR—the Forward TPC (FTPC) [20].

6. Summary

The results reported here show the durability of the STAR TPC laser calibration system. During the RHIC 2000 and 2001–02 runs the laser system was used to measure the drift velocity with ~0.02% accuracy and monitor the stability of the TPC electronics. This system was expanded to calibrate and monitor Forward Time Projection Chambers. Further improvements in TPC global position accuracy will be implemented with more laser data.

Acknowledgements

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TPC

Valid for RUN 7 and beyond 3/1/2007
Minor Updates by Jim Thomas 7/14/2009

TPC
SHORT OPERATIONS MANUAL FOR DETECTOR OPERATORS

(written by Blair Stringfellow)

Table of Contents

1. Rules of Operation

1.1 FEE's (Front End Electronics)

There are two sets of FEEs (and RDOs) for the TPC:

1. The pad plane FEE's
2. The MWC FEE's that terminate the anode wires.

Both sets are cooled by the TPC water skid (nominal temperature = 75 F). The temperature is monitored by a computer program which periodically reads out 120 thermistors mounted on the FEE and RDO cooling manifolds. These temperatures are displayed in a GUI available from the top level TPC GUI. These temperatures are also watched by the TPC alarm handler (alarm = 80 F).

RULE 1: If the overall average reads > 80F, power down the FEE's and MWC FEE's until the cooling problem is solved.

The TPC water skid exchanges heat with the STAR Modified Chilled Water (MCW). To maintain the TPC at 75, the MCW must typically be < 64F. A problem with the TPC cooling water temp can usually be traced to a MCW problem. Note also that the FEE's are interlocked to the TPC water skid – a loss of flow will automatically turn off the FEE's.

Because of an uncertainty about induced currents associated with the magnet, we also have:

RULE 2: Turn off all FEE's and MWC FEE's when the magnet is being ramped up or down.

1.2 HV

Ultimate responsibility for the safe operation of the TPC rests with the Detector Operator! For this reason, the final authority for turning on (and off) the HV also rests with the detector operator. To protect the TPC, the most important rule is:

RULE 3: The anode and cathode HV are to be kept OFF UNTIL RHIC has stable stored and cogged beams. There are NO exceptions to this rule except by explicit permission from Blair Stringfellow or Howard Wieman.

We have seen both field cage sparkdowns and multiple anode trips that were clearly beam induced. This can happen at any energy and any intensity. Note that this means turning ON the HV AFTER the beams are stored AND turning OFF the HV BEFORE the beams are dumped. It is the detector operator's responsibility to encourage the shift leader to always get advance notice of a beam dump.

1.3 Frequency and method for Pedestal Runs

It is now possible to save the TPC pedestal values on disk, so a DAQ reboot doesn't necessarily mean having to take a new pedestal run. Pending further study, it is recommended to take a pedestal run at least once per shift. Pedestal runs are configured through trigger and DAQ. Number of events > 250.
The state of the TPC should be:

FEE's and MWC FEEs ON
Gated Grid ON
Cathode HV on or off
Anode HV at pedestal values or less (pedestal values are Inner = 500V, Outer = 500V)

1.4 Frequency and method for Laser Runs

Laser runs are used to check the TPC drift velocity, and should be taken once a store, usually 1 hour into the store. (The STAR Period Coordiantor may define a different schedule so check with your shift leader or the STAR Period Coordinator for an update on this schedule.) You should stop the current physics run and make a dedicated laser run. (Include Trigger, DAQ and TPC in run control – NO other detectors.) The DAQ rate for a normal laser run should be 10 Hz, triggered by the free running laser. To turn on the laser see the separate laser operations manual. The TPC's operating parameters (HV) are the same for laser runs and physics runs. The TPC drift velocity is automatically calculated online from event pool events. The result shows up in the online histograms. Typically, ~ 2000 laser triggers are sufficient to calculate a drift velocity. For long stores (typical of pp) take a laser run every ~ 4 hours after the first one.

1.5 Frequency and method for TPC Pulser Runs

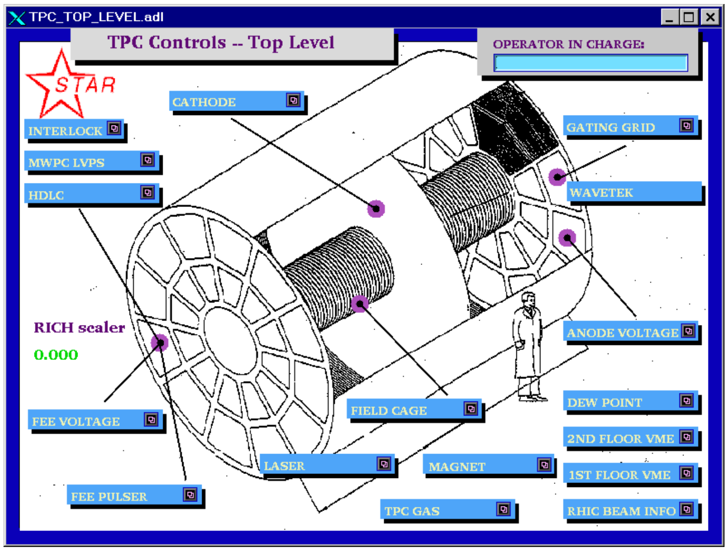
Pulser runs are used to check the TPC FEE's and RDO's. They can be taken at any time by reconfiguring trigger and DAQ for a pulser run. A pulser run should be taken once a day, typically during times with no beam. For a pulser run:

Use the LOCAL oscillator (not the RHIC clock)
Make a TPC pedestal run, then a pulser run.
FEE's and MWC FEE's ON
Gated Grid On
Cathode On or Off
Anode Off or at or below pedestal values (Inner = 500V, Outer = 500V)

2. Operations for Various Subsystems:

2.1 Boot & setup of Control Computer

All operations for the TPC are controlled from the PC Chaplin-XXX.starp.bnl.gov located in the STAR control room. To get started, log on to Chaplin (username and password posted in the shiftleader's notebook). After boot, start a putty session to sc5.starp.bnl.gov and start the TPC top level control GUI by issuing the command "tpc_top". The startup sceen looks like this: (this process is slow – WAIT)



RICH scaler 0.000

To simplify the controls for the various subsystems. Chaplin is set up to run 9 virtual desktops, each labeled for a specific function:

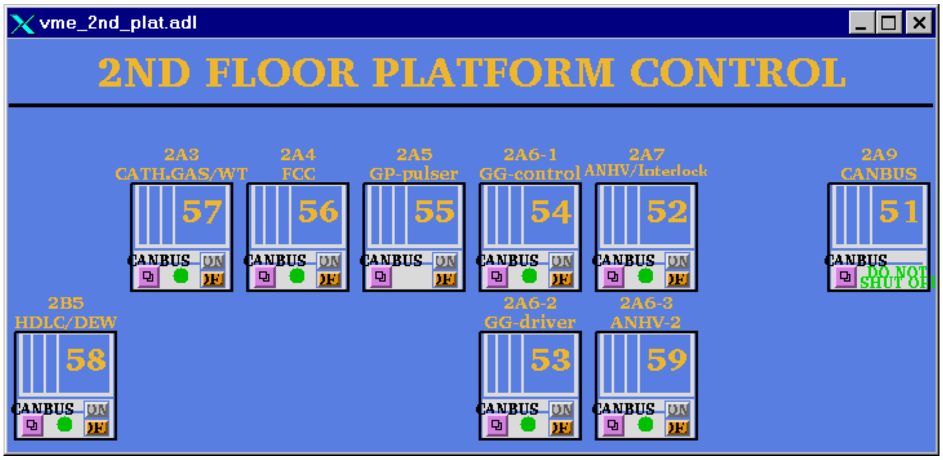
1. Anodes
2. Cathode and field cage
3. Gating grid
4. FEE's
5. Laser
6. Gas system
7. Interlocks
8. VME status
9. Pad monitor/General Use.

You can switch between desktops by clicking on the appropriate number in the virtual desktop keypad in the upper right corner of the screen. Switching desktops will reduce clutter and separate each TPC control.

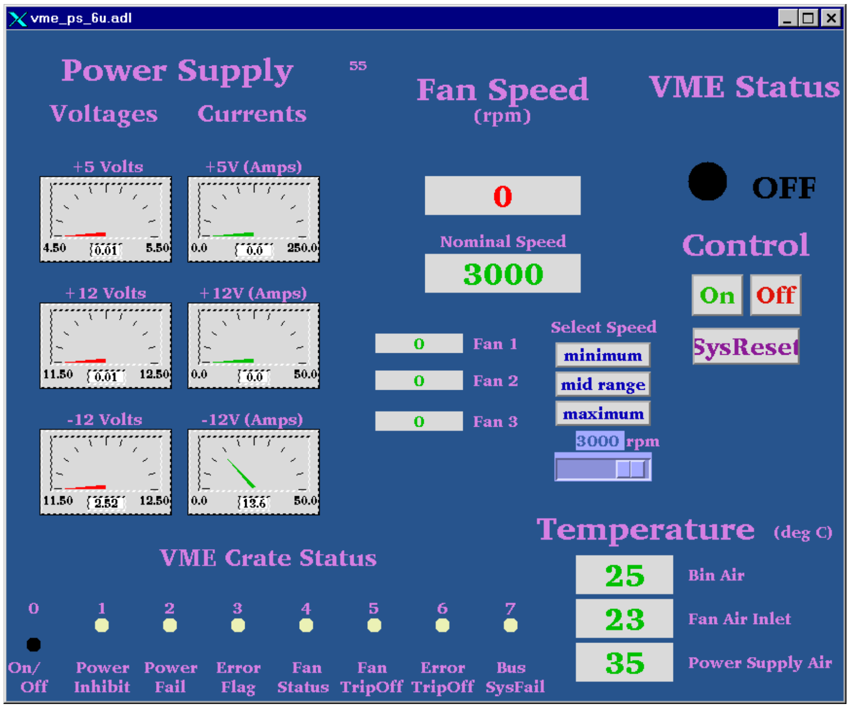
If you are starting from scratch, you will have to move the different screens to the appropriate desktops. See the procedure "How to Start TPC Controls.doc" for an explanation on how to do this. The document should be saved on Chaplin's desktop (or alternatively it is stored on the TPC Operations page as a "How To" note. http://www.star.bnl.gov/public/tpc/tpc.html)

2.2 VME Crates & Processors

All TPC functions are controlled using VME CPU's which are located in VME crates on the 2nd floor of the south platform. These crates can be remotely turned on/off using slow controls. To check the status of the crates, click on desktop 8 and select "2nd floor VME". This will bring up the VME control GUI:



Note that crates are labeled by function, canbus number and rack number. Crate 51 is for slow controls and should not be powered off. The green dot indicates that the crate is powered on (thus, #55 is off.) To turn a crate on (or off), click and hold on the purple button, drag down and release on the "VME xx" button, where xx is the canbus number. This brings up the control GUI for that crate:



To turn the crate on, click the "ON" button. The fan speed, voltages, currents, and temperatures will be indicated. Kill the window when done.

Before proceeding, make sure all crates for the TPC are ON.

VME PROCESSORS:

Typically, there is one VME processor for each TPC control task, and one CPU per crate. (Some crates may have two processors.) These processors run VxWorks and boot from the main slow controls computer (sc3.starp.bnl.gov). There are two connections for each CPU, one via ethernet and one through a terminal server. Remote login over ethernet is reserved for the slow controls expert. If problems develop with a CPU it can be rebooted by four different methods:

1. For the Gated Grid and Inner & Outer Anodes, there is a reset button on the main GUI. Clicking on this button will reboot the processor. (These three processors crash most often.)

OR

2. Push the sys reset button on the crate's control GUI – this reboots all processors in that crate.

OR

3. Cycle the power on the crate. (Not recommended, but sometimes necessary.)

OR

4. Login via the terminal server as follows:

On the ASTAIRE desktop, double click on the "putty.exe" icon. In the putty dialog box, double click on the session "sc5.starp.bnl.gov". At the sc5 prompt, type the username and password (get these from the shift-leaders notebook).

On sc5, type telnet scserv xxxx, CR where xxxx is the port number for the processor.(see below)

After you are attached to the processor, hit CR. To reboot, type "reboot,CR"

After the reboot, exit the session by typing "CTRL]" simultaneously to get back to the telnet prompt. Type quit to get back to sc3. Type exit to logoff.

ALWAYS release these terminal server sessions when you are done!

The current CPU's and port assignments are as follows:

1.Field Cage Readout	Port 9001	Crate 56	Rack 2A4	
2. Gated Grid	Port 9002	Crate 54	Rack 2A6	
3. FEE Power supplies	Port 9004	Crate 58	Rack 2B5	
4. Cathode HV	Port 9005	Crate 57	Rack 2A3	
5. Inner Anode HV	Port 9006	Crate 52	Rack 2A7	
6. Ground Plane Pulser	Port 9011	Crate 55	Rack 2A5	
7. Interlock/TPC temperature	Port 9012	Non Canbus	Rack 2A7	RPS3 Plug A4
8. Outer Anode HV	Port 9013	Crate 59	Rack 2A6	
9. Platform Hygrometer/TPC gas	Port 9015	Crate 58	Rack 2B5	

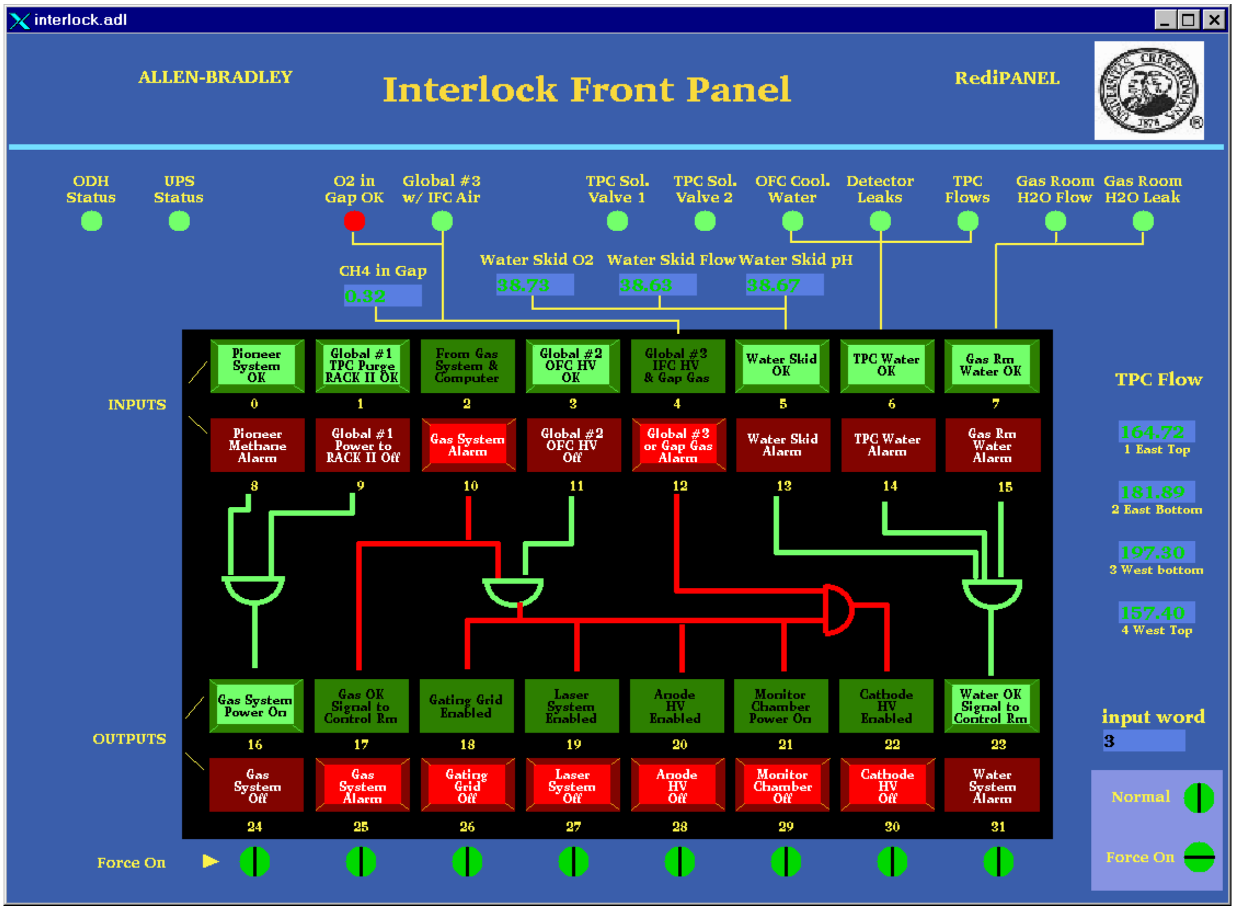
10. Autoramp programs for anode & cathode – STARGATE processor in DAQ room rack DC2 at the bottom of the rack (push the reset button)

Lecroy serial session for inner sectors	Port 9037
Lecroy serial session for outer sectors	Port 9038
Lecroy serial session for FTPC anodes	Port 9023

When a VME processor reboots, a grey MEDM Message Window will pop up with the message "network connection lost". Close this window. Also, the relevant GUI will turn white until the processor reboots.

2.3 Interlocks

The interlock status for the TPC can be checked from the control room by selecting the “Interlock” button on the top level GUI. (This is a representation of the Allen-Bradley (AB) panel which is located in Rack 4 of the gas mixing room.) The panel looks like:



CH4 in Gap 0.32

Water Skid O2 38.73

Water Skid Flow 38.63

Water Skid pH 38.67

TPC Flow

164.72 1 East Top

181.89 2 East Bottom

197.30 3 West bottom

157.40 4 West Top

input word 3

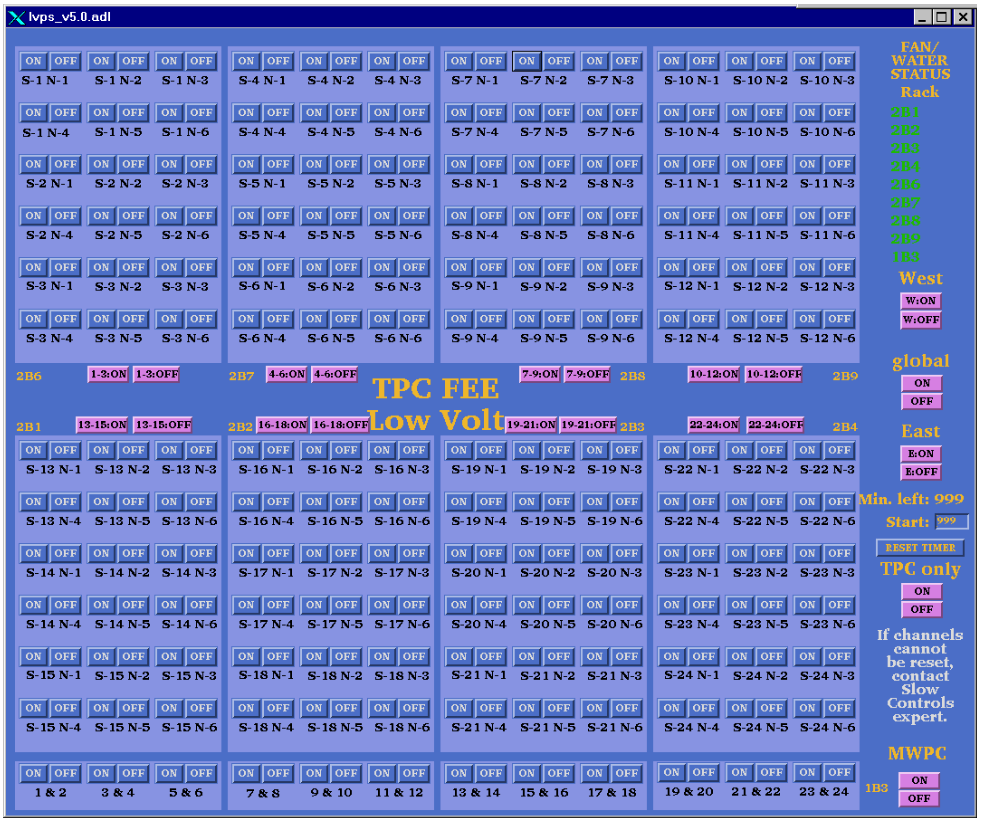
The round lights across the top and the top row of rectangular lights are status lights for the inputs to the interlock panel. The bottom two rows of rectangular lights show the status of the outputs to the various subsystems of the TPC. Under normal circumstances, ALL lights should be green. In the above example, the gas system is off, so no system can run.

Note that if, during a run, one or more of the inputs changes from OK to “not OK”, the AB PLC will take automatic action to shut down the affected subsystem or HV. NO OPERATOR ACTION IS REQUIRED to put the system into a safe state.

If one or more of the inputs changes from OK to “not-OK”, then the outputs will latch off and most TPC system cannot be operated without intervention from an expert or a trained detector operator. See the document “How to recover after a gas alarm.doc” This document explains how to recover from a simple gas alarm condition. More complex gas alarm conditions require intervention by an expert. The procedure for recovery should be saved on CHAPLIN’s desktop and is available on the TPC operations web page http://www.star.bnl.gov/public/tpc/tpc.html.

2.4 FEE's and MWC FEE's

To operate the main TPC FEE's and RDOs, go to desktop 4 and select "FEE Voltage" on the toplevel GUI. The FEE control looks like this:



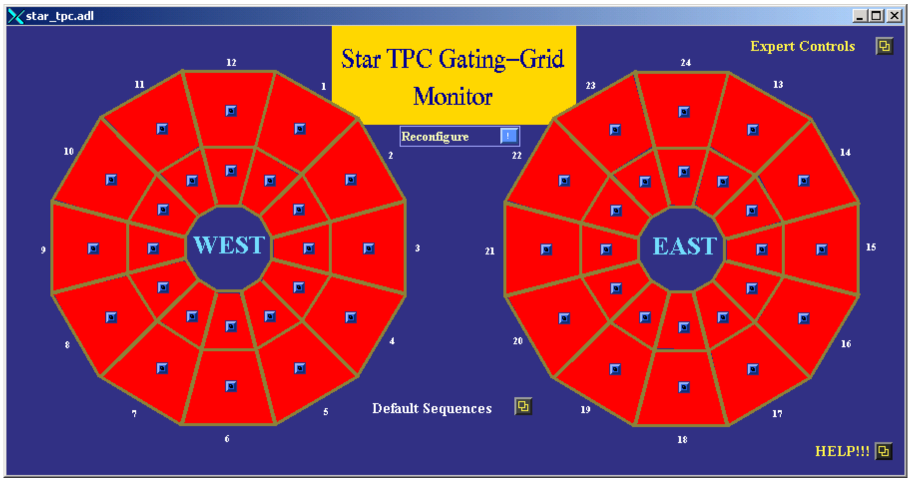
To turn all the FEE's and RDOs on click on the "global" on button. Each of the supplies will turn green in turn. There are also "on" buttons for each rack (= 3 supersectors), east and west ends, and individual supplies. To turn off, click the corresponding "off" button.

The MWPC FEES, listed on the bottom of the screen, are obsolete and are not used. Please ignore them.

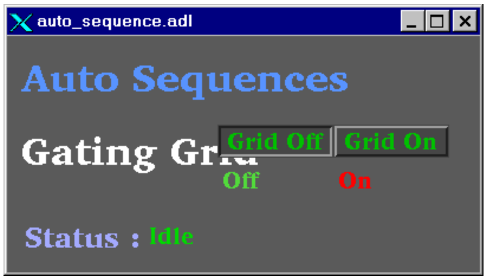
Each TPC RDO is read out by a DAQ receiver card. These cards are in VME crates and are visible from the control room. During normal data taking the LEDs on the receivers flash green as data comes in. It sometimes happens that a DAQ receiver/RDO pair will hang. This will be indicated by a slowing or stopping of DAQ and red lights on the affected receiver. For the TPC there are 12 crates of receivers with 12 cards per crate. The crates are labeled TPC 1,3,5..... Since there are 6 RDOs per TPC supersector (inner + outer) each crate reads out 2 supersectors. You can sometimes clear the bad RDO/receiver pair by cycling the power for that RDO. STOP THE RUN FIRST! As an example if the 8th card in crate TPC 3 is hung you would cycle the power for RDO S6-N2. (Crate 3 reads out supersectors 5 & 6. The first 6 cards from the left are 5-1 through 5-6, the next 6 cards are 6-1 through 6-6). If the run still freezes after cycling the power and also rebooting DAQ it may be necessary to mask out this RDO/receiver in the run. The shiftleader has instructions for this.

2.5 Gated Grid

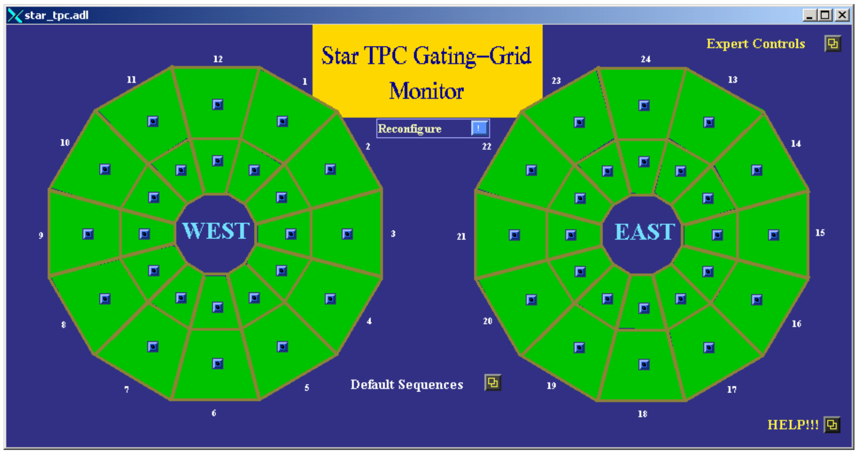
To turn on the gated grid, go to desktop # 3 and click on “Gating Grid” on the top level GUI. This brings up the main gated grid GUI:



1. Click on the “Default Sequences” button. This brings up the control screen:



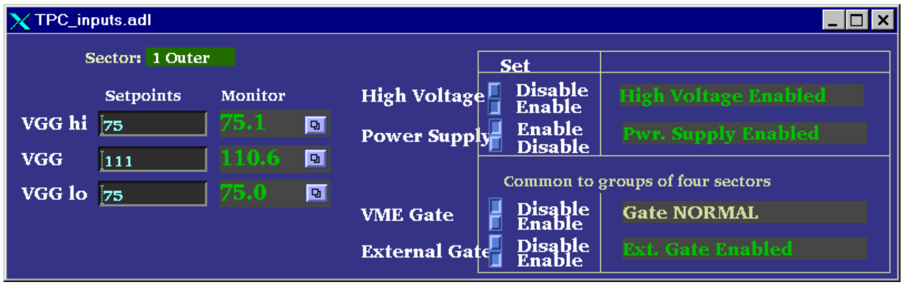
2. Click on the “Grid On” button. This will run a program to set all the GG power supplies. You should see the message “Downloading Setpoints”. It should take ~3 minutes for all sectors to come up to voltage. When the gated grid is ready, all sectors on the main screen turn green:



3. If the status remains “idle” after clicking on the “Grid On” button, you will have to regain control of the program. First, run the TPC anodes to zero and click “Grid Off”. When the anodes are at zero volts, click and hold on the “Reconfigure” button, drag down to “Recover control” and let go. Try the “grid on” button again. If this still doesn’t work, reboot the crate by clicking and holding on the “Reconfigure” button, drag down to “Reboot control crate” and let go. The processor should reboot.

NOTE: Before rebooting the Gated Grid processor run the TPC anodes to zero if there is beam in RHIC. Rebooting causes the GG voltages to turn off, causing high currents in the TPC.

4. To check on the voltage setpoint for a sector, click on the button for that sector. This brings up the control window:



Sector: 1 Outer

	Setpoints	Monitor
VGG hi	75	75.1
VGG	111	110.6
VGG lo	75	75.0

High Voltage: High Voltage Enabled
Power Supply: Pwr. Supply Enabled
VME Gate: Gate NORMAL
External Gate: Ext. Gate Enabled

5. The display for the main GG panel is color coded – a sector whose voltage deviates 2% from the setpoint will turn yellow, 5% will turn red. You will also get an alarm from the TPC alarm handler. For yellow, the run can continue – for red, STOP the run.

6. To turn the GG off, click the “Grid Off” button in the Default Sequences window.

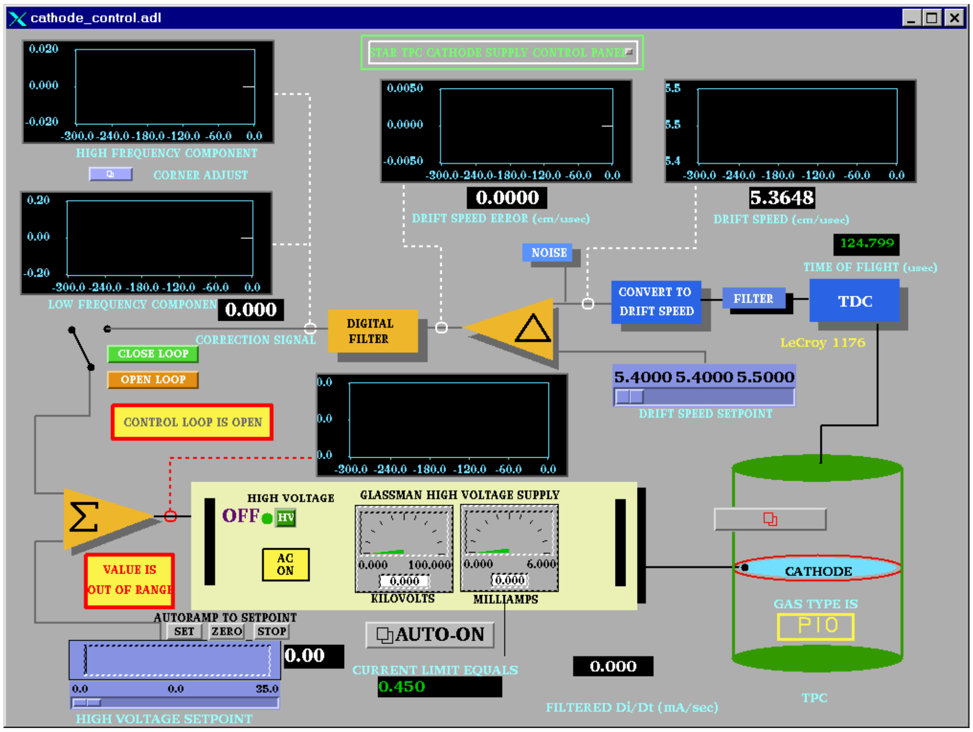
7. For normal running the gated grid stays ON all the time, even when there is no beam.

2.6 Cathode HV & Field Cage

AUTORAMP MODE

1. To turn on the cathode HV using autoramp mode, first go to desktop # 2 and click on “cathode” to open the cathode GUI. Also click on “Field Cage” to open the field cage current read back screen.

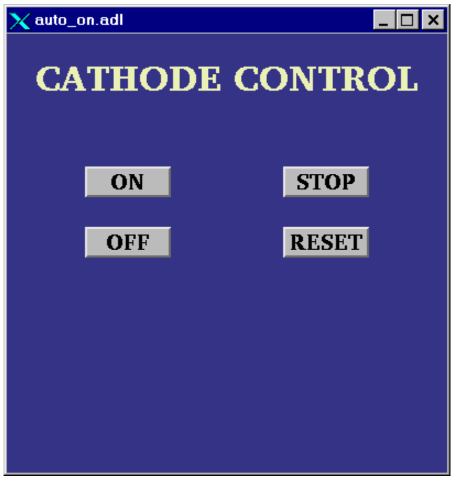
2. The cathode control looks like:



3. Make sure the slider switch is set to 0 and then click the HV button if the HV is off. The HV will turn on and the light will go to red. Note that it is not possible to turn the HV back off again by pushing this button!

4. Make sure that the RHIC beam is stored, cogged and stable before proceeding.

5. Click on the “Auto-On” button. This brings up the GUI:



6. Click the “ON” button. The program will then automatically do the following:

Ramp to 10 kV
Check that the four field cage currents are all equal.
Ramp to 20 kV
Again check the currents
Ramp to final HV (currently 28 kV)
Check the currents

This process takes ~ 10 minutes.

If the currents are not equal, the program will stop and ramp the HV back to 0. The operator can also stop the autoramp at any time by clicking on “STOP”. Clicking “OFF” ramps the HV back to 0.

IF AT ANYTIME THE AUTORAMP REPORTS A PROBLEM OR THE CURRENTS ARE NOT EQUAL (TPC ALARM HANDLER), RUN THE VOLTAGE IMMEDIATELY TO 0 AND CALL AN EXPERT!

REMEMBER: The cathode HV should not be turned ON until the RHIC beams are stable at collision energy and it should be ramped to ZERO before the beam is dumped.

AUTORAMP PROCESSOR

The VME program that controls the autoramps for the cathode and anodes is running on a processor (STARGATE) that is located in rack row DC2 in the DAQ room. If the autoramp program stops working it may be necessary to reboot this processor. First, try and run the cathode voltage to zero using the GUI for the cathode. Then go to the DAQ room and press the reset button on the STARGATE processor. After it reboots the autoramp should work again.

MANUAL MODE

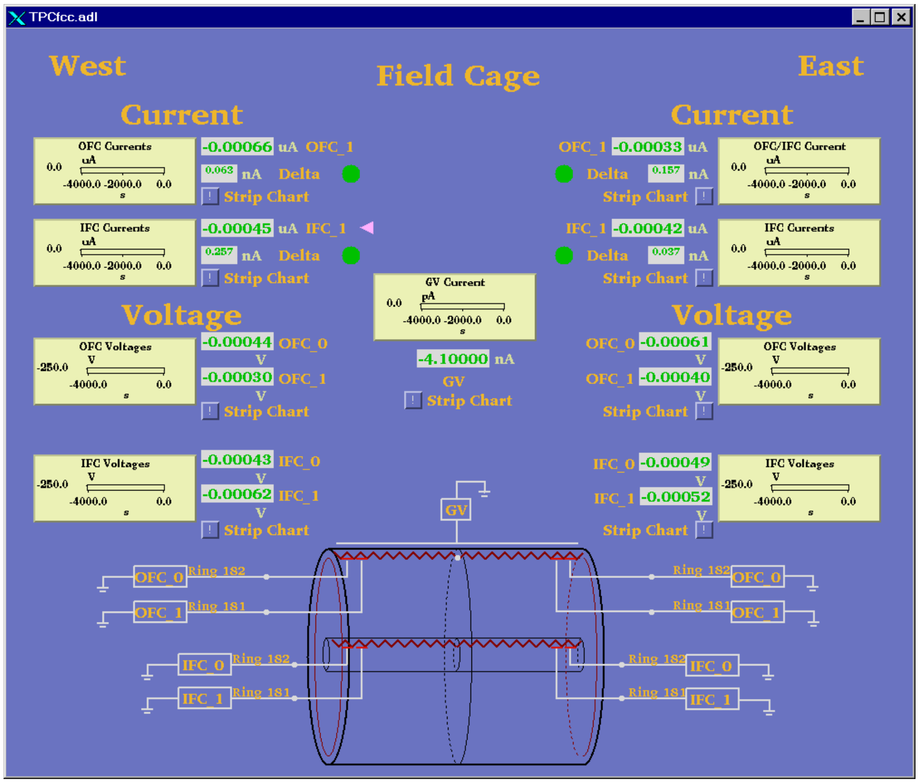
The HV can also be set manually as follows:

1. Turn on the HV as before.

2. Drag the slider switch to the desired HV (this should be done in 10 kV steps max).

3. Click on “SET” above the slider bar and the voltage will ramp up. You can stop the ramp by clicking on “STOP” and go back to 0 by clicking on “ZERO”.

4. When the HV stops ramping, check the field cage GUI:



This program is reading the 4 field cage resistor chain currents, the current going to the ground shell (GV current) and the voltage on the next-to-last and last stripes. It also checks that all four resistor chain currents are equal within 100 nA (Delta green lights.)

5. After the HV stops ramping, confirm that the currents are equal before ramping further.

6. Once the HV is set to the final value, the currents are monitored by the TPC alarm handler. For an alarm, immediately ramp the cathode to zero and call an expert.

Typical Field cage currents and voltages at 28.0 kV nominal.

OFCW	76.555 µA	OFCE	76.553
IFCW	76.547	IFCE	76.552

WOFC_0	-33.43 V	EOFC_0	-33.74
WOFC_1	-177.21	EOFC_1	-177.66
WIFC_0	-23.774	EIFC_0	-23.779
WIFC_1	-177.58	EIFC_1	-177.47

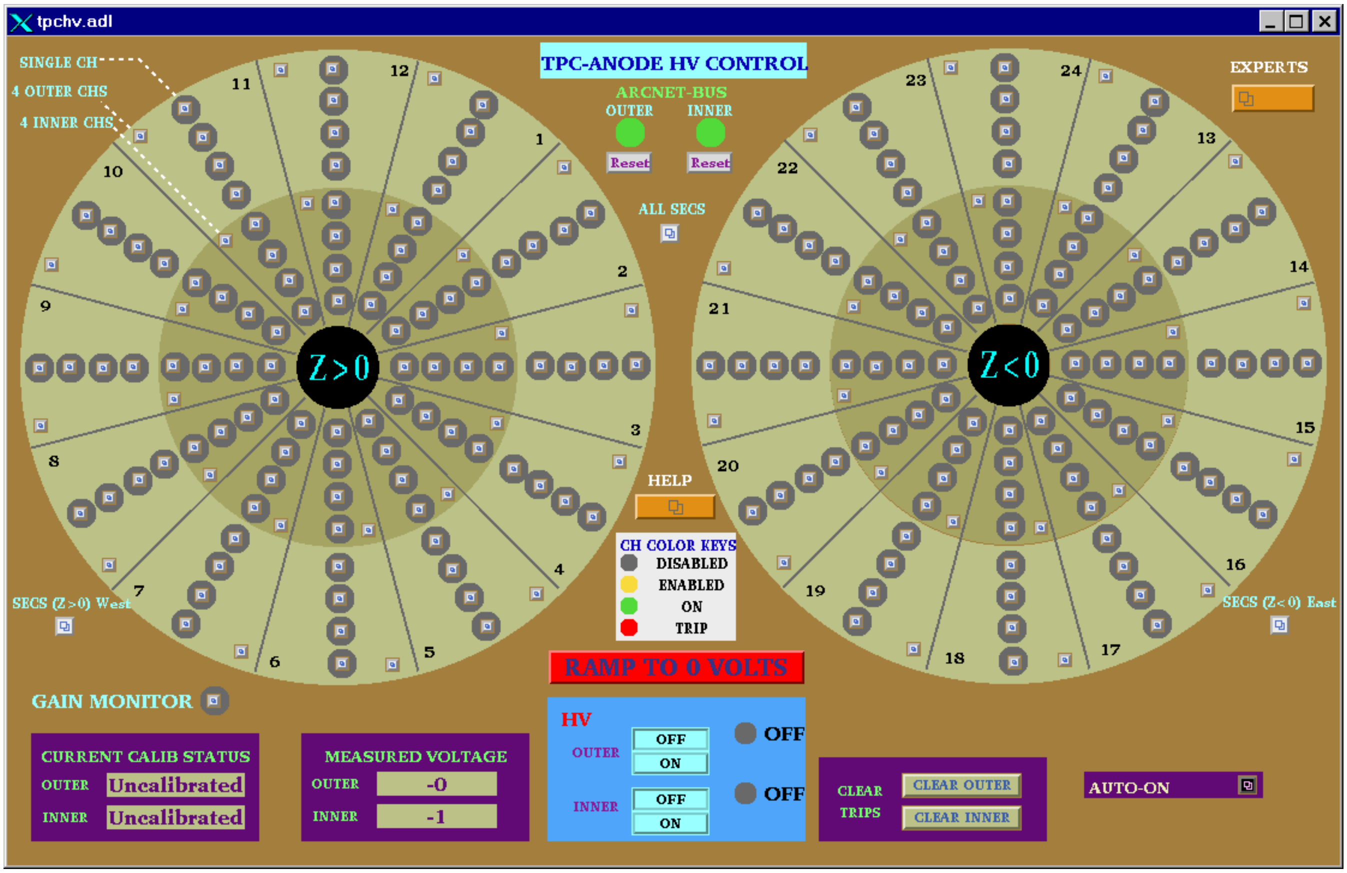
If the TPC has a short circuit across one of the resistors in the field cage, then you may see different values than listed above. Deviations by up to 0.5 µA may be normal. Check with your shift leader or a TPC Expert to see if the readings are normal.

2.7 ANODE & TRIPS

AUTORAMP

To turn the anodes on using the autoramp program:

1. Go to desktop # 1 and click on "Anode Voltage" on the top level GUI. This brings up the Anode GUI:

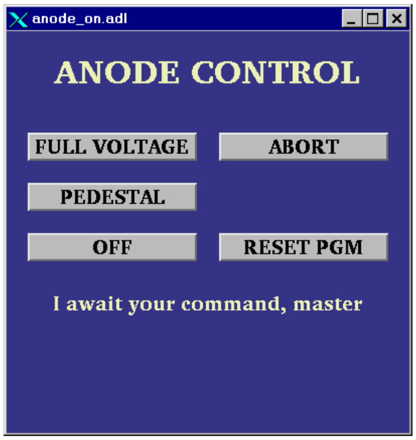


CURRENT CALIB STATUS
OUTER Uncalibrated
INNER Uncalibrated

MEASURED VOLTAGE
OUTER -0
INNER -1

2. Check the ARCNET-BUS status lights for the Inner and Outer sectors – if either or both are red, click the corresponding "reboot" button. This will reboot the processor. (The display will go white while it reboots). WAIT ~ five minutes for the reboot. The state of the anode voltages (on or off) is unaffected by rebooting the processor – the Lecroy system has local memory.

3. When the status lights have turned green, click on the "Auto-On" button. This gives the GUI:



I await your command, master

If the autoramp GUI displays the message “ARCNET connection lost”, click on the “Reset PGM” button.

4. Make sure RHIC has stored, cogged and stable beam!

5. At this point, you can go to pedestal voltage (Inner = 500, Outer = 500) or to full operating voltage (Inner = 1170, Outer = 1390). Note: as of Run 9, the full voltage values may no longer be 1170/1390. Check with your shiftleader or a TPC expert for the current settings.

6. To go to pedestal voltage, click “pedestal”. The program will:

Turn on the HV
Enable all channels
Ramp HV to 400 volts
Calibrate the currents (subtract out any DC offset)
Ramp to pedestal voltage

If the HV is already on, the program will just ramp up (or down) to pedestal values.

At any time the operator can stop the process by clicking “Abort”. This will ramp the voltage back to 0.

After the voltages are at pedestal values, the TPC is ready to take a pedestal run (make sure the GG is on!)

7. One can go to full voltage from either the off position or from the pedestal position.

From off, the program will repeat the pedestal procedure, and then:

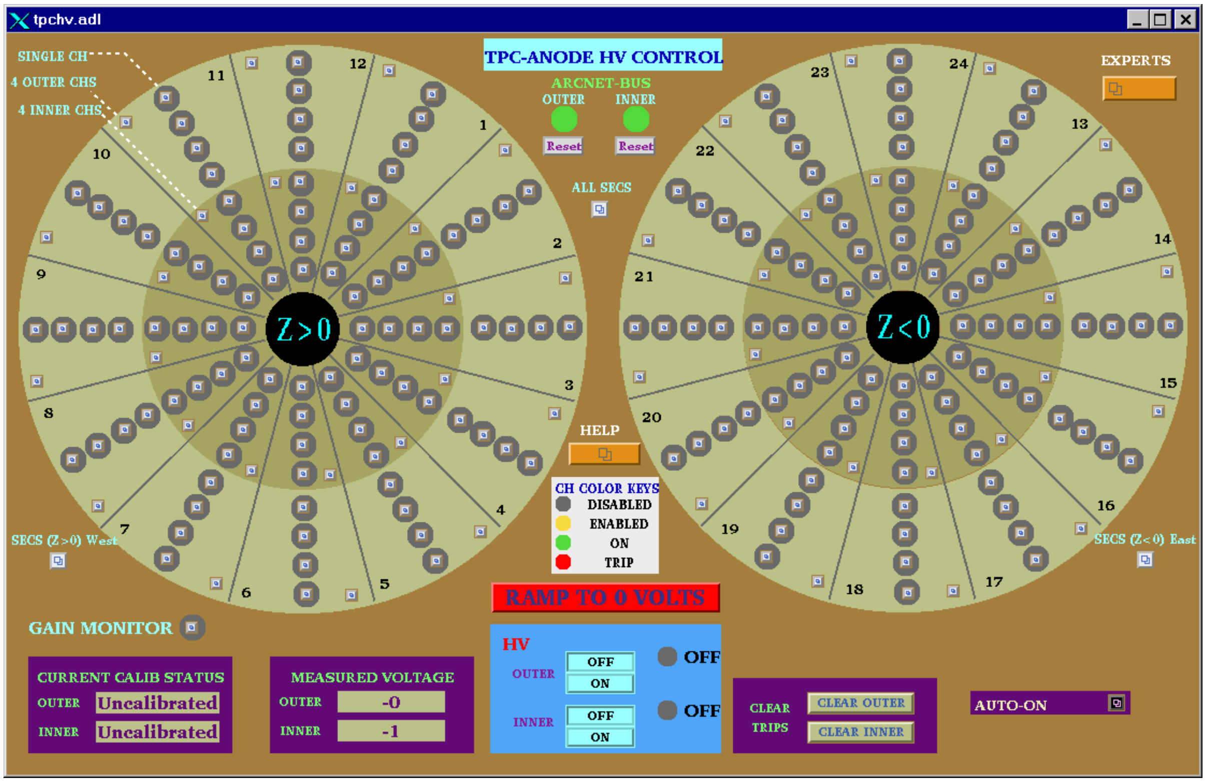
Check for tripped channels
Check for excessive currents
Ramp to Inner = 1000, Outer = 1200
Check for trips
Check for currents
Ramp to Inner = 1100, Outer = 1300
Wait for 2 minutes
Check for trips and currents
Ramp to final voltage (Inner = 1170, Outer = 1390)
Check for trips or currents.
HV ready for data

This procedure takes ~ 10 minutes.

If a trip or high current is detected during this procedure , the voltage for all channels will be ramped back to pedestal values automatically.

To turn the HV off, click on the “Off” button in the auto-on window, or click on the red “Ramp to 0 Volts” button on the main anode GUI.

MANUAL ANODE OPERATION



CURRENT CALIB STATUS
OUTER Uncalibrated
INNER Uncalibrated

MEASURED VOLTAGE
OUTER -0
INNER -1

There are 193 separate anode supplies, 1 for the gain chamber and 192 for the TPC. For each sector, the anode wires are grouped in sections, so there are four supplies per sector. The operator can control the voltage for all sectors (including the gain chamber), for the east or west end only, for a sector only (4 sections) or for an individual section (usually necessary to reset a trip.) In the main GUI above, the status of each power supply (section) is indicated by the round color field surrounding the control button. Thus:

Grey = Channel is disabled. Even if the HV is turned on and you set a demand voltage for that channel, nothing will happen.
Yellow: Channel is enabled but the HV is off or <10 volts.
Green: Channel is on at some voltage > 10 volts.
Red: Channel has tripped off due to excessive current draw. (> 2 μA)

NOTE: The Anode program is very slow. You MUST wait for each command to be acknowledged before issuing another command or it will crash!

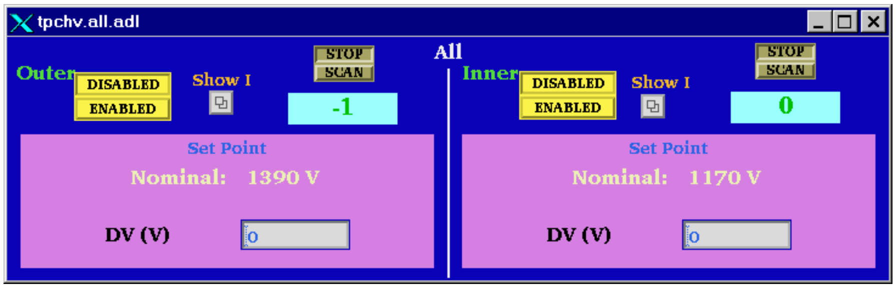
To turn on all sectors manually:

1. Check the status lights of the Arcnet-Bus. If either is red, click and drag on the reboot button to reboot the processor. Wait ~ 5 minutes. (There is a separate processor for the inner and outer sectors).

NOTE: The ARCNET link is lost frequently – you will get a TPC alarm when this happens. When this link is down the program can't get updated information from the Lecroy HV mainframe, BUT the HV is still on and the chamber is still protected. Rebooting the processor has no effect on the HV.

2. When the ARCNET lights are green, click the HV on button for the inner and outer sectors. Wait for the HV lights to turn green.

3. Open the “ALL SECS” control panel:



Outer: -1

Inner: 0

Nominal: 1390 V

DV (V) 0

Nominal: 1170 V

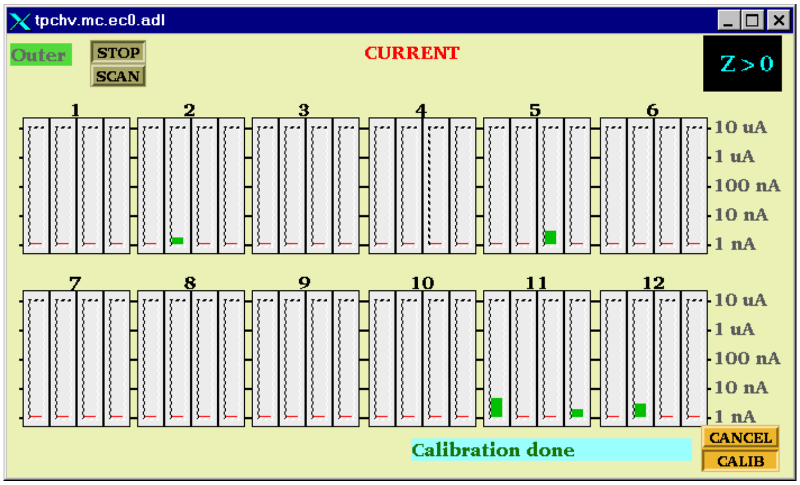
DV (V) 0

4. Check that the demand voltage DV (V) for inner and outer reads 0. If not, enter 0, CR in each window.

5. Click on “Enabled” for the inner and outer. Wait until the color circles turn green on the main anode GUI.

6. Type in a demand voltage of 400 V for the inner and outer sectors. Wait until the voltage ramps up and is confirmed in the readback window.

7.Check the Current Calibration status window in the main anode GUI. If the status is “calibrated” continue raising the voltage (see below step 10). If the status is uncalibrated, click on the Outer “SHOW I” button in the “ALL SECS” control GUI, drag down to “I (Z > 0) West) and release. This brings up the current display for all the outer sectors on the west end:



Calibration done

8. Click on the “Calib” button. The status window will say “Current is Ready” and then “Calibration in Progress”. The program will subtract the DC current offsets FOR ALL OUTER SECTORS (east and west). The status window will then say “Calibration Done”.

9. Repeat this procedure for the Inner sectors, if needed.

10. Set the demand voltage to pedestal values (Inner = 500, Outer = 500). Wait for the voltage to ramp up.

11. Continue to raise the voltage in steps, checking the currents after each step:

> Inner = 1000, Outer = 1200
> Inner = 1100, Outer = 1300
> Wait ~ 2 minutes
> Inner = 1170, Outer = 1390

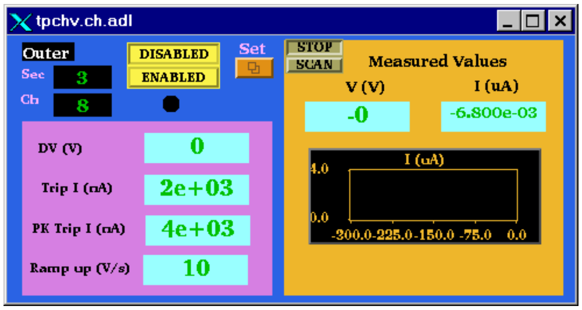
Note: as of Run 9, the full voltage values may no longer be 1170/1390. Check with your shift-leader or a TPC expert for the current settings.

12. To turn the Anodes off, either type in 0 for the demand voltage or click on the red “Ramp to 0 Volts” button on the main anode GUI.

RESETTING TRIPS

Occasionally, one or more channels will draw excessive current (> 2 µA) and automatically trip off. There will be a TPC alarm. These trips can be random or beam induced. First, STOP the current run. Then, to reset a tripped channel:

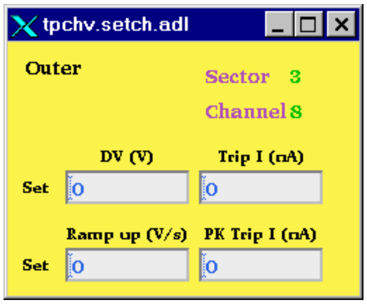
1. Click on the individual control button for the tripped channel in the main anode GUI. This brings up the channel status panel:



Outer
Sec 3
Ch 8
DV (V) 0
Trip I (nA) 2e+03
PK Trip I (nA) 4e+03
Ramp up (V/s) 10

Measured Values
V (V) -0
I (uA) -6.800e-03

2. Click on the “SET” button. This brings up the control panel:



Outer
Sector 3
Channel 8
DV (V) 0
Trip I (nA) 0
Ramp up (V/s) 0
PK Trip I (nA) 0

3. In the demand voltage window “DV (V)”, type in 0,cr to set the demand voltage back to zero. Do this FOR ALL tripped channels.

4. In the main anode GUI, click on the “Clear Trips” button for inner or outer sectors, depending on which channels tripped. Wait – the tripped channels which were red should turn back to green.

5. If the tripped channel remains grey on the main GUI after 2 minutes, it is neccesary to enable it manually. Click the “Enabled” button for the channel on the channel control GUI shown in step 1 above. If the channel is not green, you cannot raise the voltage.

6. Using the individual channel control windows, slowly raise the voltage in stages back up to the operating point. Monitor the current for each channel. For any indication of excessive current draw, lower that channel back to 0 and call an expert. (Excessive current for constant voltage = 50 nA)

7. Record the tripped channels in the “STAR TPC ANODES” binder.

NOTE: The current limits can only be changed by the subsystem manager. If a channel will not stay on with a limit of 2 μA, LEAVE IT OFF and call an expert.

ALTERNATE METHOD FOR CLEARING MULTPLE TRIPS

Sudden RHIC beam losses can cause multple anode trips. A more efficient method for clearing these trips is:

1. If the RHIC beam is lost: Use the autoramp to run ALL anode HV down to zero. Then click on the “Clear Trips” buttons. The tripped channels should clear and be ready for the next autoramp.

2. If RHIC still has beam and the run will continue then:

First, STOP the current run. Use the autoramp program to run ALL anode HV down to pedestal voltage. Then click on the “Clear Trips” button for inner and outer, depending on which channels tripped. WAIT for the tripped channels to reset – they should automatically ramp back up to pedestal voltage. You can then autoramp back up to full voltage if the RHIC losses have stopped.

2.8 LASER

See separate laser manual.

2.9 TPC ALARM HANDLER

There is a specific TPC alarm handler which is running on a separate PC – the monitor is located up and to the right of Chaplin. To start the alarm handler, click on the “Shortcut to Alarms_groups” icon on the desktop. The alarm handler monitors the following TPC parameters:

Anode trips
Excessive Anode currents (any channel)
Cathode HV not on (must be > 25 kV)
TPC FEE temperatures < 80 F
Temperature in the WAH < 82
Dewpoint in WAH < 62
Inner and Outer Arcnet links active
Field cage currents equal
All gated grid voltages at nominal
Inner Anode current sum (all channels) < 10 µA
Outer Anode current sum (all channels) < 4 µA
Anode HV – check whether any channel is not equal to demand voltage.

The alarm handler reads the status of these parameters every few minutes and will sound an audible alarm if something is out of range. There is a 10 minute snooze button that can be used when bringing up the TPC voltages to prevent frequent (false) alarms. If an alarm goes off, it can be silenced (acknowledged) by clicking the button below the alarm.

The alarm buttons are color coded:

Green = OK
Yellow = warning but run can continue
Red = alarm
Grey = the data was not read on this try – this usually clears on the next read.

An alarm condition will automatically clear and revert back to green on the next read cycle IF the reason for the alarm has been fixed. There is also a “read now” button that will initiate a read cycle.

These same parameters plus many others (gas system etc) are also monitored by the slow controls alarm handler running on sc5.starp.bnl.gov.

3. ALARMS

3.1 GAS ALARMS

In case of a TPC gas alarm:

1. Hit the acknowledge button on the alarm box in the control room. This silences the local alarm.

2. Go to the gas mixing room – hit the acknowledge button located next to the TPC AB PLC panel in rack 4

3. Call an expert – the list is posted in the mixing room.

4. The expert will tell you what to do.

For a major gas alarm all the TPC HV will trip off automatically. For a minor alarm the HV will stay on and the run can continue.

3.2 TPC WATER ALARMS

In case of a water alarm:

1. . Hit the acknowledge button on the alarm box in the control room. This silences the local alarm

2. Go to the gas mixing room – hit the acknowledge button located next to the TPC AB PLC panel in rack 4

3. Call a TPC water expert. A water alarm means the skid has shut down (the FEE’s will also trip off). This alarm is also repeated to the CAD pump room, so someone may respond from there. Do NOT restart the TPC water skid until the problem has been diagnosed and the TPC water expert has given the ok.

TPC CALL LIST

TPC

Alexei Lebedev

Office (Ops support trailer)	x3101
Cell	(631) 255-4977
Home	821-2838

Jim Thomas

Office	x3918
Cell	(510) 759-4936
Home	928-8661

TPC WATER

Alexei Lebedev
Jim Thomas

TPC GAS

Alexei Lebedev
Jim Thomas

TPC INTERLOCKS

Jim Thomas

TPC LASER

Alexei Lebedev

5. TPC State Table for Various Conditions

Standby:	Anodes	Off
	Cathode	Off
	FEES On or	Off (FEEs must be off when ramping the magnet)
	Gated Grid	On (Gated Grid should always be on)
Pedestal Run:	Anodes	ON at pedestal voltage (or less)
	Cathode	On/Off (but not ramping)
	Gated Grid	On
	FEEs	On
Physics Run:	Anodes	On at full voltage
	Cathode	On at full voltage (28 kV)
	Gated Grid	On
	FEEs	On
Laser Run:	Same as Physics Run but with Lasers On	
Pulser Run:	Anode	Off or less than pedestal voltages
	Cathode	Off/On
	Gated Grid	On
	Fees	On
	Clock in Local (not RHIC clock)	
Magnet ramp up or down:		
	Anodes	Off or at pedestal
	Cathode	Off/On
	Gated Grid	On
	FEES	OFF

Take a laser run 1 hour after the beginning of each store. Take ~ 2000 events and check the drift velocity in the online histograms.

Take a pulser run once a day. Make sure clock is set to local oscillator and take a pedestal run first!

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Laser

TPC LASER MANUAL

3/01/07 Valid for Run 7

Alexei Lebedev & Blair Stringfellow

1.0 Turning on the Lasers

There are two TPC lasers (east & west) which are used for calibration. The same two lasers are used by the FTPC (the beams are steered remotely into either chamber).

NOTE: FTPC laser runs are to be performed by experts only – they require laser steering.

For the TPC, laser runs should be taken ~ one hour after the start of a store and ~every 3 to 4 hours afterward (for as long as the store lasts.). A laser run should be a dedicated DAQ run of at least 2000 events. Check the Panitkin plots online for the automatically calculated drift velocity.

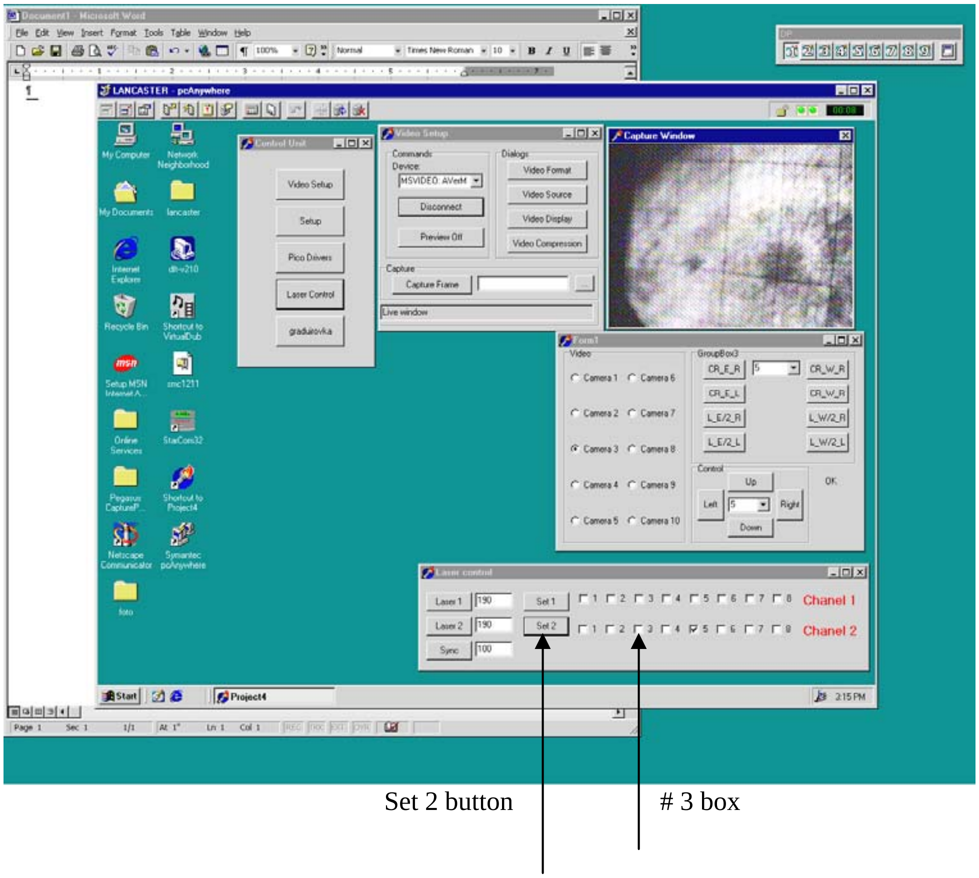
For the TPC laser runs:

1. STOP the current DAQ physics run.

2. Turn on the WEST laser AC power as follows:
   (The WEST laser overheats if the AC power is left on between runs.)

A. Go to the laser CCD control panel which is displayed on the PC TPClaser.starp.bnl.gov in the control room. If the CCD control panel is not displayed, see below for instructions to get it started.

B. Click on the “ #3” box in the channel 2 row on the CCD control panel. Then click on the “Set 2” button. (See picture below.)



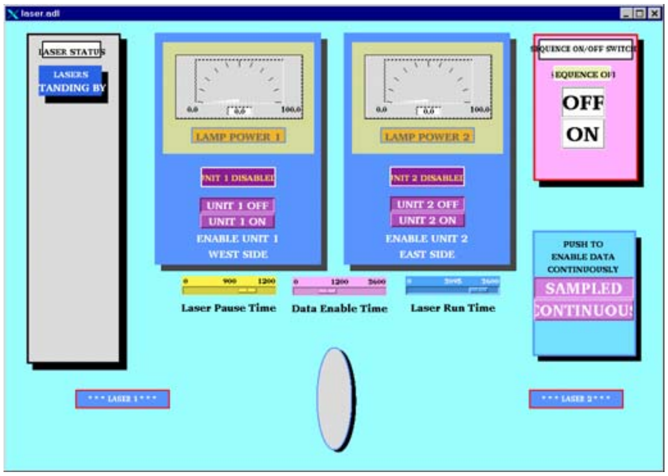
Set 2 button

3 box

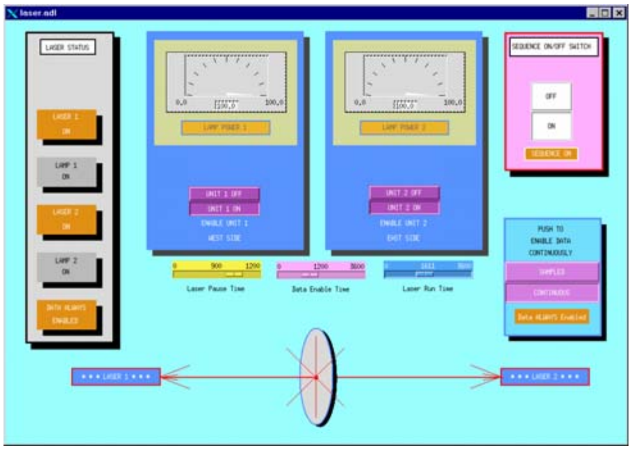
NOTE: In the following procedure, it is necessary to start both lasers together. The controls will not work for one laser only.

To turn on the lasers:

3. Go to desk top # 5 on Chaplin (TPC control computer) and click on the “Laser” button to bring up the laser control panel. Make sure the sliders for “Laser Pause Time”, “Data Enable Time” and “Laser Run Time” are slid fully to the right.



4. Click on the sequence on “ON” button and within a few seconds, click on the “Unit 1 On” and Unit 2 On” lamp power buttons. The lasers should come up to full power within 2 minute. Note that only the EAST laser will trigger DAQ. When the lasers are on, the display will look like:



5. To check that the lasers are really on, see below for a method to view the laser spot via CCD camera.

6. Wait ~ 5 minutes for the lasers to come to full power.

7. Start a DAQ laser run with ONLY DAQ, Trigger and TPC in the run. DAQ should run at ~ 10 Hz.

8. After the run, turn the lasers off by clicking on “Unit 1 Off”, “Unit 2 Off”, and the Sequence “OFF” button in turn. Wait until the “Lasers Standing By” message appears in the left hand box. Then, turn the WEST laser AC power off by clicking #3 box and “Set 2” on TPClaser.

2. Viewing the laser control boxes on the platform

Using the STAR plant remote TV system one can view the status lights on the laser control boxes on the south platform. To do this, go to the conventional systems PC (upper right monitor at the magnet control console). The TV system should be running, but may be hidden by the water system readouts. To get the TV image up, click on the iconized button labeled “Image Pull – Microsoft Internet Explorer”. To get the camera controls up, click on the iconized button labeled “VIDEOPC – pcAnywhere”. If the TV system is not running, see below to get it started or consult the manual which is in the holder on the right side of the cabinet.
To view the control boxes, do the following:

1. On the camera control window, select camera “First Floor”.

2. Click on #1 for the WEST laser control box or #2 for the EAST control box. (The row of numbered buttons are preset camera positions.) The picture should look like:

This shows the control box with the “OFF” light lit. After turning the lasers on, the picture should change to:

The lower right light is the “ON” light. The upper left is the “Lamp Sync” light. If these two lights aren’t on, the laser is not functioning properly.

If the STAR remote TV system is not running on the conventional systems PC, do the following:

1. Double click on the desktop icon labeled “Symantec pcAnywhere”. The pcAnywhere window will come up. Select the icon "VideoPC" and double click on it.

2. Logon to VideoPC – Username:BRANDIN, Password:ANDREY

3. This will bring up the VIDEOPC desktop with the remote camera controls visible. To avoid confusion you can drag and shrink the window until only the camera controls are visible (STAR Video System).

4. Back on the conventional systems PC, click on the icon labeled “VideoPC”. This will bring up a local Microsoft Explorer session that displays the remote camera images. More detailed instructions for this system can be found in the plastic holder to the right of the conventional systems montor.

3. Viewing the laser spots

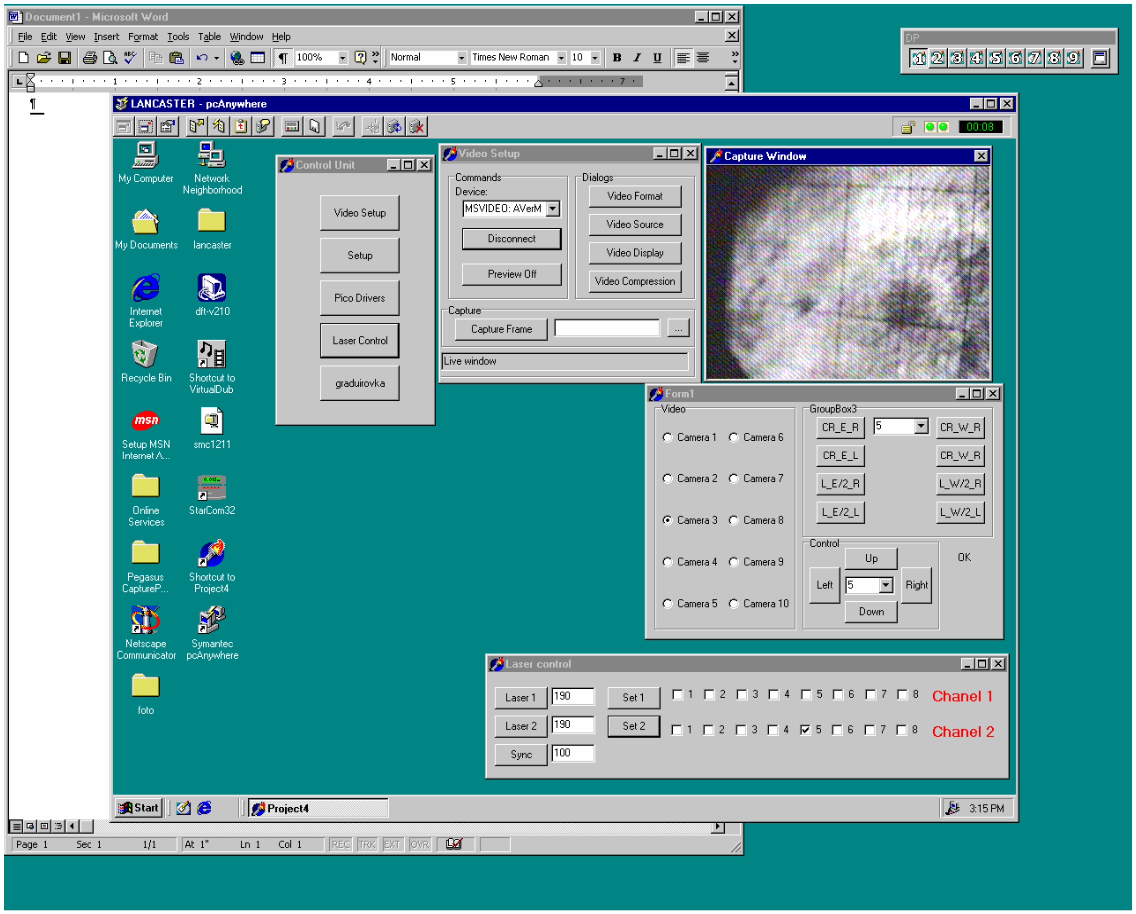
A separate remote CCD system allows one to view the East & West laser spots. To view these CCD’s:

1. Go to the PC TPClaser.starp.bnl.gov near the TPC control computer.

2. On the desktop, double click on the icon “Symantec pcAnywhere”. After the program starts, doubleclick on the “TPC laser” icon.

3. Login using Username:BRANDIN, Password:ANDREY.

4. This brings up the controls on the TPClaser desktop as shown:



Device: MSVIDEO: AVerM

● Camera 3

Laser 1 190

Laser 2 190

Sync 100

GroupBox3: 5

Control: 5

Chanel 1: ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8

Chanel 2: ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☑ 5 ☐ 6 ☐ 7 ☐ 8

5. In the “FORM1” window, the various CCD cameras can be selected, as follows:

Cameras 1 & 2 = West laser aimed at TPC
Cameras 3 & 4 = East laser aimed at TPC
Cameras 5 & 6 = West laser aimed at FTPC
Cameras 7 & 8 = East laser aimed at FTPC
Cameras 9 -16 = SMD gas bubblers.

CAUTION: Do not click on any other controls in the form 1 window, or in the “control unit” or “Video setup” windows.

When the lasers are running, a somewhat synchronized bright spot should be visible on the appropriate CCD camera. Lack of a spot usually means the laser is not working.

4. Steering the lasers to the FTPC & Back

NOTE: The following is for EXPERTS ONLY

The same lasers service both the TPC and the FTPC, but not simultaneously. To steer the beams from the TPC to the FTPC:

1. In the “laser control” window, click on the windows labeled 1 and 2 in the row labeled “Chanel 2”
A check mark should appear in each window. Then click on the “Set 2” button. This sends a TTL pulse that controls flippers on the platform. Window 1 is for the east laser, 2 is for the west laser.

2. To check that the beams are now steered to the FTPC, check for the laser spots on cameras 5 & 6 (West laser) and cameras 7 & 8 (East laser)

3. To steer the lasers back to the TPC, click on the boxes 1 & 3 again. The check marks should disappear. Then click on the “Set 2” button.

How To Docs

Valid 7/11/2009

How to startup the TPC control screens on the Main console (usually Chaplin.starp.bnl.gov, lower left)

1.) Check that Exceed is running. If not, re-start it from the start menu or quick launch tab.
2.) Select desktop number 1
    a. Look in lower right hand corner and click on "1" (from selection of 1-9)
3.) Open putty and log on to sc5.starp.bnl.gov
    a. Select sc5.starp.bnl.gov
    b. Hit "Load" button
    c. Hit "Open" button
4.) Login as 'sysuser'
    a. Password is in the Shift Leaders log book
5.) Type 'tpc_top' in the sysuser@sc5 terminal window
    a. TPC Controls – Top Level window control program will start
    b. Shrink the terminal window
    c. Note that medm window may already be shrunk. This is OK but note where it is because you will have to close it in order to stop tpc_top.
6.) Open "Anode" window from the TPC Controls – Top Level window
    a. Slide the anode window over to the right hand display
7.) Switch to desktop 2 … Red and Black window at top of page should say "Cathode"
    a. Open cathode window from the TPC Controls – Top level window
    b. Slide the cathode window over to the right hand display
8.) Repeat for Gating Grid[3], FEEs[4], Laser[5], Gas System[6], Interlocks[7],VME Status[8], Other[9]
9.) The TPC control system is setup properly. Operate the TPC controls as required. See the TPC Manual and notebook for details. Also see the Laser Manual (loose leaf pages in plastic sleeves)

Note: the TPC Control Screens can be run from any computer with an X window manager. In particular, it can be run from Chaplin, Astaire, or Sirius. Use any system that works. Default is Chaplin.

How to startup the TPC Alarm Handler (usually on Sirius.starp.bnl.gov, upper right)

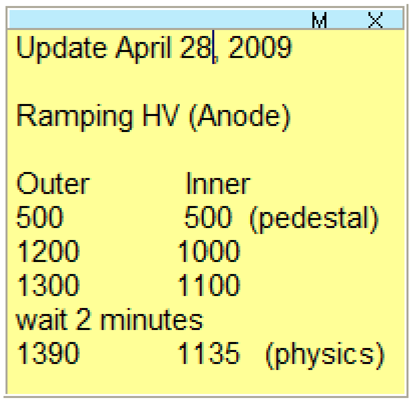
1.) Select desktop number 1
    a. Look in lower right hand corner and click on "1" (from selection of 1-9)
2.) Click on the "Shortcut to Alarms_group" icon (which should already be on the desktop)
    a. If the icon is missing, you can make a new one. It points to c:\alarms\alarms_groups.exe
3.) The alarm handler is ready to run. Operate the alarm controls as needed.

Note : the TPC Alarm Handler can be run from any computer where it is installed. It is installed on Sirius, Astaire and Chaplin; however, only one instance of the alarm handler should be running at a time. Do not run multiple copies on multiple machines. The Alarm Handler is usually left running on Sirius.

How to start Electronic Postit Notes – TKEasyNote

If the program isn't already running, start TK8 Easynote. It allows you to create an electronic postit note. The notes can be saved and they will re-appear after startup … but they may only appear on desktop #1. To move a note to a different desktop, close all unwanted notes by clicking on the 'x' in the upper right hand corner of each unwanted note. Then go to the new desktop and click the TK8 icon in the quickstart tray (lower right hand corner) and select "open closed notes". Arrange these notes on the new desktop, and repeat this process until all notes are on the proper desktops.

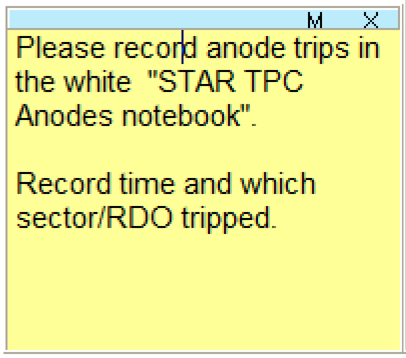
Post these notes on the Anodes screen (usually desktop #1)



Update April 28, 2009

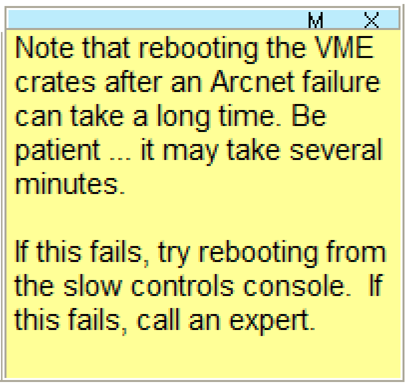
Ramping HV (Anode)

Outer	Inner	
500	500	(pedestal)
1200	1000	
1300	1100	
wait 2 minutes		
1390	1135	(physics)



Please record anode trips in the white "STAR TPC Anodes notebook".

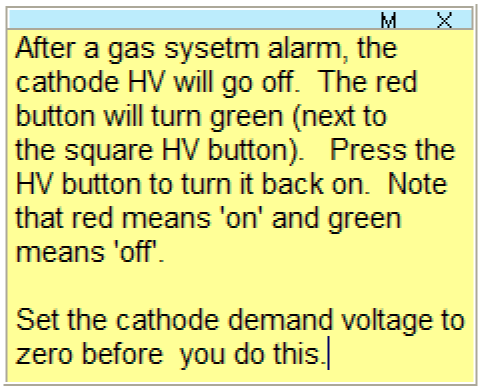
Record time and which sector/RDO tripped.



Note that rebooting the VME crates after an Arcnet failure can take a long time. Be patient ... it may take several minutes.

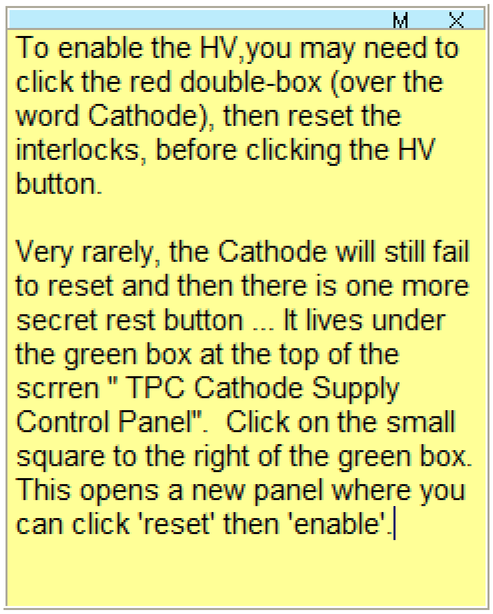
If this fails, try rebooting from the slow controls console. If this fails, call an expert.

Post these notes on the Cathode Screen (usually desktop #2)



After a gas sysetm alarm, the cathode HV will go off. The red button will turn green (next to the square HV button). Press the HV button to turn it back on. Note that red means 'on' and green means 'off'.

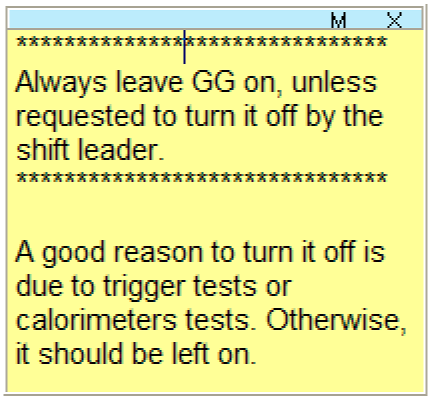
Set the cathode demand voltage to zero before you do this.



To enable the HV,you may need to click the red double-box (over the word Cathode), then reset the interlocks, before clicking the HV button.

Very rarely, the Cathode will still fail to reset and then there is one more secret rest button ... It lives under the green box at the top of the scrren " TPC Cathode Supply Control Panel". Click on the small square to the right of the green box. This opens a new panel where you can click 'reset' then 'enable'.

Post these notes to the GG Screen (usually desktop #3)

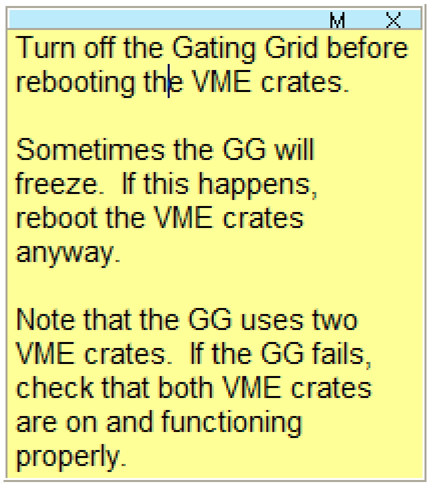


****

Always leave GG on, unless requested to turn it off by the shift leader.

****

A good reason to turn it off is due to trigger tests or calorimeters tests. Otherwise, it should be left on.

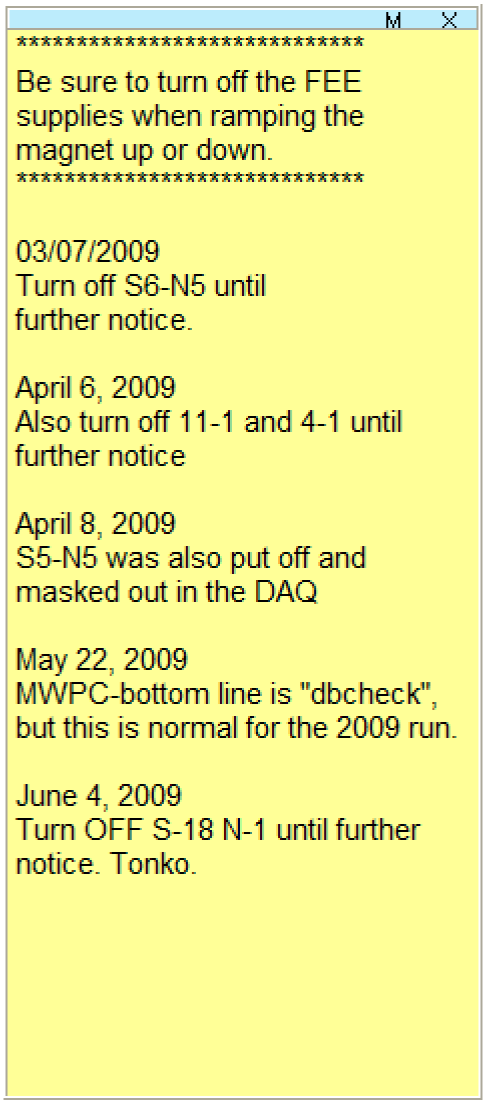


Turn off the Gating Grid before rebooting the VME crates.

Sometimes the GG will freeze. If this happens, reboot the VME crates anyway.

Note that the GG uses two VME crates. If the GG fails, check that both VME crates are on and functioning properly.

The FEE screen may have various notes. For example: "Be sure to turn off the FEE supplies when ramping the magnet up or down" or "Turn off S6-N5 until further notice". Also, put a note with the StripGas display screen on the auxiliary TPC screen (to the right).



****

Be sure to turn off the FEE supplies when ramping the magnet up or down.

****

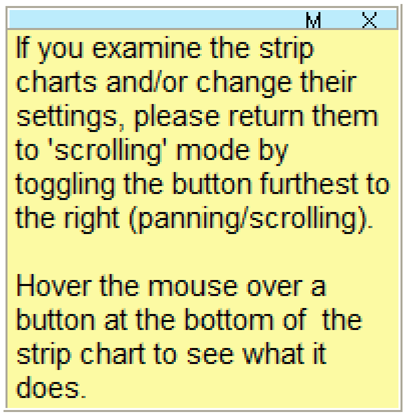
03/07/2009
Turn off S6-N5 until further notice.

April 6, 2009
Also turn off 11-1 and 4-1 until further notice

April 8, 2009
S5-N5 was also put off and masked out in the DAQ

May 22, 2009
MWPC-bottom line is "dbcheck", but this is normal for the 2009 run.

June 4, 2009
Turn OFF S-18 N-1 until further notice. Tonko.



If you examine the strip charts and/or change their settings, please return them to 'scrolling' mode by toggling the button furthest to the right (panning/scrolling).

Hover the mouse over a button at the bottom of the strip chart to see what it does.

Valid 7/14/2009

How to recover the Anode, Cathode, and GG after a Gas Alarm

Bad weather can cause the TPC gas system to hiccup, or fail. If the gas alarm stays on continuously, silence the alarm and call an expert. If the gas system hiccups (briefly sounding the alarm) and then recovers, you may proceed with normal operations just as soon as you are satisfied that you have full control of the TPC electronic systems. For example, a brief gas alarm may not interfere with the TPC control systems at all. This is good, and you can proceed with normal operations. However, some hiccups will also cause the TPC interlocks to fail and then you will lose control of the Anodes, Cathodes and Gating Grids. If this happens, try to recover them using the following steps:

0.) You can determine if the interlocks have failed by examining the ‘Interlocks’ screen at the TPC control console (usually desktop #7). If any of the buttons on the bottom row are red, then you will be prevented from using the TPC control systems.

1.) Walk to the gas room and inspect the Allen Bradley Interlock panel. If the top row is all green, then trained detector operators may push the bottom row of buttons to re-enable each channel that was switched off.

2.) Return to the control room. Turn off the GG. Ramp the Cathode to zero. Ramp the anodes to zero. Do this even if the displays are showing yellow screens or other apparent anomalies.

3.) Anode: Push the 'Reset Program' on the Anode Auto Ramp control box. Push the 'Off' button and wait a minute for the voltages to return to zero. Push the 'Pedestal' button to confirm that the supply is acting normally. Wait for the pedestal voltages to stabilize then turn the voltages off again. This may take a several minutes to complete.

4.) Cathode: Find the green 'HV' button on the image of the Glassman High voltage supply. It is above the yellow square that indicates 'AC ON'. Push and hold the 'HV' button for several seconds. The green dot for 'OFF' will shift to the other side of the button and turn red. The Cathode HV is now enabled. Go to the Cathode Control box. Push the 'RESET' button on the Cathode Control. Push the 'OFF' button and wait for the voltage to return to zero. Push the 'ON' button and wait for the voltage to start increasing to confirm that the supply is acting normally. Do not allow it to ramp to full voltage. Instead, push the 'STOP' button after about 1 minute and then hit the 'OFF' button.

5.) Gated Grid: One or both of the two VME crates for the GG are off. Turn them back on. You can do this at the Slow Controls Alarm Handler. Look for the VME pull-down menu, and select the Platform VME 2nd floor pull-down menu, and check GG crates 53 and 54 by clicking on the ‘p’ button. Turn on any crate that is off. (Don't forget to hold the 'ON' button down for several seconds or nothing will happen.) Return to the TPC control console and push the 'Grid On' button. Wait a couple minutes to confirm that the GG voltages have been applied and the panels turn green. Leave the GG on.

6.) Pulser: The VME crate for the pulser has been turned off. It is crate #55. Turn it back on. Turn it on by using the slow controls alarm handler interface (see above). (Don't forget to hold the 'ON' button down for several seconds or nothing will happen.)

7.) Wait for further instructions from the shift leader.

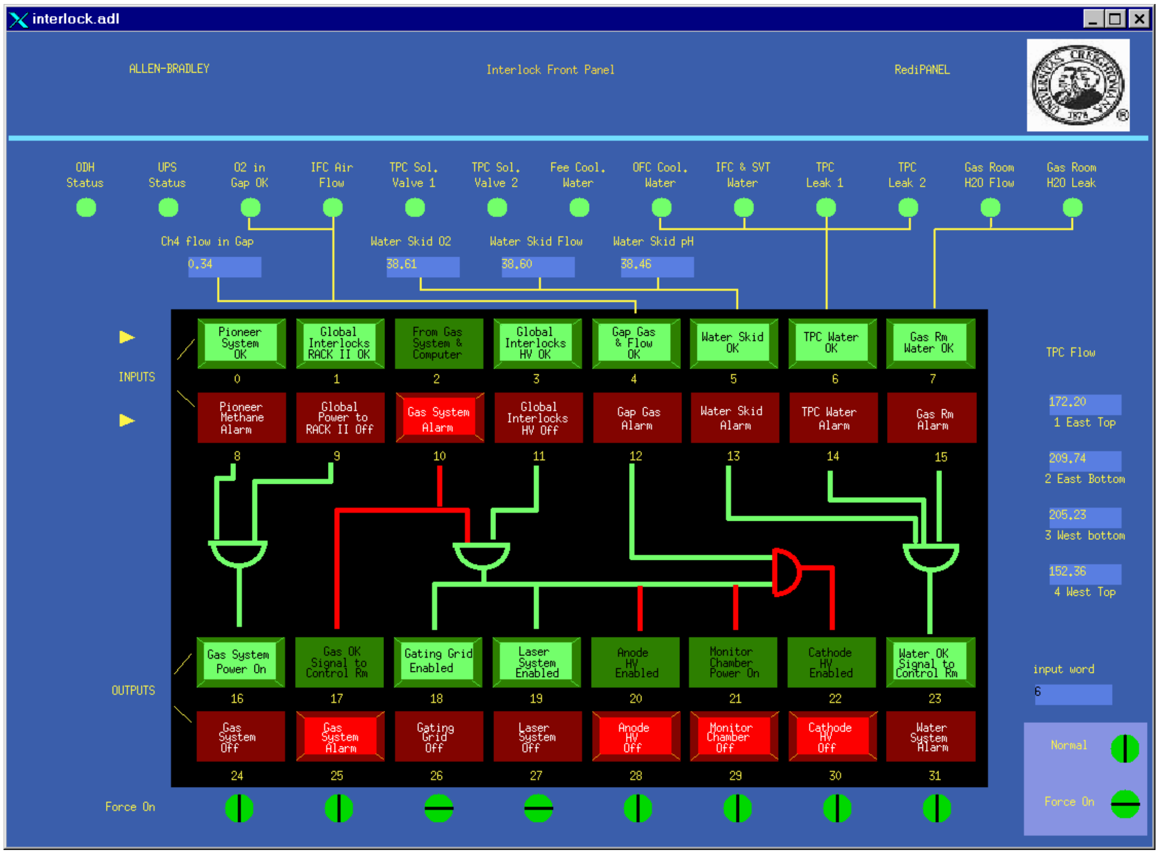
(over)

8.) If these instructions fail, call an expert. Of if you are too sleepy to think, call an expert. Sometimes a bad weather event will be accompanied by a power dip and this may cause one or more of the communications networks to fail. If you have been trained and know how to recover the Arcnet, Canbus, etc., then try to do it. If you have been trained and know how to turn on a VME crate that has gone down, then do it. But if you are uncertain about how to recover these systems, then call an expert.

Interlocks

TPC INTERLOCKS MANUAL

Blair Stringfellow
5/2/00



Ch4 flow in Gap 0.34
Water Skid O2 38.61
Water Skid Flow 38.60
Water Skid pH 38.46

TPC Flow
172.20 1 East Top
209.74 2 East Bottom
205.23 3 West bottom
152.36 4 West Top

input word 6

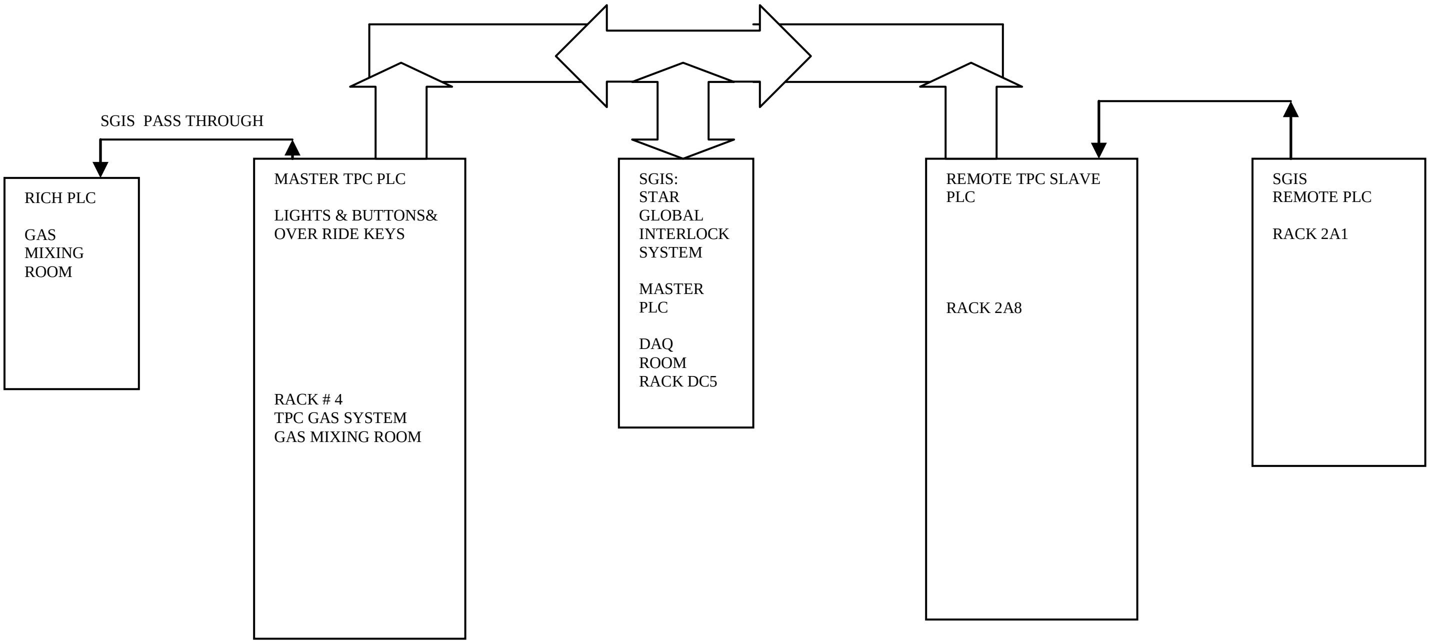
INTRODUCTION

The STAR TPC interlock system is a stand-alone Allen-Bradley PLC that is primarily used to automatically protect the TPC and sub-systems. It receives inputs from various sources and takes actions according to programmed logic. This document is intended to be a guide for dealing with the interlock trips that may arise and getting the TPC safely running again. See also the document SOP-TPC-GAS-06-A, “Allen Bradley Interlock system for the STAR TPC Gas System” by Jim Thomas.

NOTE: The PLC takes actions AUTOMATICALLY without operator intervention if unsafe conditions arise. This document is meant as a guide for the operator to figure out what happened, how to correct the problem, and get running again. Even though there is some override capability built into the system, YOU do not have authority to implement these overrides! Running with a bypassed safety system can only be attempted for debug purposes and only with the permission of Blair Stringfellow or Howard Wieman (in consultation with STAR and RHIC safety officers.) Ignoring these guidelines can result in severe damage to the TPC and/or denying STAR permission to run.

The TPC interlock system was implemented and is maintained by Jim Thomas (LBNL). Operational questions should be addressed to him or to Blair Stringfellow.

BLOCK SCHEMATIC



The master TPC PLC is in the gas mixing room in Rack #4 of the TPC gas system. This is the main indicator/input/override panel. A representation of this panel (and additional inputs) is available in the control room via slow controls. On the top level TPC GUI, click on the “Interlocks” button.

The master TPC PLC communicates over fiber optics with the main STAR GLOBAL INTERLOCK SYSTEM (SGIS) PLC located in the DAQ room. It also uses a remote (slave) PLC on the platform (back of RACK 2A8) to collect sensor inputs and send out permissives to various HV power supplies etc.

ALARM ANNUNCIATION

TPC interlock alarms (also called gas alarms) are indicated in four separate places simultaneously in the STAR complex:

1. Control room – a box is mounted on the wall containing two sets of red/green lights, a beeper and an acknowledge (silence) button. One set of lights is for gas alarms, the other for TPC cooling water skid problems. For normal running, both lights will be green. For an alarm, one or both lights will be red and the beeper will sound.

2. Counting house – a similar box is mounted in the counting house.

3. Gas Mixing Room – There is a large mechanical bell mounted on the wall of the Assembly Building (AB) just outside the gas mixing room. For any type of TPC alarm this bell will sound. There is also a flashing red light mounted on the top of Gas Rack #3 in the mixing room.

4. Detector – There is a loud horn and flashing red light mounted on the second level of the south platform. This will go off for any TPC alarm.

The global interlock system (SGIS) can also sound alarms. In the control room and counting house there is a separate box (2 red lights and beeper) for SGIS. In addition, SGIS can INDEPENDENTLY sound the horn on the detector for a global alarm. Note that for a major detector problem it is entirely possible for ALL alarms to go off simultaneously since the TPC system and SGIS have a significant degree of overlap.

TURNING OFF THE ALARM

For some alarms up to five bells or beepers will be sounding. The first job is to acknowledge (and silence) the alarms:

1. Control room and counting house – for a TPC gas or water alarm, push the acknowledge button on the beeper box and then go to the gas mixing room.

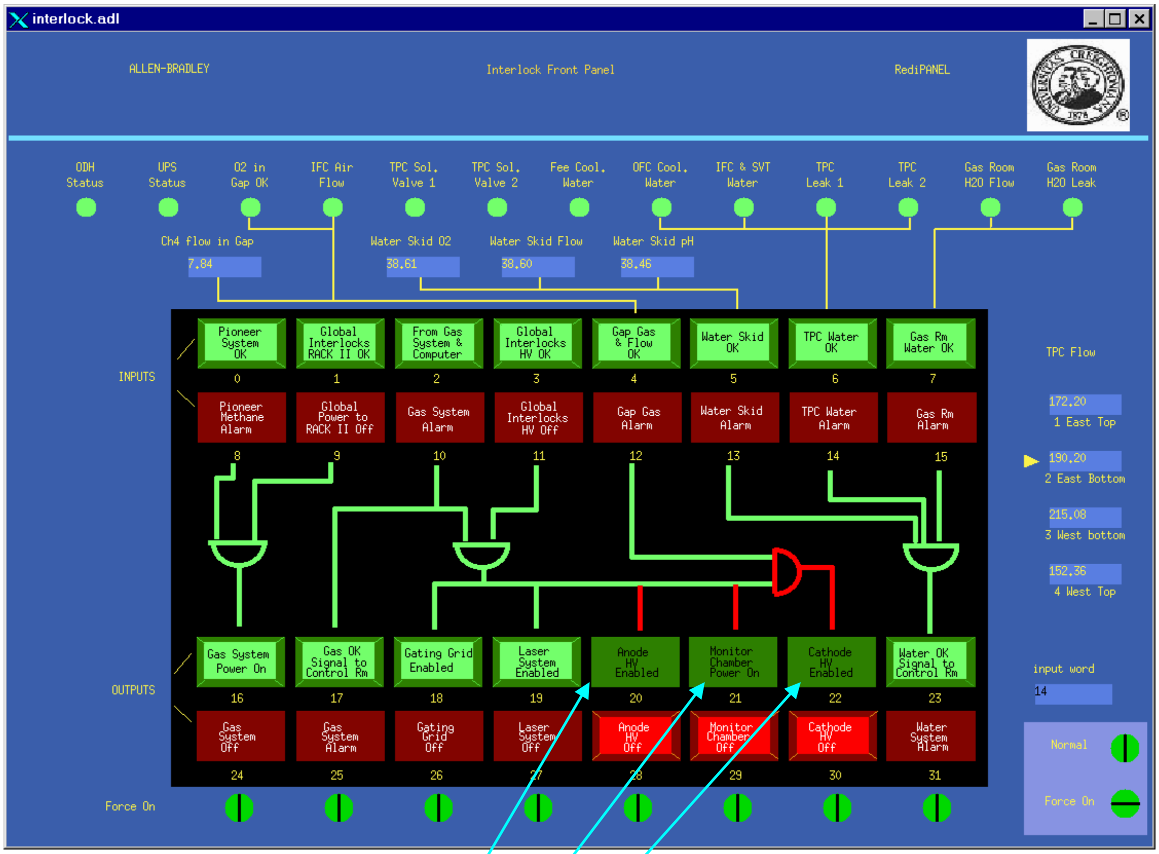
2. Gas mixing room and detector – The alarm silence pushbutton is located in TPC Gas Rack #4 near the PLC panel Pushing this button silences the alarm in both places.

3. SGIS Alarm – go to the DAQ room, Rack DC5 and push F3 on the touch panel (Alarm Silence)

Note that silencing the alarm has in NO WAY solved the problem – it just gives you peace and quiet to get on with finding out what went wrong.

TPC INTERLOCK PANEL & SCHEMATIC

The TPC interlock front panel in the gas mixing room has lights and push buttons that reflect the status of the inputs (sensors) and condition of the output permissives. As shown in slow controls, the panel looks like:



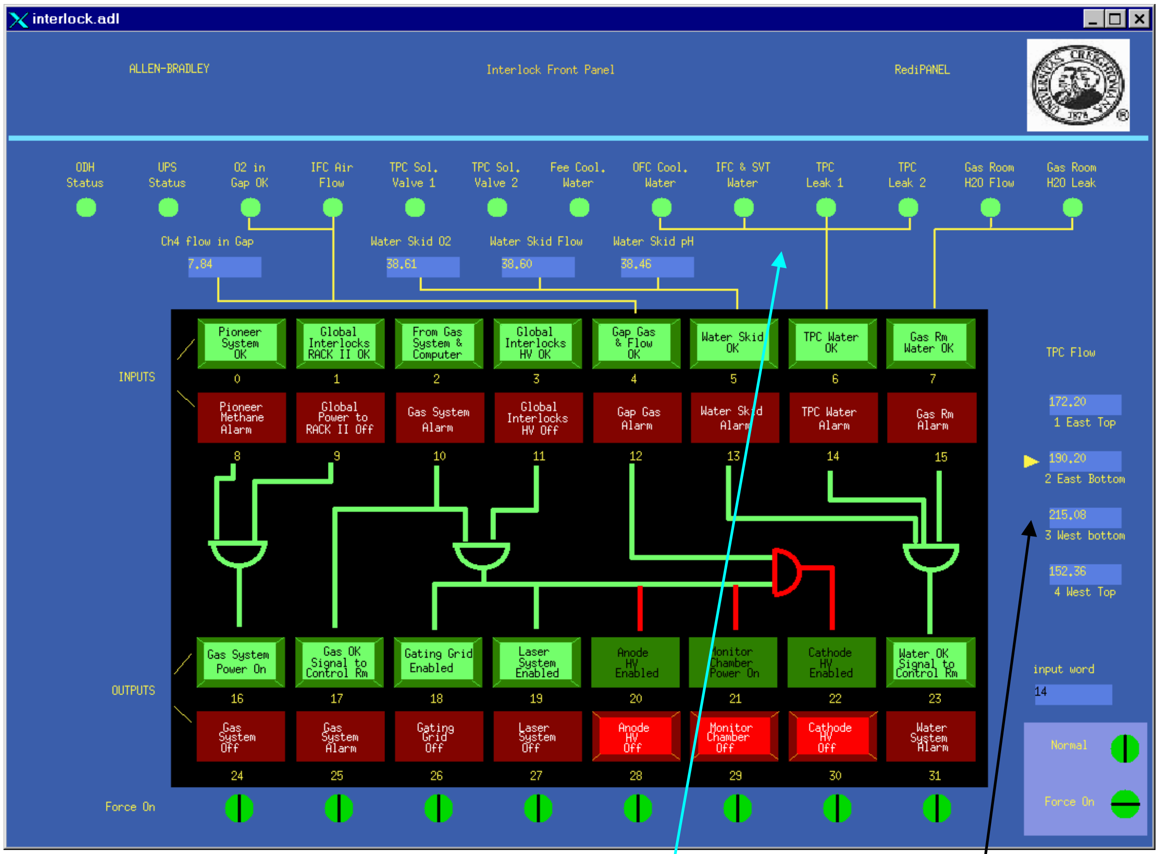
The top two rows of lights are indicators only, reflecting the status of the various safety system inputs. As shown, all inputs are green (= OK to run). If one of the inputs goes to red (= not OK) the affected subsystem will lose its permissive and the alarm will sound.

The bottom two rows of lights are both indicators and buttons. As shown, three subsystems currently do not have permission to turn on (Anode HV, Monitor Chamber and Cathode). Since the inputs for these systems are OK (i.e. all the inputs in the top row are green) their permissive can be enabled by pushing the corresponding green output buttons.

NOTE: After an alarm that drops a permissive the output will stay in a not OK state (latched off) even after the problem has been fixed. You must go to the gas mixing room to re-enable each output after an alarm.

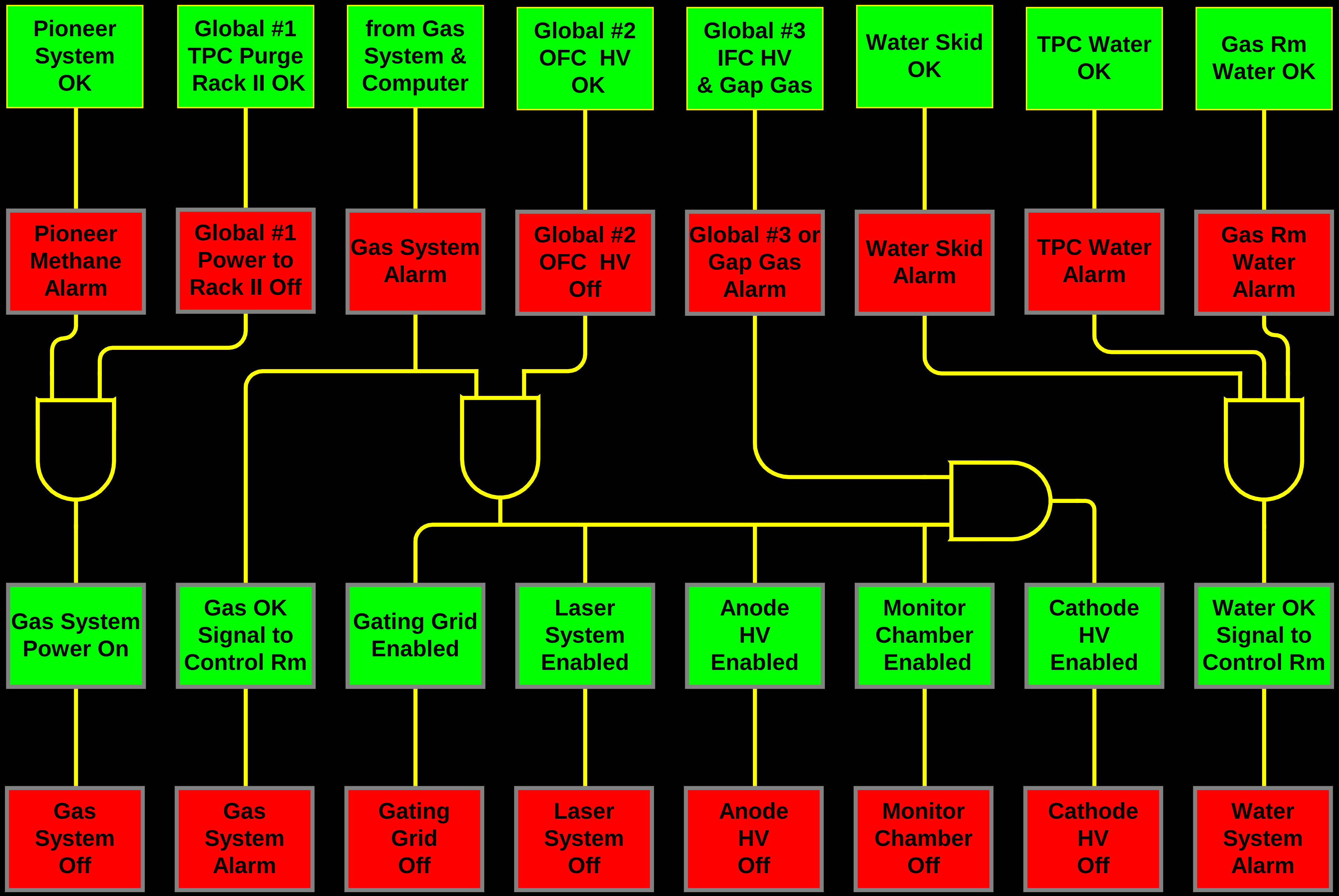
The output lights/buttons have two additional states. A permissive can be FORCED OFF at any time by pushing the corresponding red button. The light will then flash. A flashing red light means someone wants the system to stay OFF, so you need to find the reason for this. An output can also be FORCED ON by using an override key – this can only be done by the TPC subsystem manager or his designate. Note that OUTPUT permissives can be over ridden – inputs can not be.

The slow controls GUI for the interlock system contains additional information that is not shown in the gas mixing room.



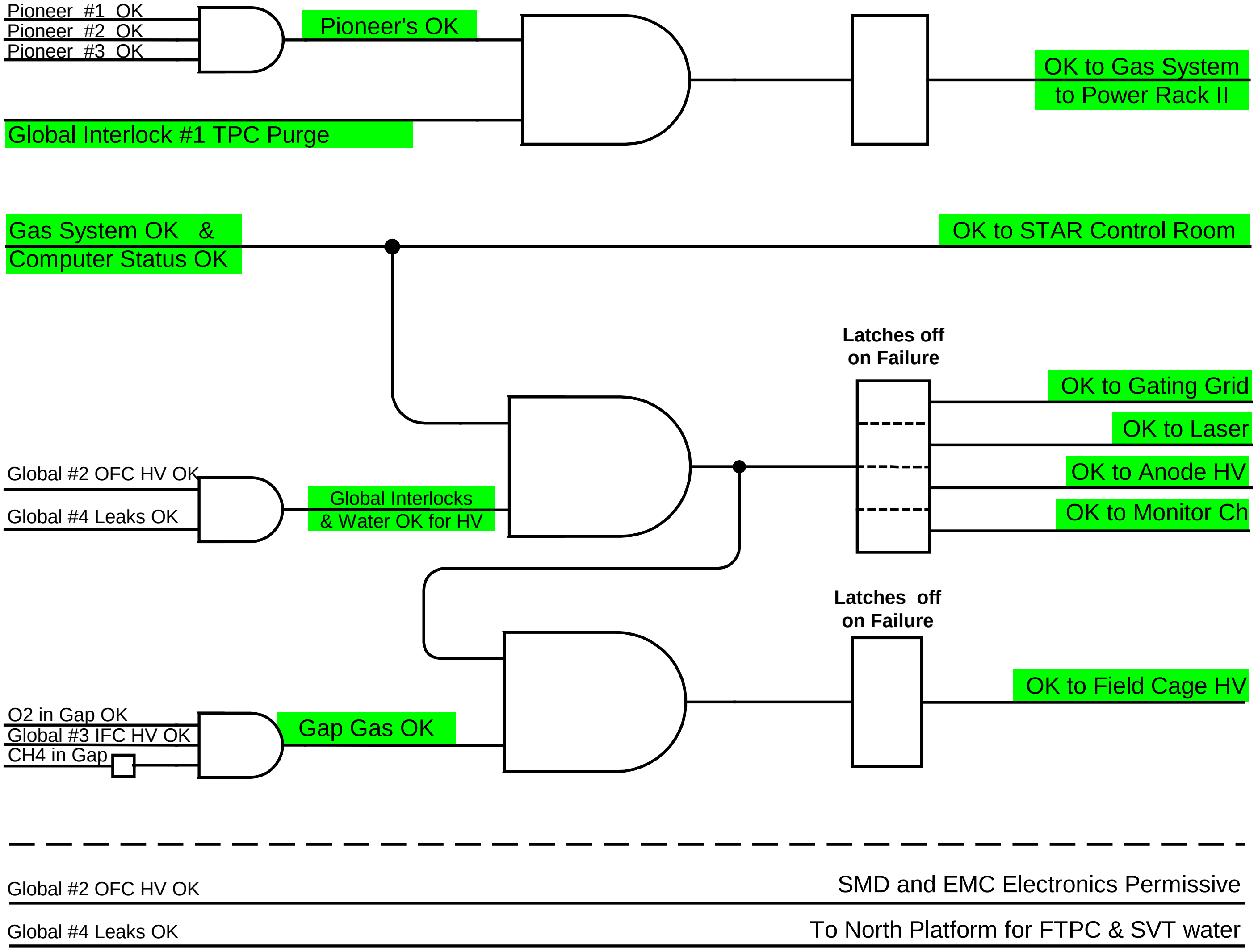
The row of round status lights across the top show various sensor inputs to the system. Also, the four TPC cooling water flow rates are shown on the right.. A more complete logic schematic for the interlock system is shown on the next several pages:

Allen Bradley Interlocks Front Panel - Attachment 1

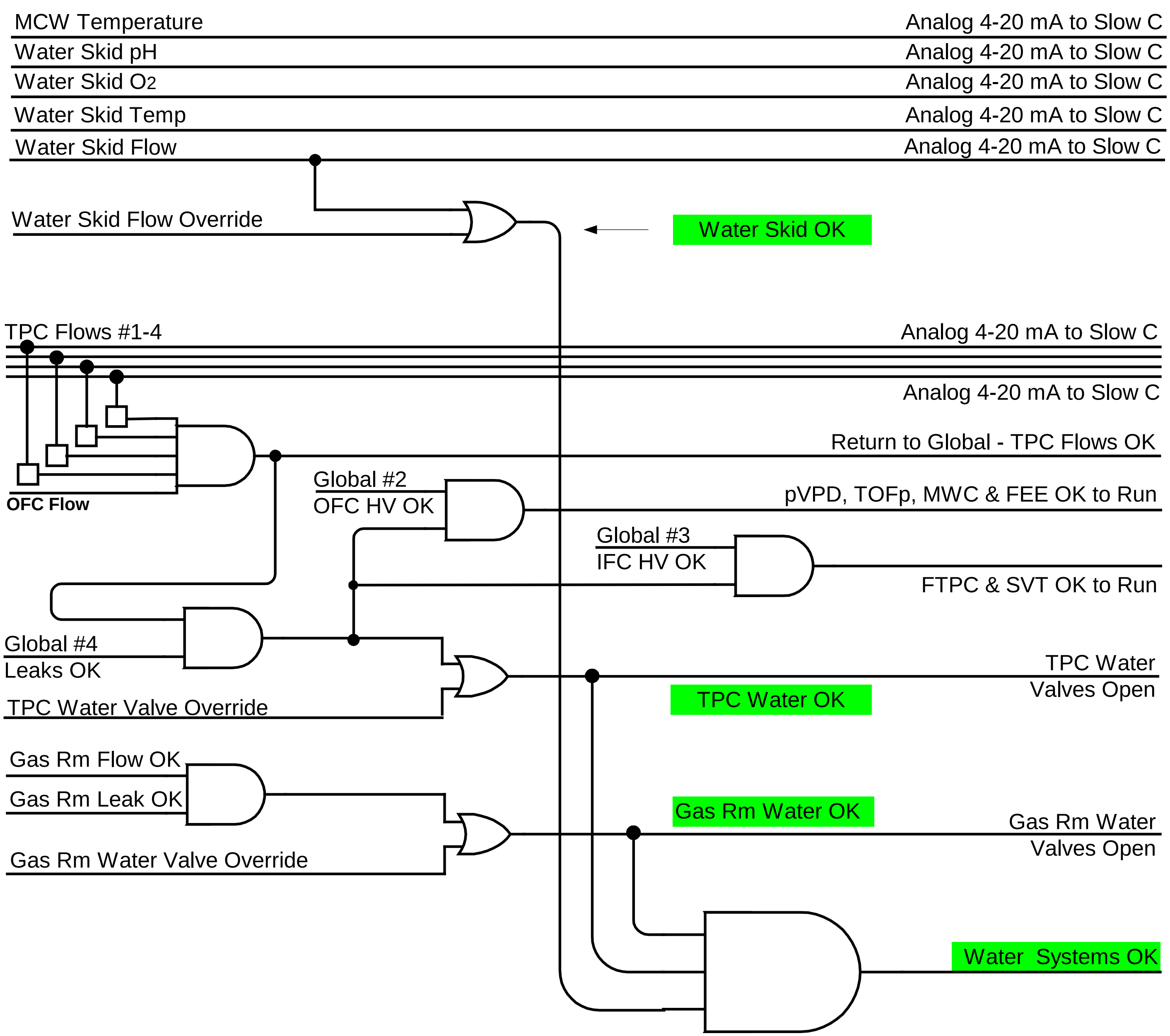


Sub-System	Global Interlocks #1 TPC Purge	High Level Methane	High Level Smoke (Delayed)	Global Interlocks #2 OFC OK to Run	High Level Methane	High Level Smoke (Prompt)	Detector Water Leaks	Global Interlocks #3 IFC OK to Run	High Level Methane	High Level Smoke (Prompt)	Detector Water Leaks	IFC Air Flow	Global Interlocks #4 Detector Water Leaks	Pioneer Gas Alarm - Methane in Gas Rm	Gas System Fault & Computer Status	Gas Room Water Leak	Gas Room Water Flow	TPC E&W Face Water Flow	OFC Water Flow	Methane in TPC Insulator Gap	Oxygen in TPC Insulator Gap	Water Skid Flow	Water Skid pH	Water Skid Oxygen Level	Water Skid Temperature	ODH Status	UPS Status	MCW Temperature
STAR Control Room - Water Alarm							X				X		X			X	X	X	X			X						
STAR Control Room - Gas Alarm		X	X		X	X			X	X				X	X													
TPC Water Valves Close							X				X		X					X	X			X						
Gas Rm Water Valves Close																X	X											
Power to TPC Gas System		X	X		X	X			X	X				X														
TPC Gating Grid		X	X		X	X	X		X	X	X		X	X	X													
TPC Anode		X	X		X	X	X		X	X	X		X	X	X													
TPC Cathode		X	X		X	X	X		X	X	X	X	X	X	X					X	X							
TPC Monitor Chamber		X	X		X	X	X		X	X	X		X	X	X													
Laser		X	X		X	X	X		X	X	X		X	X	X													
RICH		X	X		X	X	X		X	X	X		X	X														
FEE, MWC, TOFp & pVPD Electronics		X	X		X	X	X		X	X	X		X					X	X			X						
SVT & FTPC Electronics		X	X		X	X	X		X	X	X	X	X					X	X			X						
EMC & SMD Electronics		X	X		X	X	X		X	X	X		X															
SVT & FTPC Water							X				X		X															
Slow Controls		X	X		X	X	X		X	X	X		X	X	X	X	X	X	X	X	X	X	X	X		X	X	X

Attachment 2: Allen Bradley Logic Diagram



Attachment 2: Allen Bradley Logic Diagram (continued)



Attachment 3: Allen Bradley Crate & Module Map

Master Crate in Gas Room

P2 Power Supply	CPU 5/03	1747-SN	1746-NI4	1746-IB16	1746-NI4	1746-OW16	1746-OX8	1746-IB16	1746-IB32	1746-OB32
	16K Mem	RIO Scanner	Analog Input	24 V Input	Analog Input	24 V Output	Relay Output	24 V Input	24 V Input	24 V Output
	OS 302	to remote crate	4 Ch.	16 Ch.	4 Ch.	16 Ch.	8 Ch.	16 Ch.	32 Ch.	32 Ch.
			4-20 mA or 0-10 V DC **Gap CH_4** **pH Flow O_2**	**4- Pi** **Gas Flow** **Gas Leak** **Gas OK** **Gap O_2**	4-20 mA or 0-10 V DC **TPC Temp** **MCW Temp**	Two groups of 8 **Eight Kybd Out** **OFC OK** **TPC Valves** **Gas Rm Valves**	Indep ch's contact closure	**Kbrd Ovrd 8 inp** **Water Skid Ovrd** **TPC Flow Ovrd** **Gas Flow Ovrd**	Kbrd button input	Kbrd lights output
Full Slot Addressing	0	1	2	3	4	5	6	7	8	9

ODH (8)
Gas Lo Lv Alarm (9)

UPS (11)
Three Gas Rm Inputs (13)
FTPC(14)
MCW(15)

IFC OK (11)

Three Platform Outputs (13-15)

Platform Alarm & Reset (11)

Gas Alarm (1)
Pioneer Alarm (2)
Global #2 (3)
Global #1 (4)
Global #4 (5)
Gas OR Water (6)
Water Alarm (7)

Attachment 3: Allen Bradley Crate & Module Map (continued)

Slave Crate on Platform

		0	32	64	96	128	160
P2 Power Supply	1747-ASB	1746-NI4	1746-OW16	1746-IB16	1746-OX8	1746-IG16	1746-OG16
	RIO Adapter	Analog Input	Relay Output	24 V Input	Relay Output	TTL Input	TTL Output
	from master crate	4 Ch.	16 Ch.	16 Ch.	8 Ch.	16 Ch.	16 Ch.
		4-20 mA or 0-10 V DC **4 - TPC Flow**	Two groups of 8 **Eight Kybd Out** **OFC OK** **TPC Valves** **Gas Rm Valves**	**Glob #1** **Glob #2** **OFC Flow** **Glob #3** **Glob #4**	Indep ch's contact closure **MWC (0)** **Flows OK (5)** **Kybd Out (1-4,6,7)**	from Slow Control	to Slow Control
1/2 Slot Addressing		0, 1	2, 3	4, 5	6, 7	8, 9	10, 11
			IFC OK (11) Flows OK (12) Three Gas Rm Outputs (13) FTPC(14) MCW(15)	4 TPC Flow Status (8-11) Three Platform Inputs (13-15)			

TTL 1 = B3:0
TTL 2 = B3:1
TTL 3 = B3:2
TTL 4 = B3:3
TTL 5 = B3:4
TTL 6 = Kpad 1&2
TTL 7 = Kpad 3&4
TTL 8 = Local Analog 1
TTL 9 = Local Analog 2
TTL 10 = Local Analog 3
TTL 11 = Local Analog 4
TTL 12 = Rmt Analog 1
TTL 13 = Rmt Analog 2
TTL 14 = Rmt Analog 3
TTL 15 = Rmt Analog 4
TTL 16 = Local Input
TTL 17 = Rmt Input
TTL 18 = Local Analog 5
TTL 19 = Local Analog 6
TTL 20 = Local Analog 7
TTL 21 = Local Analog 8

B3:0 = Logical inputs (0-11) [First level logic] (8 == OFC OK to run, 9 == TPC Flows OK, 10 == TPC Leaks OK, 11 == IFC OK to run)
B3:1 = Temp outputs (0-11) [Second level logic] (same map as B3:4)
B3:2 = Forced On Reg (0-10) (8 == Water Skid, 9 == TPC Water Valves, 10 == Gas Rm Water Valves)
B3:3 = Forced Off Reg (0-7)
B3:4 = Enable Output (0-11) (8 == OFC OK to run, 9 == TPC Water Valves, 10 == Gas Rm Water Valves, 11 == IFC OK to run)

ALARM RESPONSE FOR OPERATORS

In the following pages, each type of alarm will be explained. Specifically, for each input to the interlock system, the following information will be given:

1. INPUT: Where the sensors are located, what they are measuring, and what the alarm threshold is.

2. ACTIONS TAKEN BY PLC: What actions are taken by the PLC and what subsystems are affected.

3. RESET: What needs to be done to reset the interlock, including who to call if it is not solely STAR's responsibility.

PIONEER METHANE DETECTOR

The Pioneer methane detector checks for leaks in the gas mixing room. The controller is mounted on the south wall between TPC Racks 1 & 2.

INPUTS: There are three sensor heads in the mixing room. One is mounted on top of TPC Rack 2, another is mounted inside TPC Rack 3 and the third is located at the bottom of the RICH gas rack. The sensors are sniffing the room air for the presence of methane and will alarm for a concentration of 18% LEL Methane in air. (LEL = Lower Explosive Limit = ~ 5% in air).

ACTIONS TAKEN BY PLC: For any ONE of the three sensors above threshold, the following actions are taken:

1. AC Power to Rack 2 of the TPC gas system is cut. This puts the TPC gas system into purge mode (Argon) and closes the methane inlet solenoid valves.

The power to Rack 2 comes from a three phase solid state relay mounted in a box on the south wall of the gas mixing room between racks 2 & 3. The power is held on by the 24 volts control voltage supplied by the interlock system. Absence of this control voltage drops the power to Rack 2.

2. ALL permissives for the TPC HV are dropped (Gating Grid, Laser, Anode, Monitor Chamber, & Cathode)

3. The RICH gas system goes into safe mode.

RESET: This is a MAJOR alarm and recovery can not be attempted by shift leaders alone! CALL:

TPC Expert
TPC Gas Expert
RICH Expert

GLOBAL INTERLOCKS RACK II OK

This is an input from the STAR Global Interlock System (SGIS) that permits the TPC gas system to run with P10.

INPUTS: There are two conditions that cause the permissive to be removed:

1. High Level Alarm: High Sensitivity Smoke Detector.(HSSD) This is a system that senses smoke around the detector in the WAH.

2. High level gas alarm. There is a sniffer system located in Rack 2A2 that draws air samples from the TPC face through 8 separate tubes. If methane is detected at the level of ~ 12% LEL, the unit generates a high level alarm.

ACTIONS TAKEN BY PLC: For a HSSD High Alarm:

1. After a 10 minute delay, drop the permissive for the gas system.

For a High Level Gas Alarm:

1. Immediately drop the permissive for the gas system.

Upon removal of the permissive, the power to Rack 2 of the TPC gas system goes off, the TPC is purged with Ar and the methane inlet valves are closed.

NOTE: The TPC volume is 50,000 liters of P10. The Argon purge is at the rate of ~ 120 lpm. To purge the TPC to a level that is considered safe by CAD (i.e. P8) takes ~ 1 hour.

Both these alarms are major STAR alarms and the SGIS will take further action, such as tripping platform power. See the SGIS manual.

RESET: These are major STAR alarms that result in complete shutdown of the STAR detector. For HSSD, the fire department will be on the way.

Call: MCR X4662
STAR Global Interlock Expert
TPC expert
TPC gas expert

FROM GAS SYSTEM & COMPUTER

This is the input from the TPC gas system. The gas system has its own system of interlocks and alarms, which can come from the hardware alarm box (top of Rack 2) or from the control computer (Rack 1). These alarms can be of varying degrees of severity, but they are ALL annunciated through the Allen-Bradley system.

INPUTS: The gas system alarms can be split into two broad categories:

1. High level alarm – usually indicates something wrong with the TPC pressure, methane content etc. Various actions are taken by both the gas system itself (compressor turned off, vent opened) and by the Allen-Bradley PLC (see below)

2. Low level (informational alarms). Usually indicates a non-emergency problem (gas bottle low, delivery pressure not adjusted etc)

ACTIONS TAKEN BY PLC:

High level alarms that turn off the permissives for the TPC HV (Gating grid, laser, anode, monitor chamber and cathode.)

From the computer:

- TPC pressure too high (PT8)
- TPC pressure too low (PT8)
- Oxygen too high (M1)
- Water too high (M2)
- Ar-Methane flowmeter ratio too high
- Ar-Methane flowmeter ratio too low

From the hardware alarm box:

- Return Pressure from TPC too high (PT5)
- Return pressure fromTPC too low (PT5)
- Oxygen too high (M1)
- Water too high (M2)

Truth tables for the gas systems (with alarm limits) are posted in the gas mixing room.

For low level alarms, the PLC merely sounds the alarm (“gas alarm” in control room, counting house, AB and WAH). No other action is taken.

RESET: ANY gas alarm needs attention from a gas system expert – call.

GLOBAL INTERLOCKS HV OK

This is a separate input from the global system (SGIS) which permits the TPC HV to be turned on. There is a significant overlap between this input and the "Global Interlocks RACK II OK" (see above), since putting the gas system into purge mode will independently turn off all HV. However, this input adds one more condition dealing with water leaks.

INPUTS: There are three conditions that cause the HV permissive to be dropped:

1. High Sensitivity Smoke Detector (HSSD) High Alarm.

2. High level gas alarm – from the methane sniffer in Rack 2A2.

3. Cooling water leak – east TPC face, west TPC face or RICH. There are three "Tracetek" water detection cable circuits that loop through the water cooling manifolds of the TPC and RICH. Any alarm from these circuits causes the HV to trip and the TPC water skid to shut down (see below).

ACTIONS TAKEN BY PLC: For a HSSD High Alarm:

1. Causes an immediate trip of the HV (but a 10 min delay before causing a gas system purge – see above). Note also that this alarm turns off ALL power on the platform, so it is triply redundant.)

For a High Level Gas Alarm:

1. Trips all TPC HV (and power to the platform)

For a Water Alarm:

1. Trips all TPC HV (Gating Grid, Laser, Anode, Monitor Chamber & Cathode) and shuts down the water skid (see below under "TPC Water OK").

RESET: Again, the smoke and gas alarms are major STAR alarms that shutdown the whole detector. Call MCR, SGIS expert, TPC gas expert.

A water alarm will require an access to investigate the cause and to reset the Tracetek controller (Rack 2A1). See below under "TPC Water OK".

GAP GAS & FLOW OK

Between the TPC outer field cage and the outer gas containment vessel is a 5 inch gas insulating gap. This volume is continuously purged with dry nitrogen, which acts as the insulator. The return gas is sampled to test for oxygen, water and methane. The controls and meters for the insulation gas system are in Rack 4 in the gas mixing room. In addition, to prevent a possible buildup of Methane in the inner field cage region (where the SVT is mounted), a continuous flow of conditioned air is maintained. The air blower is maintained by the SVT group and sits in the WAH on the floor (east end of the magnet). This are is not sampled, but there is a flow switch in the exhaust line.

INPUTS: 1. Oxygen in gap is < 200 ppm. The Oxygen meter (M6) is mounted in Rack 4 in the gas mixing room.

2. Methane in gap < 18% LEL. The methane meter is in Rack 4 in the gas mixing room (M8).

3. IFC air flow ok. The flow switch is mounted in a grey PVC tube which comes from the SVT cover plate on the west side. The end of the tube (and the switch) is mounted on the magnet face.

ACTIONS TAKEN BY PLC: 1. For high oxygen, high methane, or no IFC flow the permissive for the **cathode** only is dropped, since it is the only ignition source in these regions.

RESET: 1. For a high oxygen or high methane, contact a TPC gas system expert.

2. For the IFC air flow, request an access and check the SVT air blower. If ok, check the flow switch – it has a red LED that should be OFF if the flow is ok. If the interlock still won’t clear, contact a TPC expert or Jim Thomas (interlock expert.)

Note: The only place to check the status bit of the IFC air flow is on the slow controls Interlock GUI accessible from the top level TPC GUI. The status is indicated by the “IFC Air Flow” light (green = ok).

WATER SKID OK

This input has not been implemented yet and should always be OK (= green). It will eventually have inputs from the TPC water skid (located in AB second floor utility room) indicating total water flow, dissolved oxygen and pH.

TPC WATER OK

The TPC water skid (located in the second floor utility room) supplies water for the TPC FEE and read-out boards (RDO), SVT RDO boxes, RICH safety box and the gas mixing room. The skid exchanges heat with the STAR Modified Chilled Water (MCW) that is also cooling the racks on the platform and in the DAQ room. In general, the interlock system is checking for minimum flow rates in all branches and for leaks.

INPUTS: 1. Flow rates from the four main cooling branches:

East top, East bottom, West Top, West Bottom

The flow meters are mounted on the magnet face, shielded by mu metal.

2. Global HV OK (see above)

3. Flow rate from the branch that circulates water along the outer containment vessel (called CTB flow on the schematic).

4. IFC & SVT Flow – a dummy input always OK.

5. TPC leak #1 & #2 – from the east and west Tractek leak detection circuits threaded through the cooling manifolds.

6. RICH leak – independent Tracetek circuit for the RICH loop.

ACTIONS TAKEN BY PLC: For any alarm (low flow, Global HV or leak) the platform slave PLC for the TPC will close the main supply and return valves for the cooling water. This will cause the skid to shut down.

The TPC water alarm will sound (second red/green light in the control room and counting house) and if there is a leak there will also be a global alarm.

The valves are located in the water lines just after they cross from the west wall to the magnet. They are driven open or closed by 110 VAC. There is an indicator on the backs of the valves which shows if they are open or closed.

RESET: For a leak:

An access will be needed to check for the source of the leak. With the pole tips in this may be non-trivial! Also, the Tracetek control units, mounted in Rack 2A1 have a reset button that has to be pushed before the alarm can be cleared. For a real leak, the control box will have a red LED status light on. Once the source of the leak alarm has been determined, the skid can be restarted. Note that the leak indication MUST be cleared both at the controller and at the Global PLC.

Restarting the skid:

The skid will be shutdown for an alarm, but it can also trip off during a power dip etc. To restart:

Call the CAS watch (X2024) or MCR (4662) and request that they send a pump room person over. The skid is the responsibility of CAD but the interlocks and permission to restart are STAR's responsibility. DON'T restart the skid unless you are satisfied that there are no leaks in the WAH!

Before restarting the skid it is necessary to over ride and open the main supply and return valves. Go to the back of Rack 4 in the gas mixing room and locate the two keys labeled "TPC H2O OVRD" and "GAS RM H2O OVRD". Turn both keys to the over ride position (horizontal). This will force the supply and return valves open. On the front PLC panel (Rack 4) the top green lights labeled "TPC Water OK" and "Gas Rm Water OK" should be flashing green.

Tell the pump room tech to start the skid. When the skid comes up to full flow, a green ok light will come on (near the start pushbutton). Check that the skid flow is ~ 270 GPM or greater (flow meter on the skid front panel.) If skid flow looks ok, return to the gas mixing room and return both keys to the normal (vertical) position. The green light near the keys (labeled "FEE cooling water ok" should be green and the two lights on the PLC panel should be green and not flashing.

If the alarm goes off again when you turn the keys to normal, then there is still a problem and the skid will shutdown again.

NOTE: NEVER run the TPC skid with the keys in over ride for longer than it takes to restart the skid. In override there is NO leak protection and the entire contents of the reserve tank could be dumped on the experiment.

GAS ROOM WATER OK

A branch of the TPC water line is used to cool equipment in the gas mixing room. The lines are located on the south wall of the AB just outside the gas mixing room. A manifold with visual flowmeter, flow switch and solenoid valves is also located there. The water is used in three of the TPC gas system racks:

1. Rack 1 for the Rosemount methane analyzer water jacket.
2. Rack 2 for the heat exchanger after the compressor and for the mass flowmeters.
3. Rack 3 for the cooling jackets of the two Rosemounts.

Leak detection is provided by a local Tracetek circuit with the controller mounted in back of Rack 4.

INPUTS: 1. Flow switch ok – mounted on the manifold outside the mixing room. Flow >` 1 GPM = OK.

2. Tracetek leak detector ok.

ACTIONS TAKEN BY PLC: For lack of flow or leak indication:

1. Close the local supply and return solenoid valves mounted on the manifold. The solenoids are powered open (110 VAC) by supplying a 24 V control signal to a solid state relay mounted in a box on the south wall of the AB.

2. Sound the TPC water alarm in the control room, counting house, WAH and AB.

Closing the gas room water solenoids will NOT affect the water skid – it will keep running. Lack of cooling water to the gas system is not necessarily a major alarm. However, the Rosemount methane analyzers will quickly lose calibration and the gas being sent to the TPC will not be constant temperature.

RESET: For a leak, find the source and fix it. After the leak has been repaired, allow the Tracetek cable to dry out and then push the reset button on the Tracetek controller (back of Rack 4). Then turn the over ride key labeled “Gas Rm H2O OVRD” – this should open the solenoid valves. Go to the water manifold outside the mixing room and check that the visual flowmeter shows ~ 2 GPM and that the LED on the flow switch is out.

Return the over ride key to the normal position.

HARDWARE CONNECTIONS

The following is a brief description of how the PLC controls each system:

1. Gas system:

    The power to Rack 2 comes from a three phase solid state relay mounted in a box on the south wall of the gas mixing room between racks 2 & 3. The power is held on by the 24 volts control voltage supplied by the interlock system. Absence of this control voltage drops the power to Rack 2 . This will cause the gas system to close the methane inlet valves, open the vent valve, and start an Argon purge (~75 lpm).

2. Gas system alarm:

    1. The alarm boxes in the control room and counting house are home built devices containing lights, relays and a reset switch. They get power from local AC to DC converters. The signals from the PLC get to the alarm boxes using phone lines.

    2. The alarm bell in the AB (mounted on the wall outside the gas mixing room) is a 110 VAC bell controlled by a solid state relay mounted in a box nearby. The PLC supplies the control voltage (24 V) for the relay.

    3. The alarm horn and light mounted on the platform in the WAH are controlled from the remote TPC PLC.

3. Gating Grid – the VME crate for the gating grid driver modules (Rack 2A6) has an inhibit input at the front of the crate (DB15 connector). The remote PLC on the platform supplies 24 volts for this input, which is dropped to 12 volts by a Zener diode in the connector hood. A voltage < 12 volts = inhibit.

    Note: The pulser VME crate (Rack 2A5) has a similar inhibit input (for historical reasons.) Thus, even though the pulser is not an ignition source, it has the same interlock as the gated grid, also supplied from the remote PLC via a DB 15 connctor.

4. Laser System – the laser system is interlocked by a contact closure from the remote PLC. (Contact closed = OK to run.) The cable goes into the laser interlock box mounted in back of Rack 1A9. (Burndy twist lock connector).

5. Anode HV off – the interlock for each Lecroy HV crate is supplied by the remote TPC PLC. The permissive to run is a contact closure supplied on a BNC cable which plugs into the “Macro” input on the front of the Lecroy crates (Rack 2A7). We use the macro input in place of the normal interlock input since it is remotely resettable.

6. Monitor Chamber – the monitor chamber is located inside Rack 3 in the gas

mixing room. It can be used to measure electron transmission in the TPC gas (in case of questions about gas quality). Under normal condirtions the chamber is OFF and is of no concern. It is interlocked by turning off the Nim Bin which contains the HV modules. The Nim Bin is mounted in Rack 4 of the gas system.

7. Cathode HV – the Glassman HV power supply (mounted in Rack 2A3) is interlocked by a contact closure from the remote TPC PLC.. The cable attaches to the TB1 terminal strip on the back of the Glassman. (See the Glassman manual and documentation supplied by Greg Harper from U of Wash.)

8. Water System Alarm – the water skid is shut down by powering closed the supply and return valves located in the WAH. This slows the flow enough that the flow switch on the skid interupts the pump power. The AC power to drive the valves is controlled by the remote PLC, with the AC coming from the UPS at the top of Rack 2A9. The power for the five water flowmeters also plugs into this UPS, as does the PLC itself.

SOP-TPC-GAS-O6-A

Allen Bradley Interlock System for the STAR TPC Gas System

Text Pages 1 through 12
Attachments 1 through 6

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Version 2.6 03/10/2001

Allen Bradley Interlock System for the STAR TPC Gas System

1.0 Purpose and Scope

An Allen Bradley interlock system has been developed in order to monitor the functioning of the STAR TPC gas system and to ensure that no ignition sources are operating while the system is in a potentially unsafe state. This document will outline the operation of the Allen Bradley interlock system, define the inputs and outputs, define the operating procedures for this interlock system, and describe a calibration, maintenance, and testing schedule and procedure.

The interlock system has expanded in scope since version 1.0 of this document was issued. The system includes all of the previous functionality, and operates in an essentially identical manner, but now the system also monitors the cooling water flow to the TPC and the Gas Mixing room. If any of these water systems fails, the interlock system sends an alarm to the STAR control room and signals Slow Controls to turn off the Front End Electronics (FEE) power. The interlock system also causes the inline water valves to the TPC and the Gas Room to close, thereby stopping the water flow, until the cooling water problem is understood and corrected.

2.0 AFFECTED SYSTEMS

TPC GAS SYSTEM, ANODE HV, FIELD CAGE HV, TPC GAS MONITOR CHAMBER, GATING GRID, LASER CALIBRATION SYSTEM, FEE ELECTRONICS, TPC WATER VALVES, GAS MIXING ROOM WATER VALVES.

3.0 Description of the Hardware

The Allen Bradley interlock system enables power to all systems that are potential sources of ignition on the TPC and in the gas room. These include the Anode High Voltage for the TPC multi-wire proportional chambers, the Gating Grid, the Field Cage High Voltage, the Monitor Chamber High Voltage, and the Laser Calibration System. In addition, the Allen Bradley interlock system controls power to the TPC gas system and shuts off the power if methane gas is detected in the Gas Mixing room. The AB interlock system also kills power to the gas system if requested to do so by the Global Interlock system. Killing power to the gas system automatically puts the TPC in purge mode. (A separate document describes the TPC gas system in more detail.)

The Allen Bradley interlock system also monitors the TPC cooling water system. If the system is operating normally, the AB computer merely opens and closes the water valves in the Gas Room and at the TPC upon request. But if the water systems has insufficient flow, a leak, or highly corrosive water (measured by pH and dissolved oxygen content), then the AB computer closes the valves and alerts the operators in the STAR control room.

The Allen Bradley interlock system uses two inputs from a Pioneer gas monitoring system located in the Gas Mixing Room to sense whether the gas system is leaking methane into the Gas Mixing Room. The alarm levels for the Pioneer are set within the Pioneer system and thus the signal to the Allen Bradley is either 24V (methane below alarm level) or 0V (methane above alarm level or input disabled).

The AB computer monitors inputs from the TPC gas system that reflect the operational status of the gas system, plus two sensors that measure the Oxygen content and Methane content of the TPC insulator gas gap, and a flow sensor that tells whether cooling air is being flushed through the TPC inner field cage. The signal from the insulator gas Methane sensor is a variable (4-20 mA) current loop. The other signals are +24V or 0V.

The new additions to the AB system include monitor signals to sense the flow of cooling water throughout the TPC systems and signals to report a leak in any of these systems.

The status of the inputs and outputs are shown on an LED light panel mounted in the gas room. (See attachment 1.) These signals are also reported to the STAR slow controls system. The Allen Bradley system also sends two signals to the STAR control room showing the status of the TPC gas system and the TPC cooling water system.

The Allen Bradley system itself is very robust. The AC power for the system is backed up by a UPS (duration ~20 minutes) and the AB computer is equipped with an EEPROM that ensures proper operation after a long term power failure.

4.0 **Operating Status**

The status of the Allen Bradley inputs is shown at all times by a series of red and green lights on an LED light panel in the Gas room. (See Attachment 1.) The top two rows of the display panel show the state of the various input channels. The first column shows the status of the Pioneer methane monitoring system. The second column shows whether the Global Interlock system is ready. The third column shows the status of the TPC gas system. This system is equipped with many internal sensors that monitor the status of the P10 gas. These signals are combined into a single output that is fed into the Allen Bradley system. Should there be a problem with the P10 gas system, an LED light panel at the top of the gas system (Rack 2) allows for a diagnosis of the problem independent of the Allen Bradley. The fourth column shows whether the Global Interlock system has given permission to apply HV to the TPC anodes and cathode. The fifth column represents the status of the insulator gas gap. It monitors the output of a methane and oxygen sensor sampling the return flow from the insulation gap gas and also monitors the inner field cage air flow. The sixth, seventh, and eighth columns show the status of the water systems at the TPC cooling water skid, at the face of the TPC, and in the gas room. In all cases, a green light indicates an “OK” state, while a red light indicates an alarmed state.

The Allen Bradley system controls a series of relays that enable the power to the subsystems. The status of the outputs is shown by a series of red and green lights in the third and fourth rows of the LED display system. Each output can be in one of four states:

> **ON:** The system is enabled for normal operation. This requires that all inputs relevant to this system are OK and that the green output button has been depressed, manually, to unlatch the channel.
>
> **OFF:** The system is disabled.
>
> **FORCED ON:** The system is forced into an on state regardless of the state of the inputs. This state can only be achieved by inserting a key into the LED light panel and turning it. Access to the keys is restricted to experts, the keys are kept in a locked cabinet, and all keys must be logged in and out whenever they are used by a trained individual. The FORCED ON state is shown by a flashing green light and this information is relayed to STAR Slow Controls.
>
> **FORCED OFF:** The inputs are ignored and the system is OFF. This state has highest priority. Any system can be immediately disabled by pressing the red FORCED OFF button. This is the default mode after Allen Bradley start-up.

Note that each output can only be put into the ON mode if a button on the Allen Bradley control panel is depressed. This means that each system must be actively enabled after a power failure or alarm. Should any relevant input fail, power to these systems is immediately cut or permission to operate is denied. All inputs are ‘fail safe’ by requiring active inputs.

The outputs require the following valid inputs to be in an ON state (see Attachment 2 for a logic diagram):

> **Gas System Power On:** Pioneer methane sensors OK, Global interlocks OK
>
> **STAR Control Room and Global Interlocks Status Return Signal:** Pioneer OK, Gas System OK
>
> **Gating Grid Enabled:** Pioneer OK, Gas System OK, push button latch reset
>
> **Laser Calibration System Enabled:** Pioneer OK, Gas System OK, push button latch reset
>
> **Anode HV Enabled:** Pioneer OK, Gas System OK, push button latch reset
>
> **TPC Gas Monitor Chamber Enabled:** Pioneer OK, Gas System OK, push button latch reset

Field Cage HV Enabled: Pioneer OK, Gas System OK, Insulator Gas Oxygen Sensor OK, Insulator Gas Methane OK, Inner Field Cage air flow OK, Global interlocks OK, push button latch reset

Water Systems OK Status: Sufficient water flow at four points near the TPC; pH, dissolved Oxygen, and cooling water flow OK on the TPC water skid, CTB cooling water flow OK, Inner Field Cage water flow OK, no water leaks on either end of the TPC, Gas Room cooling water flow OK, and no water leaks in the gas room

FEE Cooling Water OK: Sufficient water flow at four points near the TPC

TPC Water Valves Open: CTB cooling water flow OK, Inner Field Cage water flow OK, no water leaks on either end of the TPC

Gas Room Water Valves Open: Gas Room cooling water flow OK, and no water leaks in the gas room

5.0 Operating Procedures

5.1 **Normal Operation:** Starting up the entire system requires the assistance of a Global Interlocks system expert, a TPC water system expert, a TPC gas system expert, and an Allen Bradley system expert (see Attachment 6).

5.1.1 Upon start-up of the Allen Bradley system, Pioneer inputs 1 & 2 should be OK.

5.1.2 Global Interlock system expert should start the Global Interlock computer. Global interlocks must be in an OK state.

5.1.3 TPC water system expert should start the TPC cooling water system in the power supply room (aka. the Water Skid.). When the Water Skid flow is sufficient and stabilized, the Water Skid OK light will be illuminated. When the cooling water flow to the TPC is sufficient and stabilized, the TPC Water OK light will be illuminated. When the cooling water flow to the Gas Mixing Room is sufficient and stabilized, the Gas Room Water OK light will be illuminated. Finally, the Water Systems OK light will be illuminated.

5.1.4 Depress green Gas System button to enable power to TPC gas system.

5.1.5 Follow start-up procedures for TPC gas system and the insulation gas system:

  5.1.5.1 SOP-TPC-GAS-02-A "Starting the STAR TPC Gas System and Purging the TPC With Dry Nitrogen."

  5.1.5.2 SOP-TPC-GAS-03-A "Operating the STAR TPC Gas System with P10 Gas”

  5.1.5.3 SOP-TPC-GAS-05-A "Operating the STAR TPC Insulating Gap Gas System"

5.1.6 After P10 is flowing in the TPC, the "**From Gas System & Computer**" status input should be OK.

5.1.7 When the insulation gas is good, the “gap gas” light will be green. (Methane less than 20% LEL, Oxygen less than 200 ppm, air flow OK.)

5.1.8 Check to see that no outputs are in **Forced On** mode (the green button will be blinking). If any outputs are in **Forced On** mode, find an expert for that sub-system.

5.1.9 To enable the TPC Anode HV, first use the Slow Controls Anode interface program to ensure that the "demand" voltage for ALL sectors is set to zero. (SOP-TPC-HV-01-A) Then push the "**Anode HV Enabled**" button on the interlock front panel.

5.1.10 To enable the Gating Grid power supply, first use the Slow Controls gating grid interface program to ensure that the "demand" voltage is set to zero. (SOP-TPC-HV-03-A) Then push the " **Gating Grid Enabled**" button on the interlock front panel.

5.1.11 To enable the Laser system, first turn the "LAMP POWER" potentiometer on the laser control box to zero (fully counterclockwise). (SOP-TPC-LASER-01-A) Then push the "**Laser System Enabled**" button on the interlock front panel.

5.1.12 To enable the Gas System Monitor Chamber, first confirm that the HV pots for the monitor chamber power supplies (NIM Bertan HV power supplies) are turned to zero (fully counterclockwise). The power supplies are in the NIM BIN in Rack 4 and are labeled "Anode", "Cathode" and "Drift". (See Attachment 6 of SOP-TPC-GAS-03-A "Operating the STAR TPC Gas System with P10 Gas.") Then push the "**Monitor Chamber Power**" button on the interlock front panel.

5.1.13 To enable the TPC Cathode HV, first use the Slow Controls Cathode interface program to ensure that the "demand" voltage for the cathode is set to zero. (SOP-TPC-HV-02-A "Operating the STAR TPC Field Cage") Then push the "**Cathode HV Enabled**" button on the interlock front panel.

5.2 After Pioneer Input Failure

5.2.1 Call a TPC gas system expert. (See Attachment #6)

5.2.2 With the assistance of the TPC gas system expert, use the slow controls display or Allen Bradley light panel to find the location of the tripped methane sensor.

5.2.3 Determine reason for tripped methane sensor with the assistance of the gas system expert.

5.2.4 Fix problem with assistance of an expert.

5.2.5 If all Pioneer inputs are OK, proceed with steps 5.1.1 to 5.1.13

5.3. After Gas System Failure

5.3.1. After a Gas System failure, the gas system will be in purge mode. In this mode, the TPC is flushed with an inert gas (Argon or Nitrogen).

5.3.2. Check status of Pioneer inputs. If they are **not** OK, proceed to step 5.2.

5.3.3. Contact TPC gas system expert (see Attachment #6) to diagnose problem.

5.4. After Insulator Gas Oxygen or Methane Sensor trip

5.4.1. Contact Insulator Gas expert (see Attachment #6).

5.5. After a Water System Failure

5.5.1. Contact Water System expert (see Attachment #6).

6. Methane Gas Sensor Calibration and Interlock Testing Procedure (See Attachment 5)

6.1. Methane Gas Sensor Calibration procedure

6.1.1. The Pioneer Methane Gas sensors must be calibrated yearly. This calibration involves setting the alarm levels on the Pioneer system so that the gas system is disabled when the methane level reaches ~18% LEL. In order to do this calibration, reference samples of methane in air are required. The procedure for setting the alarm levels is the following:

6.1.2. Place evacuated plastic bag around one sensor.

6.1.3. Fill bag with reference gas (20% LEL).

6.1.4. Refer to Pioneer manual for calibration procedure, if required.

6.1.5. Check to ensure that the corresponding Allen Bradley Pioneer input is in a failed state.

6.1.6. Repeat procedure with a second reference gas below the set point (10% LEL).

6.1.7. Check to ensure that the corresponding Allen Bradley Pioneer input is in an OK state.

6.2. Methane in Insulator Gap (N_2) Gas Calibration procedure

6.2.1. Repeat procedure 6.1 using 20% LEL methane in nitrogen reference mixture on the Matheson gas detector in the gap gas exhaust line.

6.3. Trigger Methane Alarm and Test Interlocks

6.3.1. Follow Normal operation procedure (section 5.1) to bring system into operational state.

6.3.2. All output systems should now be enabled.

6.3.3. Place evacuated plastic bag around one methane sensor.

6.3.4. Fill bag with reference gas (20% LEL)

6.3.5. All output systems should now be disabled by the Allen Bradley system. Check to ensure that this is the case:

6.3.6. For the gas system: Power to Rack 2 should be off and inert gas should be flowing in Flow Meters FI5 and FI6 (located in Rack 2) The methane mass flow controllers FM1 and FM2 (located in Rack 1) should read zero.

6.3.7. For the other systems: attempt to energize each system in turn following the steps outlined above (5.1.9 - 5.1.13). None of the systems should be operational.

6.3.8. During any maintenance to the Allen Bradley system, no interlocked systems should be used. The Allen Bradley is *required* for operation of these systems. Under no circumstances should the Allen Bradley be circumvented or bypassed. Note also that the oxygen sensors in the TPC and gap gas systems have a finite lifetime and should be replaced at regular maintenance intervals.

6.4. Power Off the Allen Bradley Computer

6.4.1. Disconnect the power cord to the Allen Bradley Computer

6.4.2. Check that all TPC electronics are disabled

6.4.3. Check that the water system shut down

6.4.4. Check that the gas system powered down and went into purge mode

6.4.5. Restart the AB system using the Normal operating procedures and verify that all systems recovered.

6.5. Global Interlock Alarms

6.5.1. Have global interlock personnel generate alarm condition #1

6.5.2. Check that the alarm disables the TPC electronics

6.5.3. Have global interlock personnel generate alarm condition #2

6.5.4. Check that the power to the gas system is off (rack 2). The gas system should be in purge mode.

6.5.5. Clear all alarms and restart all systems using normal operating procedures

6.6. Gas System Alarms

6.6.1. Have gas system personnel generate a “low level” alarm

6.6.2. Check that TPC gas system alarms ring in the control room

6.6.3. Check that no other action is taken

6.6.4. Have gas system personnel generate a “high level” alarm

6.6.5. Check that all TPC electronics are disabled

6.7. Inner Field Cage Air Flow

6.7.1. Disconnect power to the Inner Field Cage blower

6.7.2. Check that the TPC Cathode power supply is disabled

6.7.3. Power up the IFC blower

6.7.4. Check that TPC Cathode power supply can be re-enabled

6.8. TPC Leak Alarm

6.8.1. Have TPC or global interlock personnel generate a TPC leak signal

6.8.2. Check that the water flow valves located on the face of the TPC are closed when the alarms sounds

6.8.3. Check that the TPC water skid has stopped

6.8.4. Clear the leak condition and restart the water skid

6.9. Gas and Water System Alarms

6.9.1. Initiate any alarm condition that will trigger the gas system or water system alarms.

6.9.2. Check that the alarm lights light, and the bells sound in the STAR Trailer, in the STAR Control room, and in the Collision Hall.

6.9.3. Replace any burned out bulbs or failed horns & bells.

6.10. TPC Water Flow and FEE

6.10.1. Turn the TPC water skid on and off.

6.10.2. Observe the flow meters on the second floor platform

6.10.3. Check that the FEE low voltage power supplies are enabled when the flows are normal and that the FEE supplies are disabled when the flows are low.

6.10.4. Also check that the green indicator lamp located inside the back door of the TPC gas system rack is working and reports the proper FEE status.

6.11. UPS System Test

6.11.1. Unplug the power to the UPS system on the second floor platform. The Allen Bradley remote crate should remain on and the flow meters should continue operating.

6.11.2. Test for 2 minutes and reconnect the power.

6.11.3. Unplug the power to the UPS in the gas room. The Allen Bradley master crate should remain on and the gas system should continue operating.

6.11.4. Test for 2 minutes and reconnect the power.

7.0 Documentation

All readings, calibrations, and Allen Bradley control program changes should be recorded in the STAR TPC Gas System Interlock logbook.

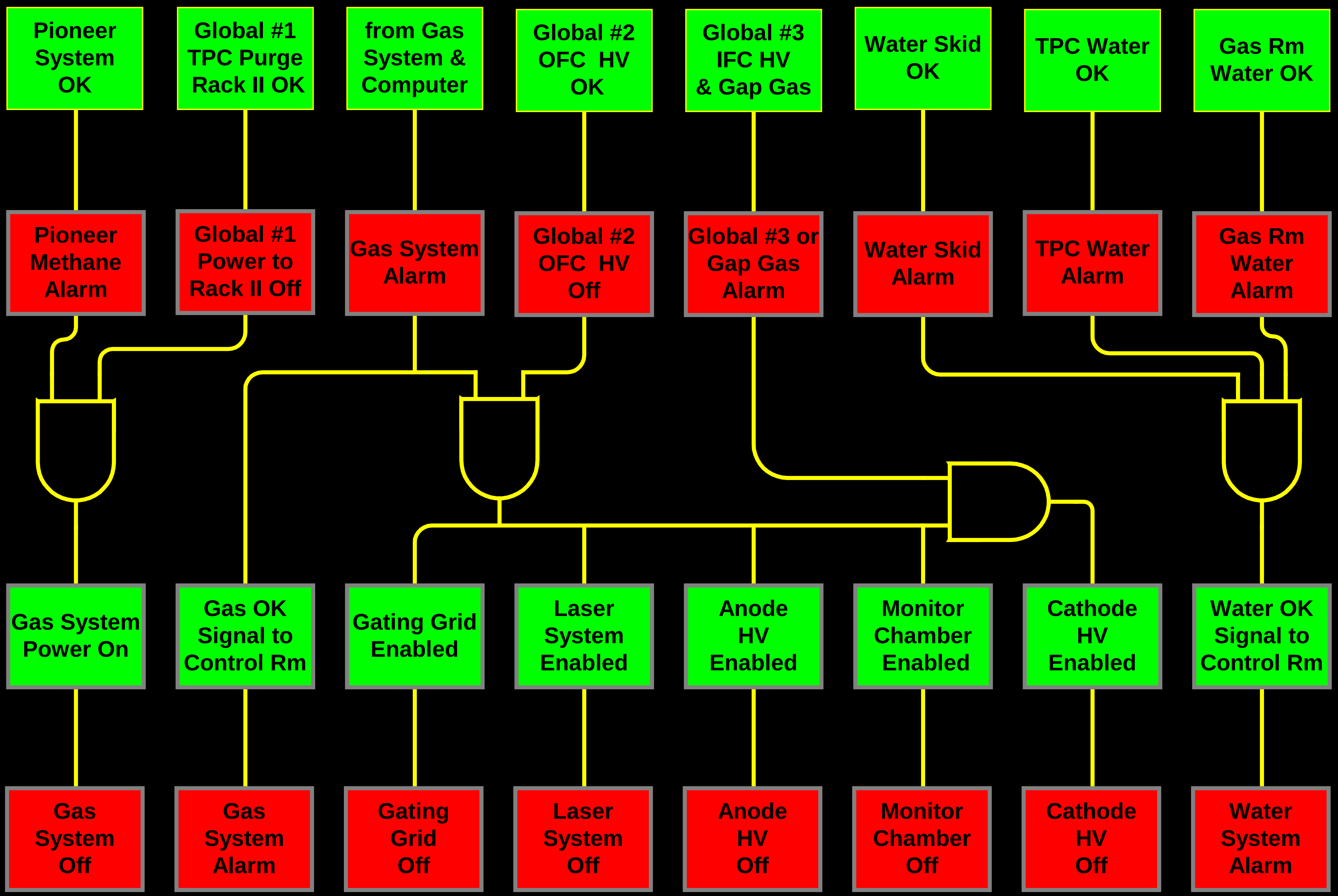
8.0 References

1. TPC gas mixing room schematic - STAR Drawing # TPC584-E-1
2. TPC insulation gas schematic - STAR Drawing # TPC585-E-1
3. TPC gas pad schematic - STAR Drawing # TPC 586-E-1
4. Pioneer Gas Monitor Operator's Manual
5. Allen Bradley SLC Operator's Manual

9.0 **Attachments**

1. Allen Bradley Interlock Front Panel
2. Allen Bradley Logic Diagram
3. Allen Bradley Crate & Module Map
4. Rules for Issuance of Allen Bradley override keys.
5. TPC Interlocks Certification Log
6. List of System Experts

Allen Bradley Interlocks Front Panel - Attachment 1



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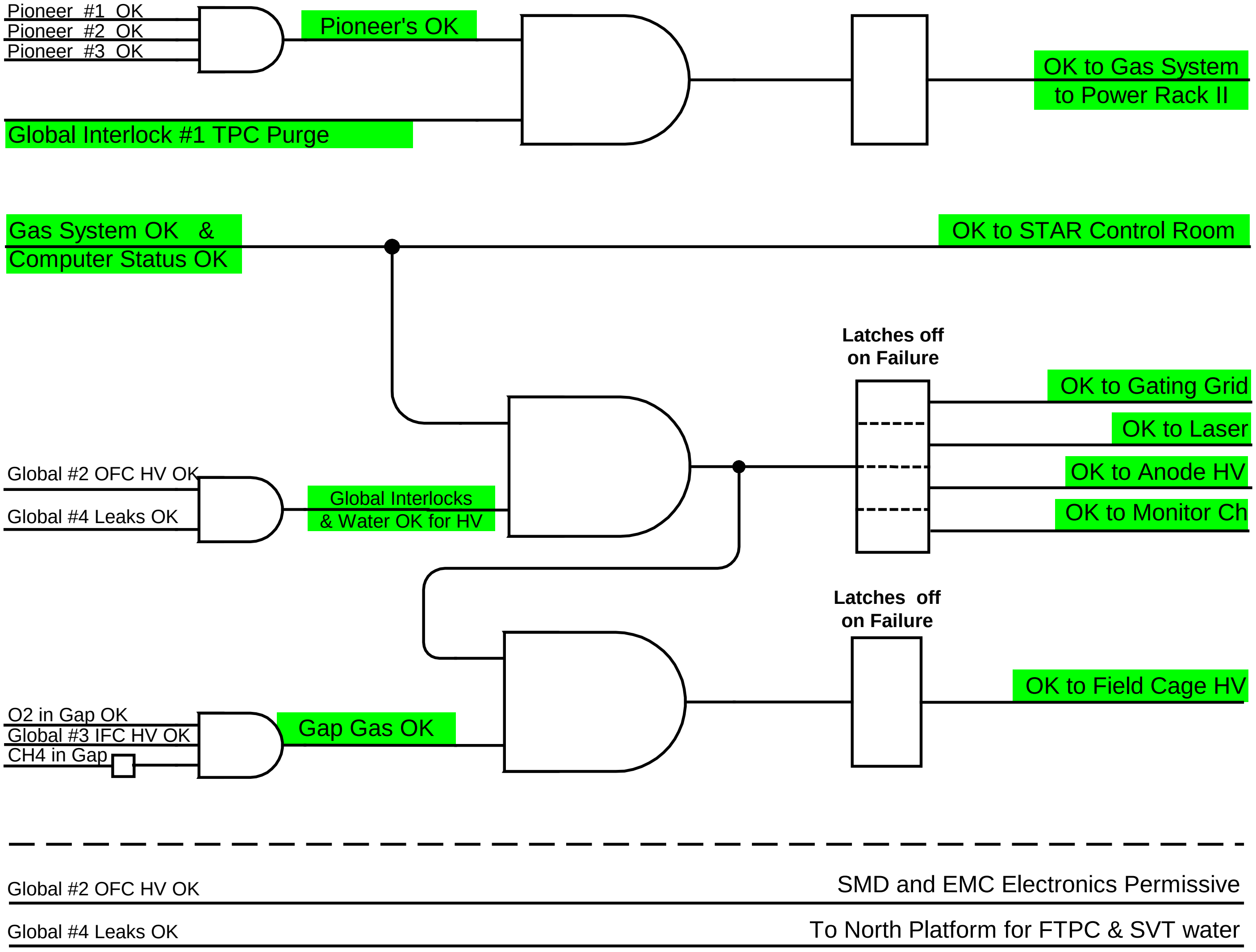
Attachment 2: Allen Bradley Logic Diagram



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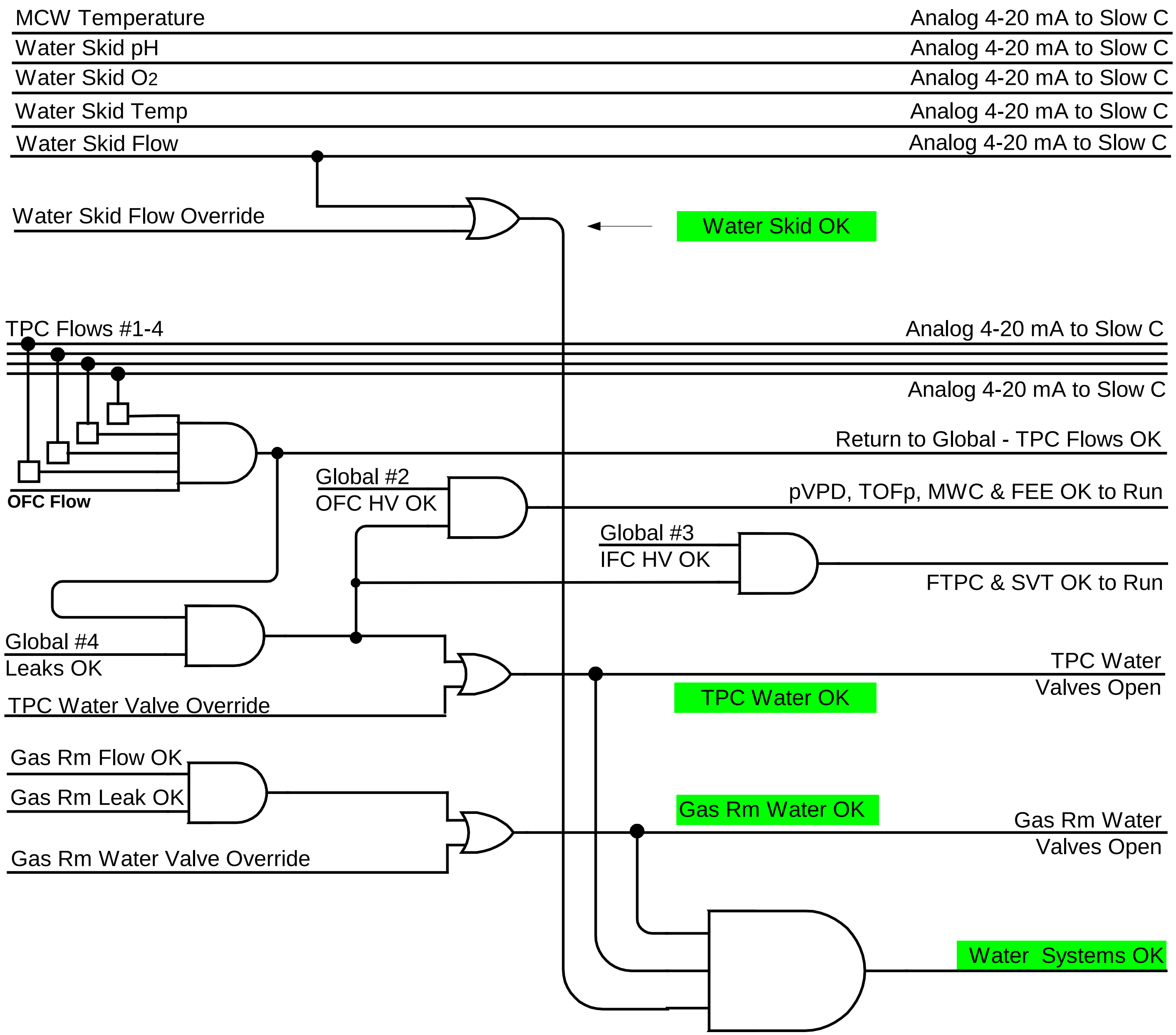
Attachment 2: Allen Bradley Logic Diagram (continued)



Attachment 3: Allen Bradley Crate & Module Map

Master Crate in Gas Room

P2 Power Supply	CPU 5/03	1747-SN	1746-NI4	1746-IB16	1746-NI4	1746-OW16	1746-OX8	1746-IB16	1746-IB32	1746-OB32
	16K Mem	RIO Scanner	Analog Input	24 V Input	Analog Input	24 V Output	Relay Output	24 V Input	24 V Input	24 V Output
	OS 302	to remote crate	4 Ch.	16 Ch.	4 Ch.	16 Ch.	8 Ch.	16 Ch.	32 Ch.	32 Ch.
			4-20 mA or 0-10 V DC	**4- Pi** **Gas Flow** **Gas Leak** **Gas OK** **Gap O_2**	4-20 mA or 0-10 V DC	Two groups of 8	Indep ch's contact closure	**Kbrd Ovrd 8 inp** **Water Skid Ovrd** **TPC Flow Ovrd** **Gas Flow Ovrd**	Kbrd button input	Kbrd lights output
			Gap CH_4 **pH Flow O_2**		**TPC Temp** **MCW Temp**	**Eight Kybd Out** **OFC OK** **TPC Valves** **Gas Rm Valves**				
Full Slot Addressing	0	1	2	3	4	5	6	7	8	9
				ODH (8) Gas Lo Lv Alarm (9) UPS (11) Three Gas Rm Inputs (13) FTPC(14) MCW(15)		IFC OK (11) Three Platform Outputs (13-15)	Gas Alarm (1) Pioneer Alarm (2) Global #2 (3) Global #1 (4) Global #4 (5) Gas OR Water (6) Water Alarm (7)	Platform Alarm & Reset (11)		

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Attachment 3: Allen Bradley Crate & Module Map (continued)

Slave Crate on Platform

		0	32	64	96	128	160
P2 Power Supply	1747-ASB	1746-NI4	1746-OW16	1746-IB16	1746-OX8	1746-IG16	1746-OG16
	RIO Adapter	Analog Input	Relay Output	24 V Input	Relay Output	TTL Input	TTL Output
	from master crate	4 Ch.	16 Ch.	16 Ch.	8 Ch.	16 Ch.	16 Ch.
		4-20 mA or 0-10 V DC	Two groups of 8		Indep ch's contact closure	from Slow Control	to Slow Control
		4 - TPC Flow	**Eight Kybd Out** **OFC OK** **TPC Valves** **Gas Rm Valves**	**Glob #1** **Glob #2** **OFC Flow** **Glob #3** **Glob #4**	**MWC (0)** **Flows OK (5)** **Kybd Out (1-4,6,7)**		
1/2 Slot Addressing		0, 1	2, 3	4, 5	6, 7	8, 9	10, 11
			IFC OK (11) Flows OK (12) Three Gas Rm Outputs (13) FTPC(14) MCW(15)	4 TPC Flow Status (8-11) Three Platform Inputs (13-15)			

TTL 1 = B3:0
TTL 2 = B3:1
TTL 3 = B3:2
TTL 4 = B3:3
TTL 5 = B3:4
TTL 6 = Kpad 1&2
TTL 7 = Kpad 3&4
TTL 8 = Local Analog 1
TTL 9 = Local Analog 2
TTL 10 = Local Analog 3
TTL 11 = Local Analog 4
TTL 12 = Rmt Analog 1
TTL 13 = Rmt Analog 2
TTL 14 = Rmt Analog 3
TTL 15 = Rmt Analog 4
TTL 16 = Local Input
TTL 17 = Rmt Input
TTL 18 = Local Analog 5
TTL 19 = Local Analog 6
TTL 20 = Local Analog 7
TTL 21 = Local Analog 8

B3:0 = Logical inputs (0-11) [First level logic] (8 == OFC OK to run, 9 == TPC Flows OK, 10 == TPC Leaks OK, 11 == IFC OK to run)
B3:1 = Temp outputs (0-11) [Second level logic] (same map as B3:4)
B3:2 = Forced On Reg (0-10) (8 == Water Skid, 9 == TPC Water Valves, 10 == Gas Rm Water Valves)
B3:3 = Forced Off Reg (0-7)
B3:4 = Enable Output (0-11) (8 == OFC OK to run, 9 == TPC Water Valves, 10 == Gas Rm Water Valves, 11 == IFC OK to run)

Sub-System	Global Interlocks #1 TPC Purge	High Level Methane	High Level Smoke (Delayed)	Global Interlocks #2 OFC OK to Run	High Level Methane	High Level Smoke (Prompt)	Detector Water Leaks	Global Interlocks #3 IFC OK to Run	High Level Methane	High Level Smoke (Prompt)	Detector Water Leaks	IFC Air Flow	Global Interlocks #4 Detector Water Leaks	Pioneer Gas Alarm - Methane in Gas Rm	Gas System Fault & Computer Status	Gas Room Water Leak	Gas Room Water Flow	TPC E&W Face Water Flow	OFC Water Flow	Methane in TPC Insulator Gap	Oxygen in TPC Insulator Gap	Water Skid Flow	Water Skid pH	Water Skid Oxygen Level	Water Skid Temperature	ODH Status	UPS Status	MCW Temperature
STAR Control Room - Water Alarm							X				X		X			X	X	X	X			X						
STAR Control Room - Gas Alarm		X	X		X	X			X	X				X	X													
TPC Water Valves Close							X				X		X					X	X			X						
Gas Rm Water Valves Close																X	X											
Power to TPC Gas System		X	X		X	X			X	X				X														
TPC Gating Grid		X	X		X	X	X		X	X	X		X	X	X													
TPC Anode		X	X		X	X	X		X	X	X		X	X	X													
TPC Cathode		X	X		X	X	X		X	X	X	X	X	X	X					X	X							
TPC Monitor Chamber		X	X		X	X	X		X	X	X		X	X	X													
Laser		X	X		X	X	X		X	X	X		X	X	X													
RICH		X	X		X	X	X		X	X	X		X	X														
FEE, MWC, TOFp & pVPD Electronics		X	X		X	X	X		X	X	X		X					X	X			X						
SVT & FTPC Electronics		X	X		X	X	X		X	X	X	X	X					X	X			X						
EMC & SMD Electronics		X	X		X	X	X		X	X	X		X															
SVT & FTPC Water							X				X		X															
Slow Controls		X	X		X	X	X		X	X	X		X	X	X	X	X	X	X	X	X	X	X	X		X	X	X

4/20/2001

Attachment 4: Rules for Issuance of Allen Bradley Override Keys

Override keys for the various subsystems protected by the Allen Bradley system will be kept in a cabinet in the STAR control room or the trailers outside Building 1006. To obtain a key for a certain subsystem the requestor must first contact the STAR shift supervisor. The shift supervisor will first determine if the requestor has the proper training for the subsystem by consulting the STAR training database. The shift supervisor must also obtain authorization from a STAR TPC gas system expert who will make a determination of the status and safety of the TPC gas. This authorization can be in writing or by phone. Once this has been done, the operator will take a key and sign the checkout sheet kept with the keys. The operator is responsible for checking the key back in when the work is completed.

Attachment 5: TPC Interlocks Certification Log

Procedure	Date checked	Certified by:	Frequency of Update
Calibrate Pioneer Methane heads			Annual
Calibrate Methane in N_2 monitor			Annual
Trigger Methane alarm to kill gas system, and disable electronics			Annual
Power Off/On to AB to kill gas sysem, disable electronics and close water valves			Annual
Global Interlock Alarm #1 kills enable for electronics			Annual
Global Interlock Alarm #2 kills power to gas system			Annual
Gas system low level alarm rings TPC gas alarms but takes no action			Annual
Gas system Hi level alarm kills enable for electronics			Annual
IFC Air flow alarm kills enable to cathode			Annual
TPC leak alarm closes water valves to TPC & shuts down water skid			Annual
Gas alarm rings in Control room			Annual
Gas alarm rings in collision hall			Annual
Gas alarm rings in STAR trailer			Annual
Water alarm rings in Control Room			Annual
Water alarm rings in collision hall			Annual
Water alarm rings in STAR trailer			Annual
TPC Water Flows OK enable FEE			Annual
UPS system test			Annual

Attachment 6: List of System Experts

TPC Gas System and Insulation Gas System:

Leonid Kotchenda	x7386 x7599 (BNL Dorm)
Blair Stringfellow	x7386 (BNL Office) x1042 (BNL Apartment) x8158 (BNL Beeper) 516-662-3466 (Cell Phone) 765-494-5391 (Purdue Office) 765-497-0161 (Home)
Howard Wieman	x7386, x7762 (BNL Office) 298-2195 (Home)

Allen Bradley System:

Jim Thomas	x3918 (Office) 928-8661 (Home)
Blair Stringfellow	see above
Howard Wieman	see above

Global Interlock System:

Bill Christie	x7137
Bill Edwards	x2923

TPC Water System:

Ed Dale	x7943
Jim Thomas	see above
Howard Wieman	see above

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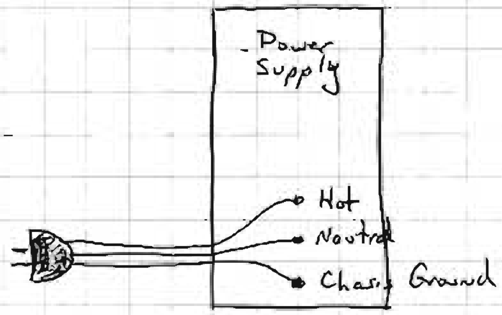
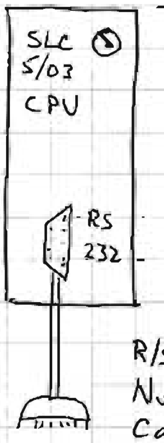
12/2/99

Old Diagrams on pages 9-11

Allen Bradley Wiring Diagrams

Gas Room



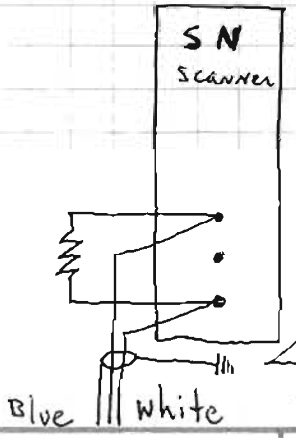


Set key switch to "Run" for normal operation

Set key switch to "Remote" for remote programming from PC

R/S 232 Null Modem Cable To IBM PC for Programming. See Page 14.

9 Pin Din Connector



[See Page 47 for Fiber Optic Module on the platform. It is the same]

Terminate with resistor for 57.6 kbaude

Ground [illegible] goes to chassis ground. Do Not connect to shield on scanner

Blue Hose goes to Fiber Optic Module

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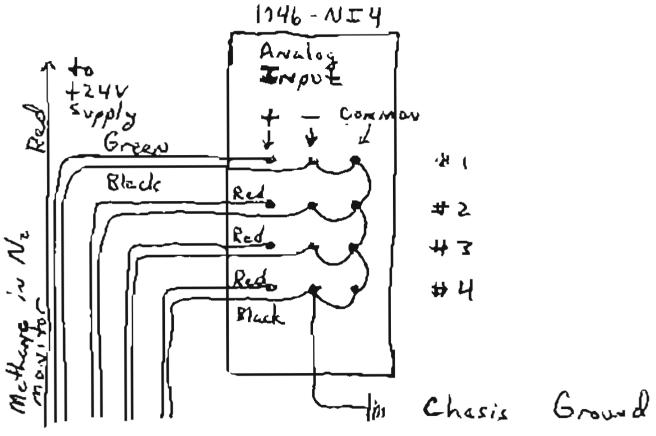
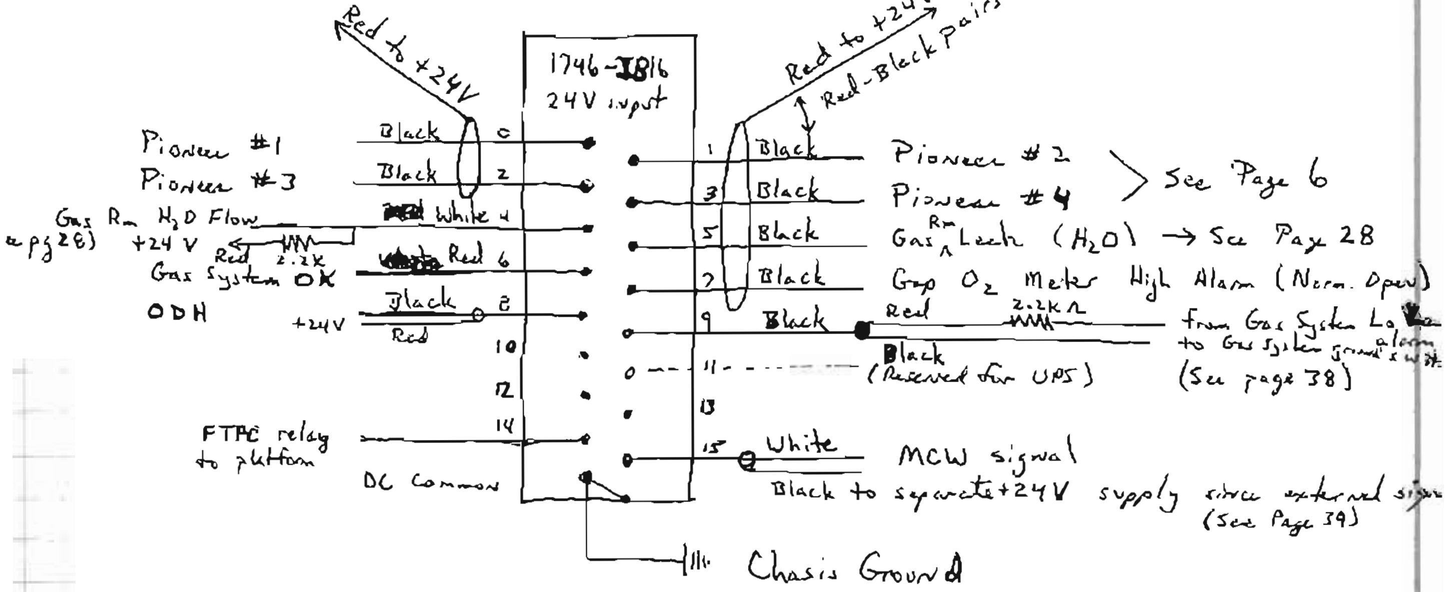
More Gas Room Modules in Gas Room Crate (master)
(See Page 55 for more modules)



4-20 mA current Loop into 16384 count ADC full scale. So "Zero" is at 3277 counts.

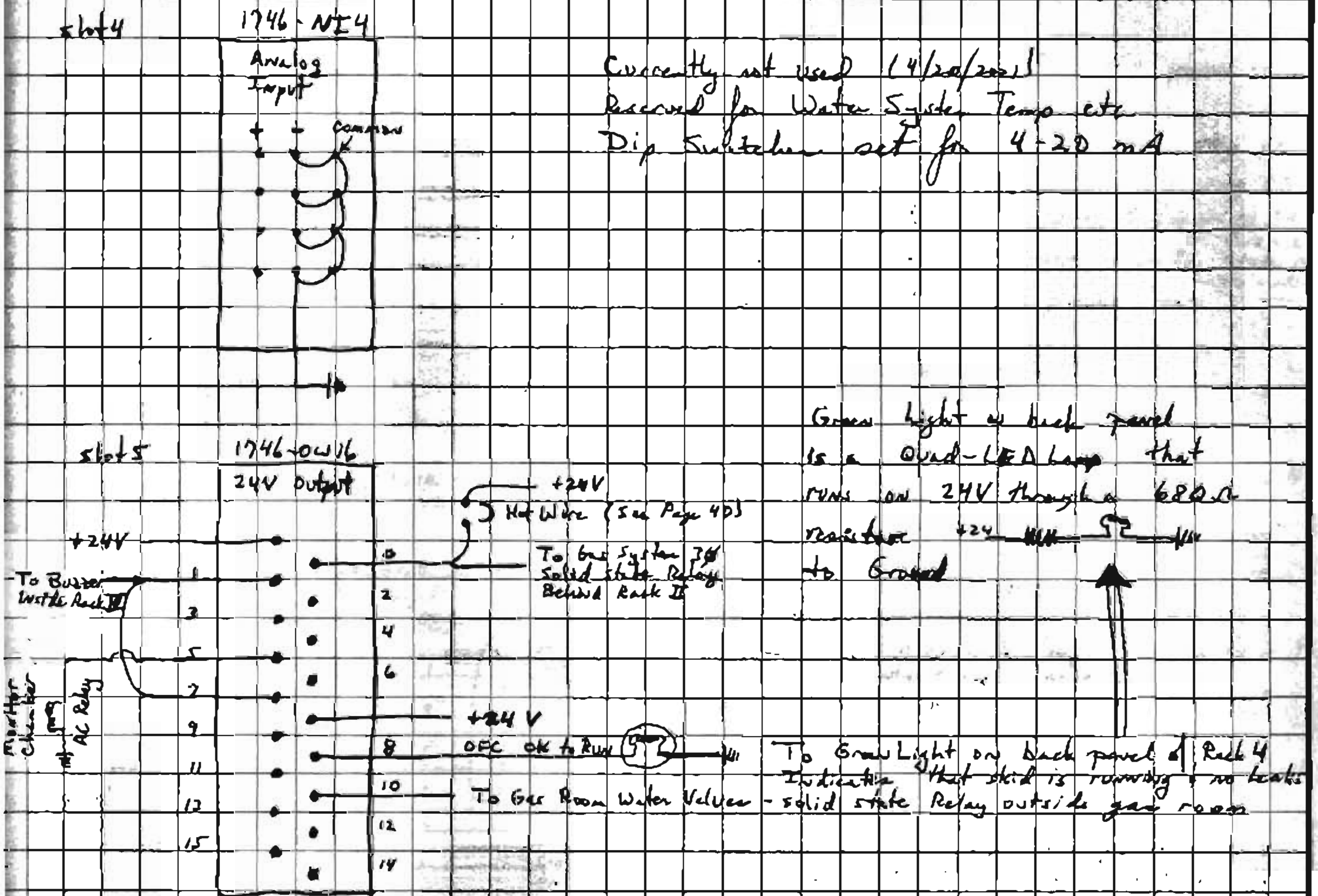
ΔP Flow O_2

Water skid (not used as of 12/99)
diagnostics (currently go to fixed resistors to +24 Volts)



4/20/2001

AB Wiring Diagram - Gas Room Crate (Continued from Page 44)



Currently not used (4/20/2001)
Reserved for Water System Temp etc
Dip Switches set for 4-20 mA

Green Light on back panel is a Quad-LED Lamp that runs on 24V through a 680Ω resistor to Ground

To Green Light on back panel of Rack 4 Indicates that skid is running & no leaks

Note: 24 V enable for 3Ø breaker behind Rack II enables the power to rack II. But it goes through the Pioneer detector first, via the Alarm level 2 relay "NO" (See Page 2)

24 Volt Buzzer is mounted inside Rack IV for water or gas alarm. See Page 40 for comments on current loop

24V Power to solid state relay outside the gas room door is not isolated [redacted] power. It should be because it is far away.

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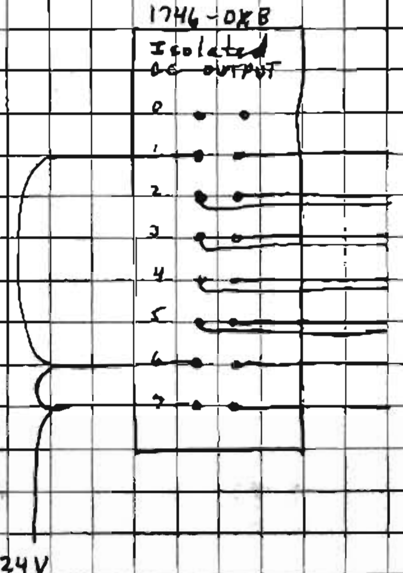
LE AB Wiring Diagrams Gas Rm Book No. 4/20/2001

m Page No.__

Slot 6



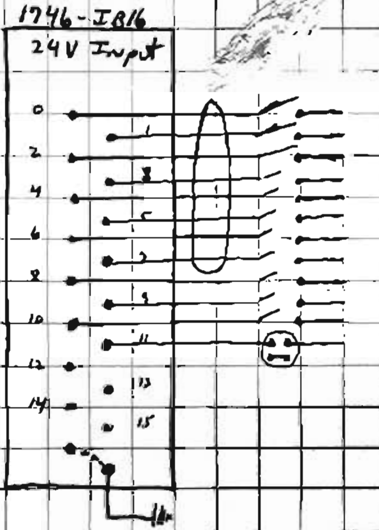
Gas Alarm (24V=OK) to Control Room via phone lines
Pioneer Alarm relayed to RICH using cc
Global #2 - OFC ok to Run - relayed to RICH using cc
Global #1 - TPC Purge - relayed to RICH using cc
Global #4 - Detector Leaks - relayed to RICH using cc
Gas 'OR' Water alarm to Bell outside Gas Rm
Uses a solid state relay to switch AC
Water Alarm to Control Room via phone lines

Separate Power Supply (See Page 39)

Key switches on Front Panel of Rack 4 go to separate +24 V supply to distribute load (See Page 39)

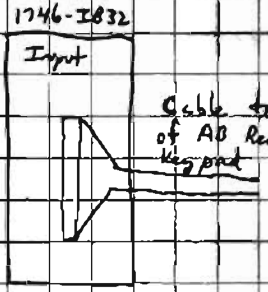
Slot 7

channels 0-7
on separate 24V
supply.
channels 8-11
use the regular
24V supply



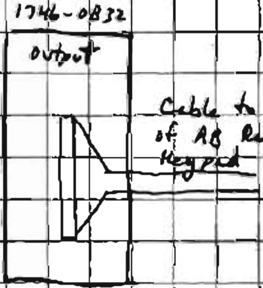
Gas System Power over-ride key switch on Front Pane
Gas ok signal to Control Room over-ride
Gating Grid over-ride
Laser over-ride
Anode over-ride
Monitor chamber over-ride
Cathode over-ride key switch on Front Panel of Rack 4
Water system Alarm over-ride key switch on Front Panel
Water skid over-ride key switch on Back of Rack 4
TPC Flow switch over-ride on Back of Rack 4
Gas Room Flow switch over-ride on Back of Rack 4
Platform Alarm silence switch and reset on Front Panel of Rack 4

Slot 8



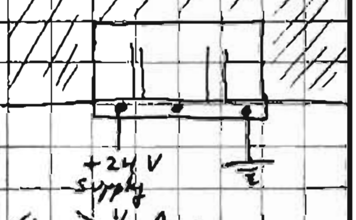
Cable to Input of AB Redi Panel Keypad

Slot 9



Cable to Output of AB Redi Panel Keypad

Redi-Panel Connector Viewed from the back of the Redi Panel



Redi Panel is powered by the Separate 24V supply (See Pg 39)

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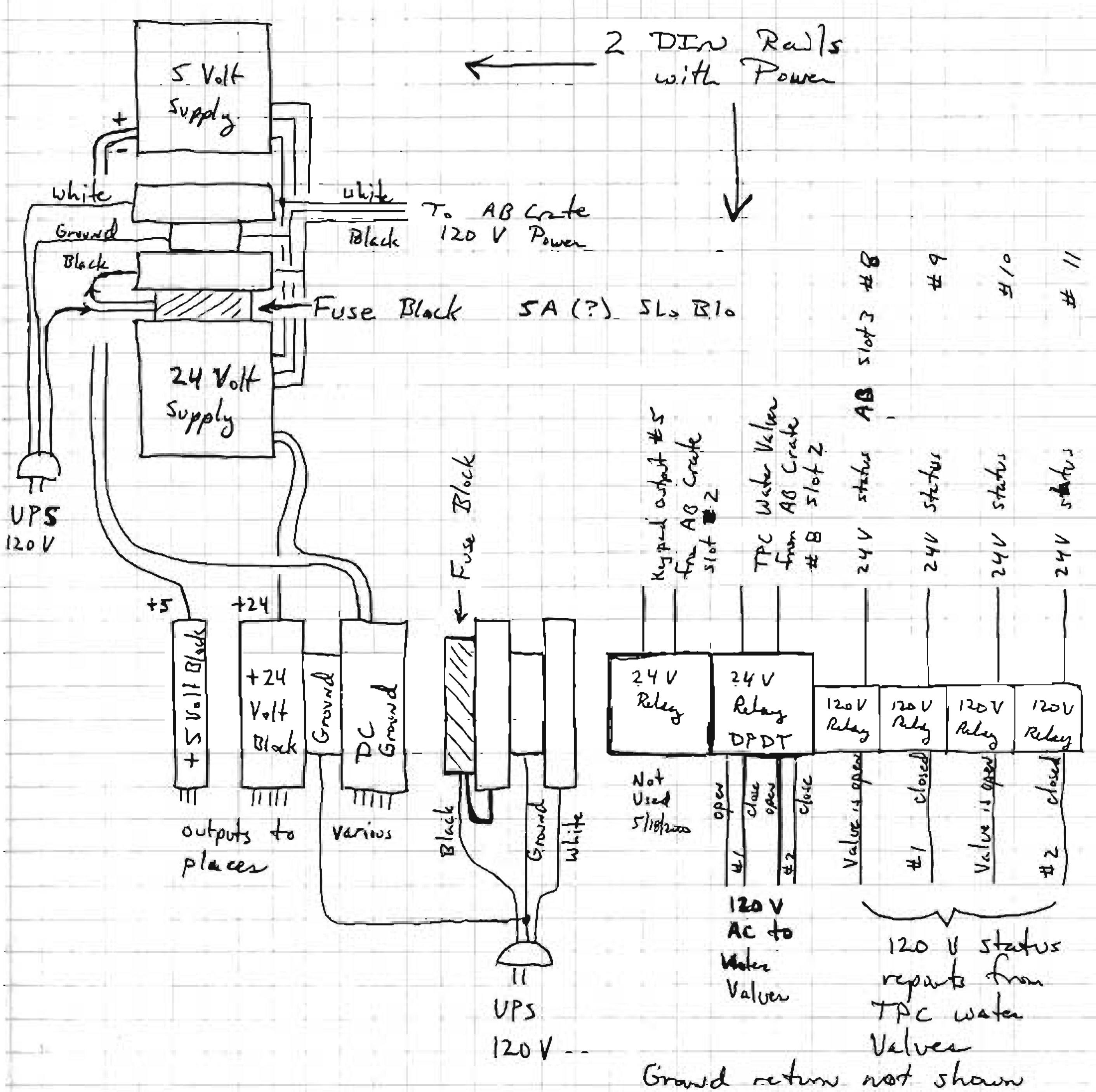
5/18/2000 Slave Crate on Platform



Ground return not shown for relays (above)

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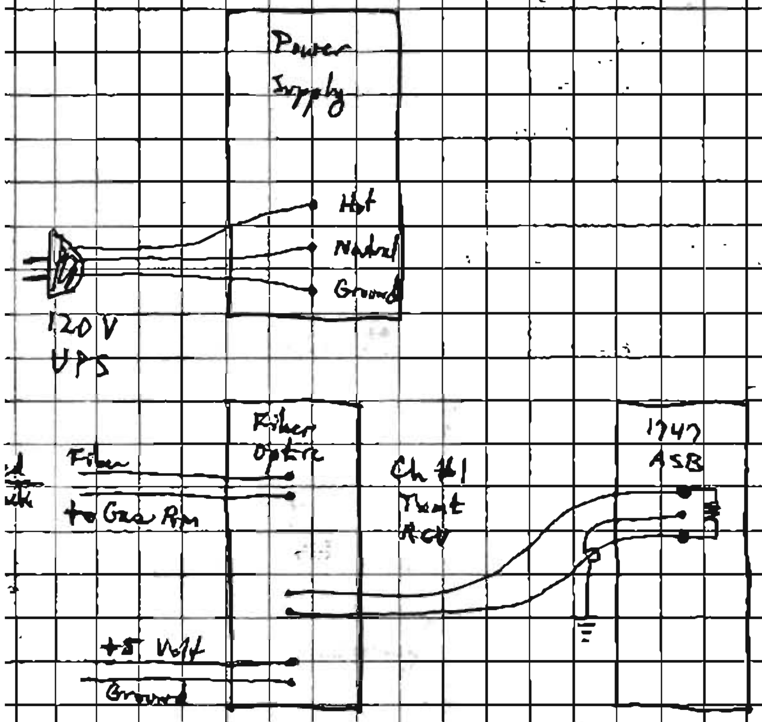
Allen Bradley Wiring Diagrams - Slave Crate on Platform

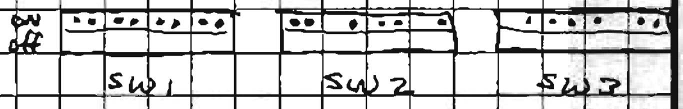
Old Diagrams on Page 11

This work continued on Pg 52

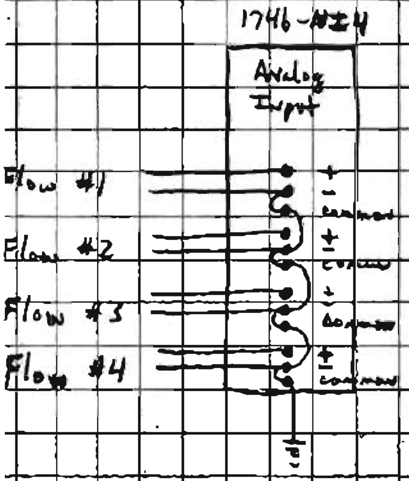


Scanner adapter/receiver

Termination resistor for 57.6 K baude (See page 11)



Dip switch settings for 1747 ASB



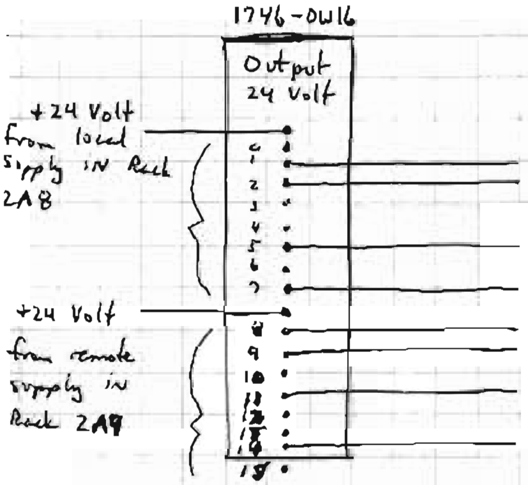
Internal Dip Switches set for 4-20 mA

Analog Inputs go to the TPC Cooling water Flow meters in Rack 2A9

East Top & Bottom Flow
West Top & Bottom Flow

To Page No.____

Allen Bradley Wiring Diagrams – Slave Crate on Platform (Cont) See Page 47



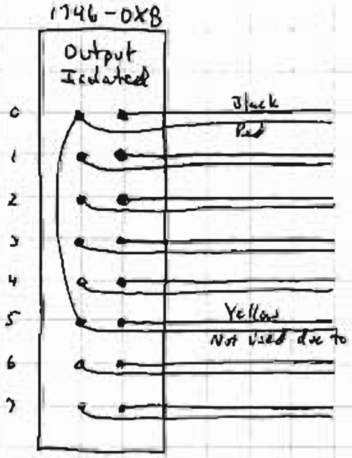
Gas Alarm to DIN #16 in Rack 2A9
Gating Grid Enable ; Pad Plane Pulser Enable (split)

To Potter Brumfeld Relay on Din Rail ... not used (pg 46)
Water Alarm to DIN #16 (same as above) in 2A9

OFC ok to run$_{20}$ – to DIN #20 in rack 2A9
TPC water valve open – to Potter Brumfeld AC Relays on Din Rail see Page 46
IFC ok to run$_{21}$ – to DIN #21 in rack 2A9

FTPC signal Relay from Gas Room –$_{22}$ to DIN #22 in 2A9

Note that the Pulser enable (above) sends +24V through a 330 Ω resistor to a pin on the front panel of the Wiener VME Crate The GG enable seems to put the +24V through ~~a~~ one or more Zener diodes (?)



MCW Relay Signal from Gas Room to Global Cable #1 Red/Black
+24V from Global
Gas System Alarm to Horn (R/B) (14/15) to DIN Rail in 2A9
GG enable (not used)
Laser enable (cc)
Anode enable (cc)
TPC Flows OK to Global Cable #2 Yellow (only)
Cathode enabled on CC
Water System Alarm to Horn (G/W) (13/12) to DIN Rail in 2A9

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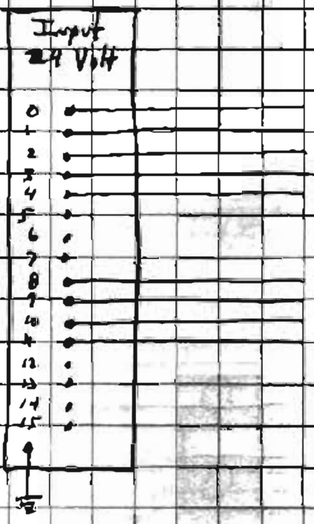
Allen Bradley Wiring Diagrams – Slave Crate on Platform



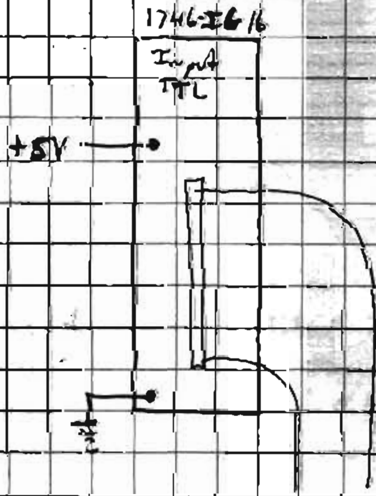
Global Purge #1 Blue wire on Global Cable #1
Global OFC ok to Run #2 Brown Wire on Global cable #1
OFC Flow in Rack 2A9 .. using cc in 2A9 and 24V from 2A8
Global IFC ok to Run #3 Blue wire on Global Cable #2
Global Leaks #4 Orange Wire on Global Cable #2

TPC Water Valve Status (open) (closed) (open) (closed) See page 46 from Pothe Bramfeld AC Relays on DIN Rail in 2A8

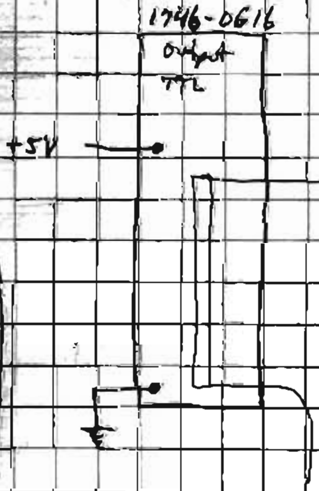
Yellow & Orange on Global Cable #1 go to +24V in 2AB

Note that due to a lack of wires going between Global and the TPC interlocks, we do not send pairs of wires for the Blue & Orange wires on Global Cable #2 ... we assume that they will jumper the +24V from 2AB that comes on on the Yellow & Orange cables on Global Cable #1 to the other side of the cc for the Blue & Orange wires (#2)

1746-IG16



1746-OG16



TTL input/output
on Ribbon Cable
to I/O modules
in slow controls crate
in 2A7
(AVME 948X)

See Page 33
for wiring map to
Ribbon cable

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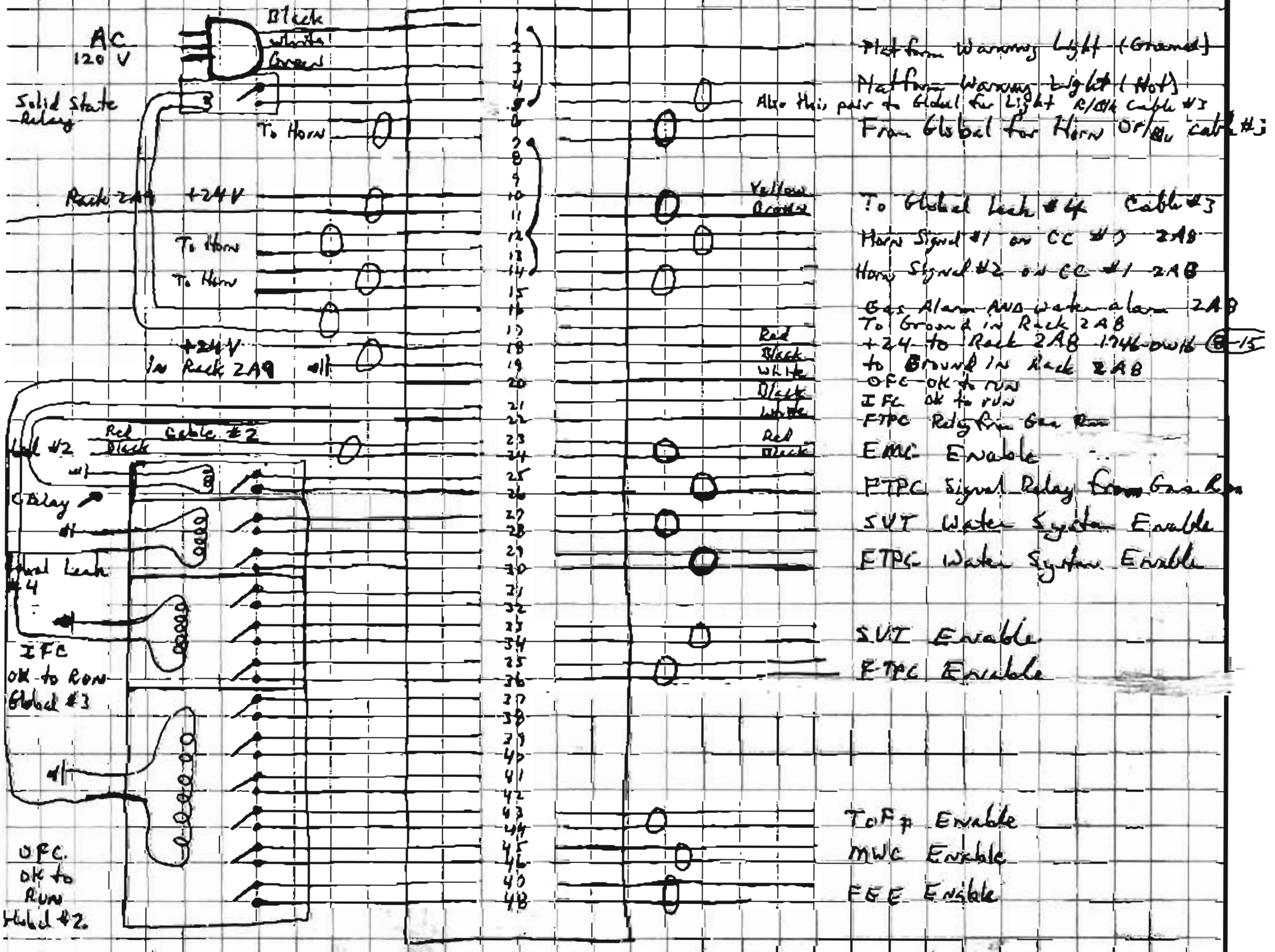
20/2001 AB Wiring Diagrams – DIN Rail in 2A9
(Flop down panel in back)



In this diagram: Global #2 is a cc provided by Global Interlocks
It comes on the Red/Black Pair in Global Cable #2
Global #4 is a cc provided by Global Interlocks
It comes on the Yellow/Brown Pair in Global Cable #3

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8/3/98

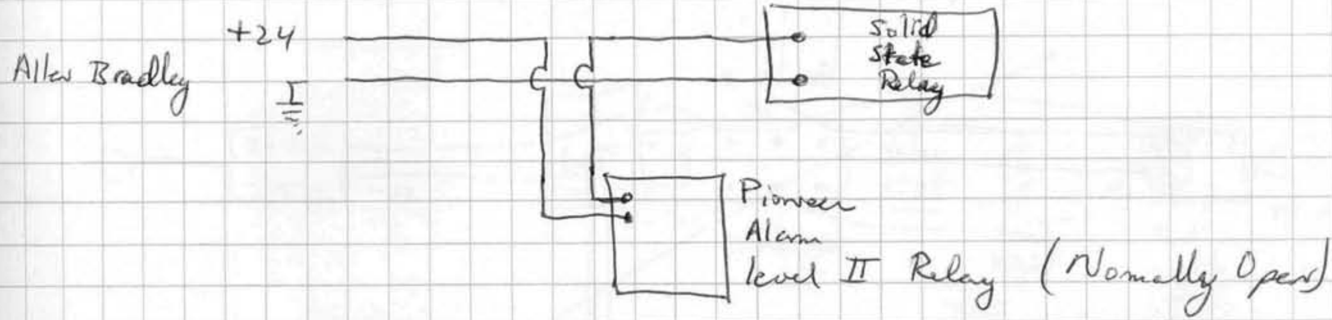
B.S.
L.K.

Modified Wiring between the Allen Bradley system, and the 3ø Solid State Relay. Asher Ethan requested that the Pioneer hardware force the 3ø relay off if the Pioneer heads trip off.

We accommodated this request by putting the Pioneer level 2 alarm relay in series with the 24 Volt power to the 3ø relay.

The 3ø relay requires +24 Volts to stay open. Previously this was provided by the Allen Bradley and its Logic.

Now, the Pioneer is part of the circuit



All four Pioneer heads must be "OK" for the relay to be energized.

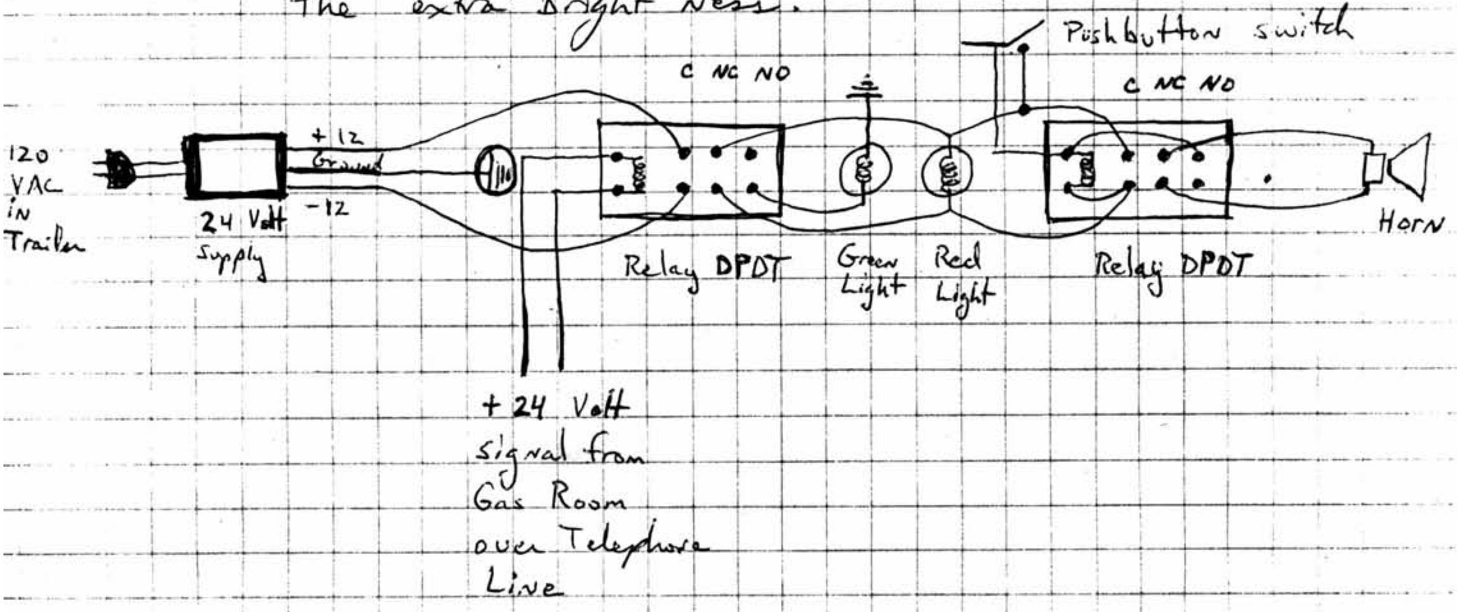
Tested the circuit modification by placing the AB in forced on mode. We then tripped one Pioneer head with 20% LEL methane gas and observed that the gas system power (3ø) shut off.

om Page No.

3/10/98

Add Pushbutton to system for announcing
the gas alarm in the Trailer to kill the
(See page 3) audible alarm but leave the red light on.

Also changed the green light to run
off of 12 Volts rather than 24 Because
it was running hot (temperature). Red
light is still 24 volt since we need
the extra brightness.



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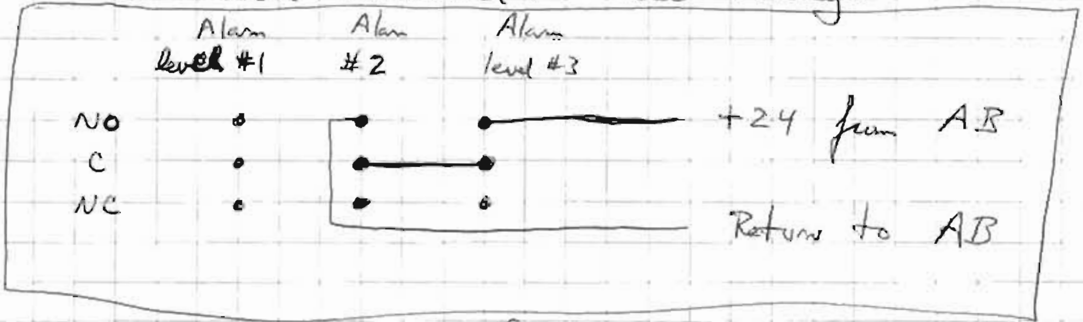
Pioneer Gas System Configuration

In set up mode, I have configured alarm level three (for the individual channels) to become the "Fail" Relay. These are "NO" relays that are closed when the sensor head is connected and working properly. If the sensor head is disconnected (such as by driving a bull dozer through the connecting wire) the relay will open.

I use this to protect the signal to the Allen Bradley interlock system.

The Allan Bradly system sends 24 volts to the Pioneer level two relay for each channel. These relays will be closed if the sensor is OK and PIO is below the level two threshold. If either fail, then the 24 volts is not returned to the AB and it goes into an Alarmed state.



The alarms ring on power failure, too.

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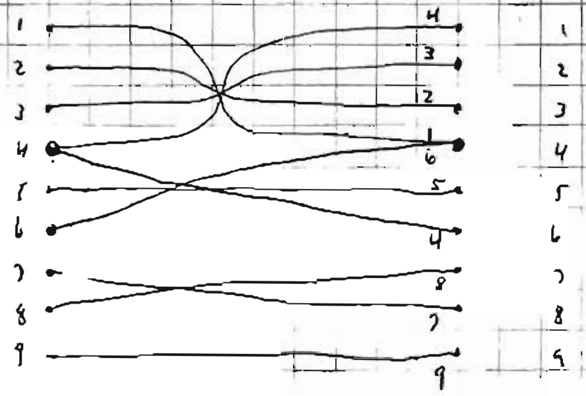
0/9/98 Pioneer head #2 has drifted so "zero" reads -4 on front panel.

Readjust "zero" at head. (ie set tp to 100.0 mV)
Readjust "zero" programming inside the pioneer box (Press (enter + yes) three times)
(and follow your nose to set zero)

/8/99



Null Modem cable for PC to AB communication

5 to 5
9 to 9
swap 7 & 8
(1 & 6) goes to 4
4 goes to (1 & 6)
swap 2 & 3

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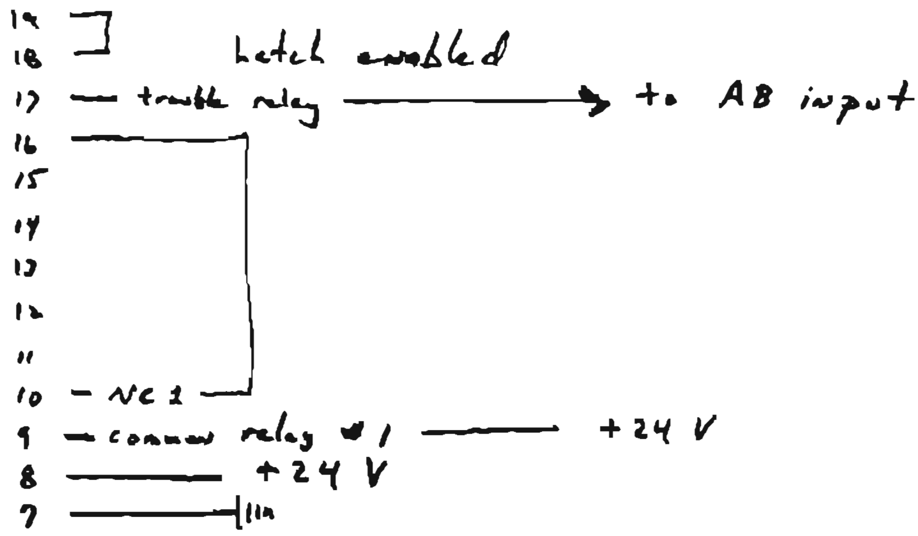
4/15/99 Water Leak detector in gas Room
Trace Tek in Rack J4

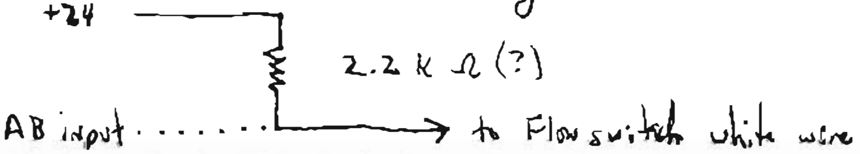


Note: must push latch reset button on leak detector after a leak has occured.

jumper signal through trouble relay to set off alarm if the leak cable is disconnected.

Flow Switch - white wire is a true ground (Black wire equiv) when flow switch is off. It is open circuit when water is flowing
So try this

See pg 29 Bottom



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4/15/99 Possible program changes

ok done 4/25/99 - Change logic so HV kill from Global Interlock kills all HV including anodes, I can etc.

- Put override on gas system power so that it overrides global interlock but not pioneer. We will have to fix pioneer before trying to start gas systems.

- Override to Gas system should be able to ignore a comm link problem

- ~~Ignore Arbor HV kill. Use water on face of TPC instead as an HV kill.~~

OK 4/25/99 done - Put our system on UPS on platform

4/16/99

✓ Connect ODH meter to AB main crate input # 8

~~(What about the UPS? Weren't we going to add this to slow control checks)~~

Additional Program Changes

Fixed 4/25/99 - Flow switches currently work but broken cable is "ON" state. We can fix this by reversing the logic inside the AB and also changing polarity at the flow switch.

Do this to both Gas water and IFC vent gas
Also IFC Water?

- IFC Water switch doesn't exist for 2-3 months not wire it!!

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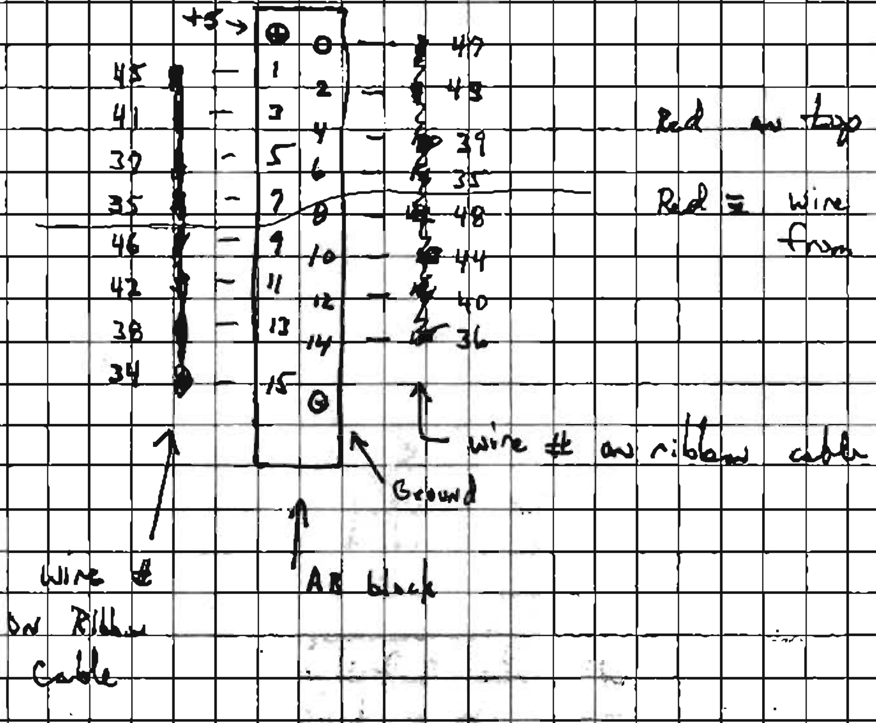
4/28/99 Install cables to enable each sub-system

- Anode - BNC cable provides CC to LeCroy
- Cathode - Gray cable to provide CC to pins 2 & 3 on back of Supply
- Laser - Gray cable to rack 1A9 - CC
- GG - Gray cable to Vahe's crate.

5/3/99 Archer educated me with respect to the Ribbon Cable wiring scheme. It was wrong. Now it is correct

TTL input block to Allen Bradley

Output Block is the same



Red on top (ie near #0)

Red = wire #50 on ribbon from I/O module

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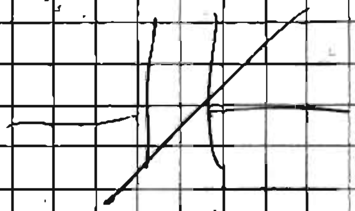
/10/99

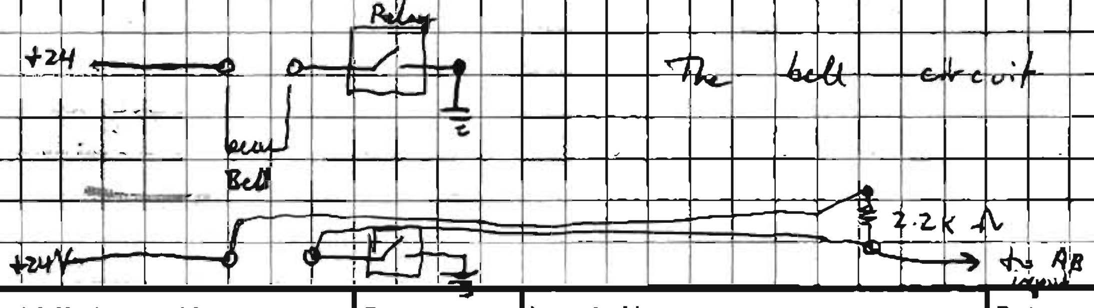
03:30 Called Larry to restart gas system
Called MCR @ 4662 to restart water

03:40 Disconnect green light on back panel near over-ride keys. It is redundant with "Water Alarm" Light

We should change program so water alarm light does not go green until TPC flows are OK, etc etc. Currently it goes green while in over-ride. But this would make it hard to run long term with the gas run bypassed, for example.



/14/99 Historical note: The Gas system "bell" has a very strange relay to enable it. The relay switches the ground side of the circuit So... I used a 2.2 kΩ resistor across the [redacted] +24V to switch side of the bell. This gives a Lo:Hi at the AB input... but not 0:24V It is something else but at least it works.



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6/24 Wish List for Program Change

1) Shield status Light - when is it OK
to go out of over-ride. Use light
on Back panel

2) Fix Horn & Bell - remove the intermittent
on the horn for water & gas

3) ~~Change~~ change Blink rate to 1 sec

4) Light for status of horn in the hall

5) Replace bell with small horn in
the gas room.

6) Put bell (or horn) outside the gas room

6/22/99 The alarm circuits for the trailer &
control room go through the CC
relay output on the master crate.
I did this so they can be given
a separate 24V supply.

Currently the alarms use the keypad
power supply. Should go to a separate
supply someday

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/25/99 Wired up the Buzzer in the gas room.
It is connected to the Master Crate 24V output for both Ch #1 and Ch #7 (gas and water)

However, the AB program logic is expecting to send 24V = OK to the trailer ; control room.

The buzzer needs 24V = fail So I reversed the logic on the output to ch 1 & ch 7.

/17/99 We powered down the platform in order to move the detector. This killed the power to The remote AB crate on the platform with the consequence that the AB master crate faulted and shot down the gas system. In order to restore operation, I built a hot wire for the gas system

16:00 Use channel #1 of the patch panel on The back of Rack 4 to provide 24 Volts directly to the gas system breaker. A jumper on The back of rack 4 can be removed to disable The hotwire.

The gas system is permanently on without any protection.

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Checklists

If you are using a printed copy of this procedure, and not the on-screen version, then you MUST make sure the dates at the bottom of the printed copy and the on-screen version match.
The on-screen version of the Collider-Accelerator Department Procedure is the Official Version.
Hard copies of all signed, official, C-A Operating Procedures are available by contacting the ESSHQ Procedures Coordinator, Bldg. 911A

C-A OPERATIONS PROCEDURES MANUAL

ATTACHMENT

11.4.1.c STAR Flammable Gas Procedure Checklist

Text Page 2

C-A OPM Procedures in which this Attachment is used.		
11.4.1		

Hand Processed Changes

HPC No.	Date	Page Nos.	Initials

Approved: *Signature on File* ______
Collider-Accelerator Department Chairman Date

W. Christie

STAR Flammable Gas Procedure Checklist

Please check, date and initial each item below:

1. A shift schedule must be in place. For the duration of time that the flammable gas is in the detector system, a manned shift must be in place at the STAR site.

   ☐ Date: _____________ Initials: ___________

2. The chamber to receive the flammable gas must have been properly purged.

   ☐ Date: _____________ Initials: ___________

3. All high voltage to the subsystem receiving flammable gas must be off.

   ☐ Date: _____________ Initials: ___________

4. The flammable gas detection system, which resides on level 2 of the South electronics platform, must be operational.

   ☐ Date: _____________ Initials: ___________

5. The STAR Global Interlock System (SGIS) must be operational.

   ☐ Date: _____________ Initials: ___________

6. The flammable gas operator must get the approval of the relevant detector sub system manager. The relevant detector sub system manager must receive the permission of the STAR Detector Support group leader.

   ☐ Date: _____________ Initials: ___________

7. The C-A Operations Coordinator (x4662) must be informed that flammable gas is about to be introduced into the detector.

   ☐ Date: _____________ Initials: ___________

8. The C-A MCR Group Leader and Deputy Group Leader must be informed via email that flammable gas is about to be introduced into the detector (ingrassia@bnl.gov and Sampson@bnl.gov).

   ☐ Date: _____________ Initials: ___________

9. The CAS watch supervisor must be informed that flammable gas is about to be introduced into the detector. This can be accomplished by asking the C-A Operations Coordinator to inform the CAS watch supervisor.

   ☐ Date: _____________ Initials: ___________

10. The “Blue sheet” for the SGIS must be currently certified.

    ☐ Date: _____________ Initials: ___________

11. A list of experts for the relevant gas system, with phone numbers, must be posted.

    ☐ Date: _____________ Initials: ___________

Checklist for TPC after long shutdown: valid 7/14/2009

All tasks to be performed BEFORE pole tips are inserted.

CABLES

1. Check all cable connections on TPC face that were uncabled for maintenance work:
    - Check labels ____
    - Check ground sleeves ____

ANODES

1. Both VME processors boot and ARCNET OK ____
2. Both serial sessions OK ____
3. Ramp HV to 100 V (N2 in chamber) ____
4. All channels draw ~500 nA on ramp up? ____
5. No channels trip ____
6. Check DC current at 100 V – any new high currents? ____
7. Check hardware trip limit for all cards:
    - Inner = 1210 V ____
    - Outer = 1500 V ____
8. Test interlock from PLC

CATHODE & FIELD CAGE

1. Field cage current and voltage read out by Kiethley? ____
2. Remote power switch turns Glassman on/off? ____
3. Glassman turns on remotely? Slow controls) ____
4. Ramp Glassman to 1000V (N2 in chamber) ____
5. Check field cage currents and voltages. ____
6. Test interlock from PLC

GATED GRID

1. Both crates (control & driver) OK? ____
2. Check capacitance for each cable/sector – pin to pin & pins to ground ____

2A. Check cable ground braid to platform ground ____

3. Turn on GG – download setpoints ____
4. Pulse GG with pulser – check monitor out for all sectors ____
5. Calibrate outputs if needed. ____
6. Check that ground sleeves in back of rack are in place. ____
7. When done, ensure trigger cable from TCD is plugged in ____
8. Test interlock from PLC ____

GROUND PLANE PULSER

1. Wavetek on and downloaded pulse selected? ____
2. Downloaded pulse looks ok? (Parameters stored correctly?) ____
3. Rate limiter plugged in? ____

4. Check that rate limiter is working before plugging into fanouts ____
5. Trigger Wavetek with pulser – check all outputs from fanouts ____
6. Replace bad fanout modules. ____
7. Make sure trigger cable from TCD plugged into Wavetek ____
8. Check PLC interlock ____

FEES & MWC FEES

1. Check that all blowers in rack row 2B are running ____
2. Turn on VME crate and boot processor ____
3. Make sure all manual switches on LVPS are in remote position ____
4. Turn on all FEEs and MWC FEEs remotely. ____
5. Turn off TPC water skid – do all FEEs go off? ____
6. TPCTEMP computer running and updating? ____

LASER

1. Power on both lasers – locally ____
2. Beams aligned? ____
3. Photodiode signal ok to TCD and cathode TDC? ____
4. Check remote on/off of lasers (slow controls) ____
5. Check remote viewing of lasers ____
6. Test PLC interlock ____

TPC & GLOBAL INTERLOCKS

1. Check inner field cage air blower – on & flow switch ok? ____
2. Wet, in turn, east and west TPC Tracetek – alarm & skid stops? ____
3. Platform methane sniffer ok? Contact CAS if not ____

GAS SYSTEM

1. Close SV18 and do leak rate test with N2 ____
2. Calibrate and test trips of Pioneer methane system ____
3. Calibrate and test trip of gap methane detector ____
4. Calibrate CAI methane analyzers ____
5. Check limits and test hardware & PC alarms. ____
6. Bake out dryer & purifier ____
7. Check two big compressors ____
8. Test all gas pipe clamps and tighten ____

ELECTRONICS

1. Do a geometry run – compare to baseline ____
2.Do a pulser run – compare to baseline ____
3. Do a full pedestal run – check RMS offline ____

Attachment 3. STAR TPC GAS SYSTEM CHECK LIST Valid from 11/1/2007

(To be filled out once per shift and placed in Gas System Binder)

Computer Monitored Sensors

Sensor	**Function**	**Value**	**Range**	**Comments**
PI1 (PT1)	Output of Big Compressor		95 - 125 mbar	
PT2	Input to TPC		2.0 – 4.5 mbar	
PT3	Monitor Chamber Pressure		0.3 – 2.0 mbar	
PT5	Input of Big Compressor		0.5 – 1.6 mbar	
PT7	TPC/Gap Differential Pressure		0 – 2.0 mbar	
PT8	Input Pressure to TPC		1.5 - 2.5 mbar	
PT9	Pressure across Dryer Filter		10 - 90 mbar	< 0 If dryer loop off
PT10	Pressure across Main Filter		2.0 - 20 mbar	
FT1	Exhaust Rate		-6.0 – +20.0 lpm	Oscillates
PTB	New barometer		970 – 1040 mbar	
PI8	Argon Delivery Pressure		1.0 - 1.7 bar	
PI9	Methane Delivery Pressure		0.98 - 1.5 bar	
PI10	Nitrogen Pressure on Pad		2.2 - 4.0 bar	
PI13	Argon Pressure on Pad		2.2 – 4.3 bar	
PI14	Methane Pressure on Pad		5 - 155 bar	
PI15	Nitrogen Delivery Pressure		0.9 - 1.8 bar	
FM1	Methane mass flow controller		0.9 - 1.9 lpm	
FM5	Argon mass flow controller		10 – 20 lpm	
FI7	Recirculating flow in TPC		450 - 600 lpm	
O2 M1	Oxygen content		5 - 80 ppm	
O2 M5	Oxygen content		< 0 %	
H2O M2	Water Content		0 - 80 ppm	
CH4 M3(a)	Methane Content		9.5 - 10.5 %	
CH4 M4	Methane Content		9.5 - 10.5 %	
Leakage	Calculated Leak Rate		0 – 14.5 lpm	
CH4FM%	Methane/Argon Ratio		9.0 – 11.0	

Rack 1

FM5	Fresh Argon Flow		10 - 20 lpm	
FM1	Fresh Methane Flow (slaved)		1.0 - 1.9 lpm	
FI7	Recirculating Flow to TPC		500 - 600 lpm	
PT8	TPC Pressure		1200 - 2600 μbar	
M2	Water Content		0 - 80 ppm	

TURN OVER FOR MORE!

Rack 2

Sensor	Function	Value	Range	Comments
PI7	Input to Big Compressor		6.0 - 12. mm H2O	
PI2	Output of SC#1		8.2 – 12.5 PSIA	
PI1	Output of Big Compressor 1		40 - 48 in H2O	Oscillates
PI3	Intermediate Input Pressure		5.0 – 12.0 in H2O	
PI4	Input To TPC		1.0 - 1.55 in H2O	
FI1a	Gas to Vent		0 – 50 SCFH	Oscillates
M4	Fresh Methane Content		9.5-10.5%	
FI2a	M4 P10 flow		4.0-6.0 x 100 cc/min	
SV14	Input to M1, M2, M3a		Open (Green)	
SV6,7,8	Input to M1,M2,M3a		Open (Green)	
TIC1	Purifier Temperature		205 - 240	
PI8a	Output of SC#2 (Back)		0.4 – 0.8 Bar	
FI3	M2 Flow (Back)		9-12x100 cc/min	

Rack 3

Sensor	Function	Value	Range	Comments
M1	Oxygen Meter		5 - 80 ppm	
M5	Oxygen Meter		< 80 ppm	
PI8	Argon Delivery Pressure		15.0 – 19.0 PSIG	
PI9	Methane Delivery Pressure		15 PSIG +/- 1	Must be less than PI8
PI15	Nitrogen Delivery Pressure		13 - 17 PSIG	
M3b	Methane Analyzer		9.5 - 10.5 %	
SV21	Methane Inlet		Open (Green)	
SV22	Argon-Methane Bypass		Closed (Red)	
FI2	M1 Flow		0.1-0.3 lpm	
FI4	M3a Flow		4.0 -6.0 x100 cc/min	
FI10	Insulation Gap Flow		10.0 – 20.0 lpm	
FI12	M4 Case Purge (Back)		2.0 – 4.0 lpm	
FI13	M3a Case Purge (Back)		2.0 - 4.0 lpm	

Mixing Room

Sensor	Function	Value	Range	Comments
PI10	Nitrogen Supply Pressure		26 - 52 PSIG	
PI11	Nitrogen Delivery Pressure		15 - 22 PSIG	
PI12	Argon Delivery Pressure		15 - 25 PSIG	
PI13	Argon Supply Pressure		30 - 45 PSIG	
FI16	Laser Nitrogen Flow		< 10 lpm	
FI17	Water Skid Nitrogen Flow		1- - 20 lpm	
PVENT	Vent Line Pressure		0 – 0.5 in H2O	
ODH	Room Oxygen content		19 – 22 %	
Bubbler	Oil Level		Between Marks	

Rack 4

M6	Gap Oxygen		0 – 40 ppm	
M7	Gap Water		0 – 40 ppm	
M8	Gap Methane		0 – 16 %LEL	
FI51	Gap N2 flow		5 – 20 lpm	
FI55	Gap return flow		0.8 – 3 lpm	

Software Alarms Enabled? ____________

Chilled water flow to gas system (gpm) _________

Operator___________________________ Date & Time_____________ valid from 7/14/2009

STAR TPC GAS SYSTEM CHECK LIST for CH4 Purge

(To be filled out every 2 hours from ________________ to ________________)

Rack 1

Sensor	**Function**	**Value**	**Range**	**Comments**
FM2	Fresh Methane Flow (slaved)		10.2 -11.2 lpm	
FM3	Fresh Argon Flow to TPC		85-105 lpm	
PT8(PI6)	TPC Pressure		250-450 μbar	

Rack 2

Sensor	**Function**	**Value**	**Range**	**Comments**
M4	Fresh Methane Content		9.5-10.5%	

Rack 3

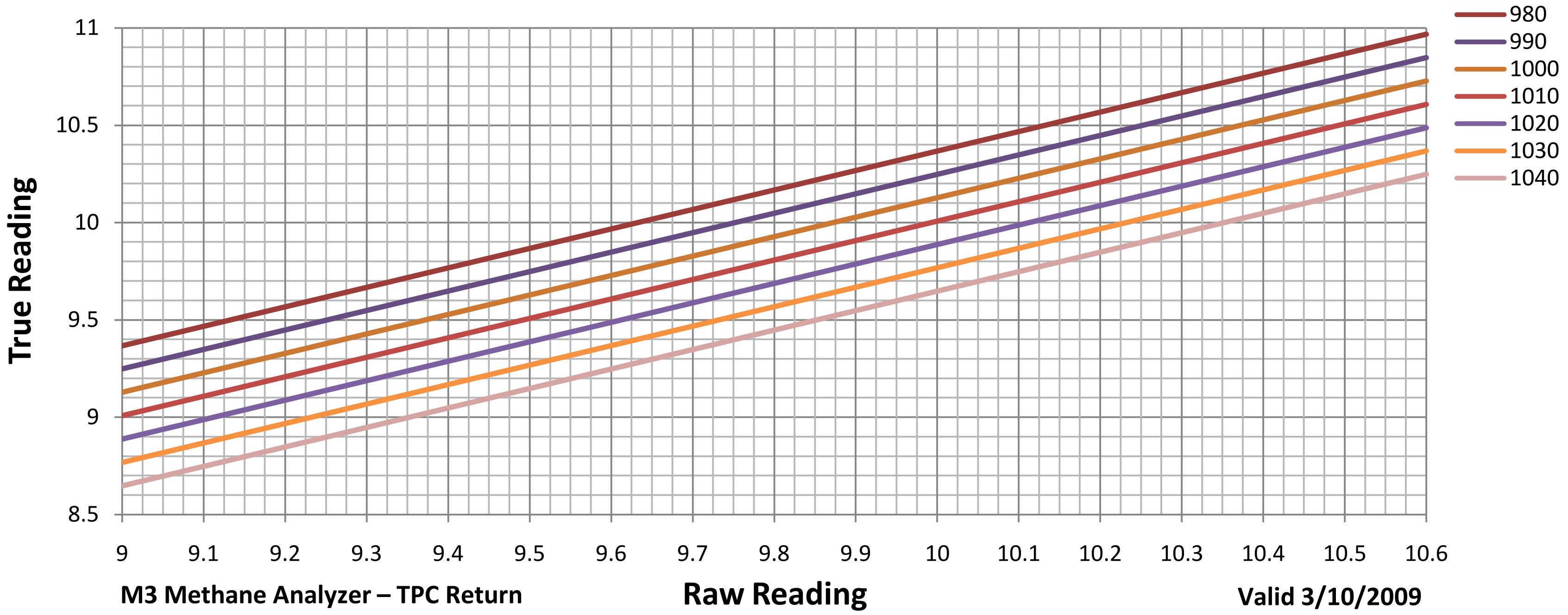
Sensor	**Function**	**Value**	**Range**	**Comments**
M3a	Methane Meter		9.5-10.5%	
M1	Oxygen Meter		5 - 80 ppm	
PI9	Methane Delivery Pressure		13.0-17.0 PSIG	Should be less than PI8
PI8	Argon Delivery Pressure		15.0 – 19.0 PSIG	

Rack 4

Sensor	**Function**	**Value**	**Range**	**Comments**

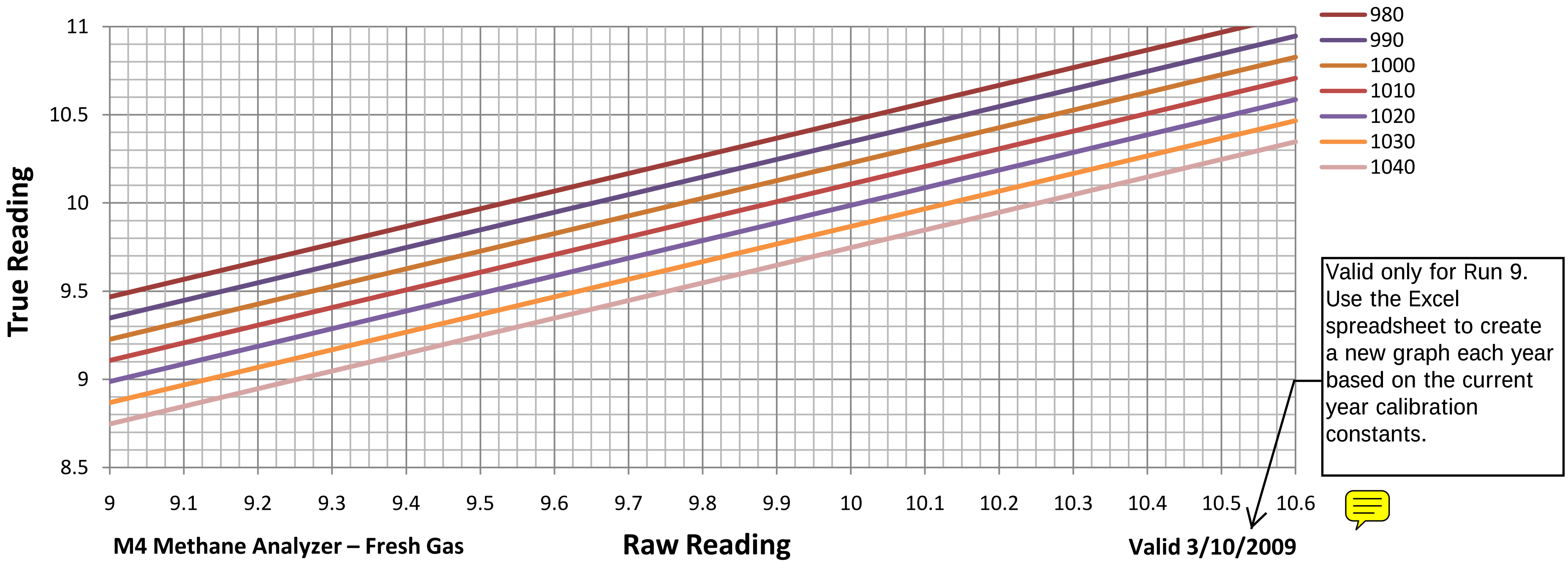
Operator___________________________ Date & Time____________

Alexei Lebedev		**Jim Thomas**	
Office:	(631) 344-3101	Office:	(631) 344-3918
Cell:	(631) 255-4977	Cell:	(510) 759-4936
Home:	(631) 821-2838	Home:	(631) 928-8661



M3 Methane Analyzer – TPC Return

Valid 3/10/2009



Valid only for Run 9. Use the Excel spreadsheet to create a new graph each year based on the current year calibration constants.

M4 Methane Analyzer – Fresh Gas

Valid 3/10/2009

Date	Time	Section	Voltage	Trip	pTrip	Code	Beam On?	Serial #	Comments

2/19/2008

TPC tasks from Run 8 shutdown to start of Run 9

Shutdown after Run 8:

1. Purge TPC with N2, sign the blue sheet when purged
2. Shutdown gas system and establish summer maintenance N2 flow.
3. Monitor LAr tank and order refill when needed
4. If STAR doesn't roll, nothing else to do for gas system.
5. If STAR rolls, make sure TPC gets N2 during roll and in assembly building.
6. When (if) STAR rolls back, put up gas pipes to wall.
7. Shutdown platform crates and breakers - everything off except interlock system.
8. Remove pulser and put in office (plug it in!)

TPX work over summer:

1. Contact Danny and Bob Sheetz - offer assistance for FEE testing etc
2. Supervise removal of old electronics - help in "GO" decision for removal.
3. Supervise installation of new FEEs, RDOs and grounding cards.
4. Supervise (help) installation of new cables - new fiber optics from platform to TPC face and from platform to DAQ room.
5. Supervise (help) installation of new LVPS (138 new power supplies in existing boxes) Test slow controls of new LVPS and interlocks.
6. Supervise (help) installation of new DAQ PCs in DAQ room.
7. As new electronics is installed on TPC start testing with pulser and pad monitor.
8. Do R&D on new Alice prototype gated grid driver - initiate construction if needed.

Other summer projects:

9. Work with Creighton on slow controls migration from Solaris to Linux. Also possible replacement of some VME processors with PC based controls - test any new software.
10. If work is done in the IFC, make sure to test for shorts.

RUN 9 startup:

1. When Leonid comes in the fall, turn on gas system racks and PC.
2. Calibrate methane analyzers, pressure transducers, reconstitute purifier and dryer, test system leak rate.
3. Calibrate and test interlocks for gas room Pioneer methane system (3 sensors) and gap methane sensor.
4. Make sure Bob calls for maintenance on the gas room 3 phase UPS.

5. Work with CAD during certification of STAR global interlock system - confirm actions sent to TPC interlock system.
6. Turn on all platform racks and crates - reinstall pulser.
7. Perform TPC checklist - see separate sheets.
8. Confirm with Alexei the laser status - is a site visit by SpectraPhysics needed?
9. Perform pulser run - check with pad monitor. Give Danny list of bad channels for replacement.

RUN 9 Physics:

1. Three days before “start of physics”, start Ar purge of TPC (typically 6 volumes = 2 days).
2. If blue sheet is signed and shift crews are in place, start P10 purge of TPC - 2 volumes.
3. Start gas system recirculation - all alarms active, all interlocks green.
4. Turn HV on chamber and make laser run - check the position of the membrane flash to check drift velocity.

Good Luck!

valid 3/20/2008

#	Description	Port#	Crate	Location	Processor	IP address
1.	CANbus (STAR) 1st 2nd Floor	9003	51	2A9	grant.starp	130.199.61.103
2.	CANbus (BARREL) Barrel crates	9040	100	2C4-1	bemccan.starp	130.199.60.59
3.	CANbus (EEMC) EEMC/QT/West PT	9020	99	2C4-1	vtpc1.starp	130.199.60.189
4.	Field Cage	9001	56	2A4	vtpc4.starp	130.199.60.192
5.	Gated Grid	9002	54	2A6	vtpc3.starp	130.199.60.191
6.	TPC FEE	9004	58	2B5	vtpc2.starp	130.199.60.190
7.	Cathode HV	9005	57	2A3	cath.starp	130.199.60.162
8.	Inner Anode HV	9006	52	2A7	vtpc7.starp	130.199.61.78
9.	BBC HV ZDCsmd, and upVPD	9010	77	1A7-1	bdb.starp	130.199.61.218
10.	Ground Plane Pulser	9011	57	2A3	vsc2.starp	130.199.60.217
11.	Interlock TPC Temperature	9012	52	2A7	epics2.starp	130.199.60.149
12.	Outer Anode HV	9013	59	2A6	vtpc5.starp	130.199.60.193
13.	Platform Hygrometer TPC Gas	9015	58	2B5	hdlc.starp	130.199.60.161
14.	Trigger HV ZDChv programs	9021	63	1A6	cdb.starp	130.199.60.40
15.	SSD	9026	79	1C6	sdvmesc.starp	130.199.60.120
16.	SVT	not used			svtmonitor.starp	130.199.61.50
17.	FTPC Slow Controls	9033	71	1B5-1	ftpc.starp	130.199.61.83
18.	EMC TDC & Slow Controls	9039	80	2C4-2	creighton5.starp	130.199.60.229

19.	DAQ temp & humidity & gain	DAQ room	DC2	burton.starp	130.199.61.104
20.	CDEV Scalars and Magnet	DAQ room	DC3-2	vsc1.starp	130.199.60.188
21.	Autoramp anode & cathode & testbits	DAQroom	DC2-1	stargate.starp	130.199.61.48
22.	TOF_Gas program	DAQroom	DC3-3	taylor.starp	130.199.60.6
23.	CANbus iowritest Program (needs to be rebooted daily)	DAQroom	DC3-1	tutor.starp	130.199.60.46
24.	DAQ Hygrometer & GID (PC in daq room)	DAQroom	DC3-1	medm.starp	130.199.60.49

TPC	Lecroy serial session for inner sectors	Port 9037
TPC	Lecroy serial session for outer sectors	Port 9038
FTPC	Lecroy serial session	Port 9023
SVT??	Lecroy serial session	Port 9034
SMD??	Lecroy serial session	Port 9035

REMOTE POWER SUPPLIES---requires a telnet

rps1.starp.bnl.gov	130.199.60.26	2A4
rps2.starp.bnl.gov	130.199.60.205	2A3
rps3.starp.bnl.gov	130.199.60.206	2A6
bemcpower.starp.bnl.gov	130.199.60.54	2C4
eemccanpower.starp.bnl.gov	130.199.60.90	1C2
pmdrps2.trg.bnl.local	172.16.128.208	1A3

Name: scdaqpower.starp.bnl.gov Address: 130.199.60.95

COMPUTONE SERVERS
Name: scserv.starp.bnl.gov Address: 130.199.60.167
Name: scserv2.starp.bnl.gov Address: 130.199.60.96

SCSERV: NOTES
telnet scserv
then type help
There is also a web interface http://scserv.starp.bnl.gov/

Name: scserv2.starp.bnl.gov Address: 130.199.60.96
username and password not assigned yet

Gas System

C-A OPERATIONS PROCEDURES MANUAL

11.4.1 STAR Flammable Gas Procedure

Text Pages 2 through 3

Hand Processed Changes

HPC No.	Date	Page Nos.	Initials

Approved: ___________***Signature on File***_________________ ______
Collider-Accelerator Department Chairman Date

W. Christie

11.4.1 STAR Flammable Gas Procedure

1. Purpose

The scope of this procedure is those safeguards and operations that are necessary for turning on flammable gas for a STAR detector gas system.

2. Responsibilities

The flammable gas system operator is responsible for seeing that all steps and conditions outlined in this procedure are followed or complied with when introducing flammable gas into the detector.

3. Prerequisites

In order to operate any of the STAR flammable gas detection systems, the following requirements must be met:

3.1 C-A User training

3.2 STAR Gas system authorization. (See C-A-OPM-ATT 11.4.1.a and C-A-OPM-ATT 11.4.1.b)

3.3 All personnel working on any electrical system or equipment in the C-AD shall be familiar with BNL SBMS Electrical Safety, BNL SBMS Lockout/Tagout (LO/TO), C-A-OPM 1.5, "Electrical Safety Implementation Plan", C-A-OPM 1.5.3 "Procedure to Open or Close Breakers and Switches and Connecting/Disconnecting Plugs", C-A-OPM 2.36, "Lockout/Tagout for Control of Hazardous Energy". C-AD will provide on-site/work specific training to individuals in the electrical safety aspects of their job functions and assignments.

4. Precautions

Before initiating flow of flammable gas, the following precautions must be taken.
The checklist for items 4.1 through 4.10 below, available as C-A-OPM-ATT 11.4.1.c, must be filled out by the gas system operator and filed with either the STAR Detector Support group leader, or the STAR Technical Support group leader:

4.1 A shift schedule must be in place. For the duration of time that the flammable gas is in the detector system, a manned shift must be in place at the STAR site.

4.2 The chamber to receive the flammable gas must have been properly purged.

4.3 All high voltage to the subsystem receiving flammable gas must be off.

4.4 The flammable gas detection system, which resides on level 2 of the South electronics platform, must be operational.

4.5 The STAR Global Interlock System (SGIS) must be operational.

4.6 The flammable gas operator must get the approval of the relevant detector subsystem manager. The relevant detector subsystem manager must receive the permission of the STAR Detector Support group leader.

4.7 The C-A Operations Coordinator (OC), (x4662), and the MCR Group Leader/Deputy Group Leader, must be informed that flammable gas is about to be introduced into the detector. The MCR Group Leader and Deputy should be informed via email (ingrassia@bnl.gov and sampson@bnl.gov).

4.8 The Collider-Accelerator Support (CAS) watch supervisor must be informed that flammable gas is about to be introduced into the detector. This can be accomplished by asking the C-A Operations Coordinator to inform the CAS watch supervisor.

4.9 The "Blue sheet" for the SGIS must be currently certified.

4.10 A list of experts for the relevant gas system, with phone numbers, must be posted.

5. Procedure

See the STAR Documented Work Procedure (DWP) for the appropriate subsystem listed in section 6.0.

6. Documentation

Each subsystem using flammable gas has its own procedure for start up, maintenance, and monitoring.

6.1 Operating the TPC Gas System SOP-TPC-GAS-03-A

7. References

7.1 C-A-OPM 1.5, "Electrical Safety Implementation Plan".
7.2 C-A-OPM 1.5.3 "Procedure to Open or Close Breakers and Switches and Connecting/Disconnecting Plugs".
7.3 C-A-OPM 2.36, "Lockout/Tagout for Control of Hazardous Energy".
7.4 SBMS Electrical Safety.
7.5 SBMS Lockout/Tagout (LOTO).

8. Attachments

8.1 C-A-OPM-ATT 11.4.1.a "List of authorized operators for the STAR TPC gas system".
8.2 C-A-OPM-ATT 11.4.1.c "STAR Flammable Gas Procedure Checklist".

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Ordering TPC gas (methane and Argon) valid summer 2008

We order methane and Argon from Praxair, who are the official suppliers of gas for all of BNL. However, the ordering goes through different paths.

Methane:

STAR owns three sixpacks (6 1A size cylinders ganged together on a cart). The STAR sixpacks are made up of silver colored cylinders that are marked BNL, STAR and 1006. The bottles were recently re-certified by Praxair and don't need to be certified again until 2012. Praxair usually will repair any damage to the manifold on top of the six pack. For normal operation we only use these 3 six packs since we know they only have had high purity methane in them. As a back up emergency I keep on hand a Praxair owned six pack (red bottles) to be used only if none of ours are available. This happened in 2007 because of the Christmas and New Year's holidays and a problem with one of our 6 packs.
We use "Ultra High Purity" methane (Praxair grade 3.7). which should have O2 < 10 ppm and N2 < 40 ppm. One six pack under normal usage (i.e. recirculation mode) lasts 2 weeks. Praxair usually sends a truck for pickup and delivery once a week on Tuesday, and it takes 2 weeks to refill a 6 pack. So, under normal usage, one 6 pack is in use, one is in standby, and one is being filled.

To order a pickup or to check on delivery:

1. Call Praxair at 1-800-772-4059
2. Ask for our account rep, who is currently Jennie. Identify yourself as being from BNL and Bldg 1006 - use my name to jog her memory!
3. Tell her you have a methane 6 pack ready for pickup and confirm if they have one coming back.
4. Make sure the 6 pack for pickup is rolled out to the edge of the covered area on the gas pad. The truck usually comes at ~ 8:30 on Tuesdays and I try and be around when he delivers. The driver will load and unload.
5. The methane is paid for using a BNL standing PO. Usually once a year it has to be refilled with money by transferring funds from STAR. Contact Liz Mogavero or Bob Soja to arrange this.

ARGON:

We have a 900 gallon liquid Ar tank on the gas pad. The tank is rented from Praxair and they are responsible for maintenance and repair, if needed. (We've never had a problem.) We pay a monthly rental fee and for bulk LAr when the tank gets filled. As for methane, there is a standing PO to pay for the rental and LAr which gets renewed every year - see Liz or Bob for particulars. The quantity on hand in the tank is measured by a gauge at the tank - measurement is in inches. A full tank is 120 inches and we usually call for a refill when the tank gets to 30 inches. (We are required to keep sufficient product on hand to purge the TPC in an emergency, hence the limit of 30.) The contract requires Praxair to fill the tank within 48 hours of our phone call. You do not have to be present for the delivery - the driver knows what to do and refilling does not interfere with the Ar flowing to the TPC gas system. The driver is already qualified to get past the BNL gate and the posted signs if we are running. The driver will leave the invoice in a green canister at the tank.

For normal operation, a full tank will last 2 months. If STAR is shutdown a small amount of gas is still used by the PMD group and the rest is lost to boil off - in this case a full tank lasts 3 months. We never let the tank warmup - to refill a warm tank takes ~ 50% more LAr, so it is cost effective to always keep it cold.

To order a refill:

1. Call 1-800-praxair (1-800-772-9247)
2. It is an automated system to start with - select the choices to order product for an existing account.
3. When asked, enter our Praxair number - 8523548
4. An operator will come on the line - tell her you want a refill of our tank. She will ask you the reading and when it was taken and your name etc. Request the fill within 48 hours. She will give you a confirmation number.
5. Hang up.
6. Check after 48 hours that the tank got filled - note that I normally don’t ask for delivery over the weekend or after hours because of possible BNL gate or receiving problems.

A folder labeled “Supply-Gas” with historical documents (initial spec on the tank etc) and past order history is kept in my desk drawer at the counting house.

Startup of TPC gas system after summer shutdown

valid 7/14/2009

This procedure brings the TPC gas system to a ready state after the long summer shutdown. During the shutdown power to all racks is off and the TPC is continuously purged with N2 through the analog flowmeter FI5. This procedure will power all racks, boot the control computer, turn on all meters (O2, H2O, CH4 etc) and start the small compressors.

1. Make sure the circuit breakers on top of Racks 2, 3, and 4 are on. Turn them on if they are off - use appropriate PPE.
2. Push the green button on the TPC interlock panel (Rack 4) labeled “Gas System Power”.
3. Check that the red LED on the solid state relay mounted on the wall between Racks 2 and 3 is on - this supplies the power to Rack 2.
4. Turn on the CAI methane meter M3a (Rack 3)
5. Turn on the two Illinois Oxygen meters M5 and M1 (AC switch on the back of each meter inside Rack 3)
6. Open the exhaust valve for M1 and M5 (mounted on the back of the meter)
7. Crack open the input valve on M1 and M5 ¼ turn (mounted on the back of the meter.)
8. Plug in the small compressor SC3 (located inside Rack 3) (Supplies flow to M5)
9. Adjust the flow on M5 by turning the input valve - set flow to be between 0.1 and 0.2 lpm. If you need to make a courser adjustment than is allowed by the input valve, then adjust the unmarked bypass valve that goes around SC3.
10. Turn on the CAI methane meter M4 (top of Rack 2)
11. Confirm that there is N2 flowing to the TPC through FI5 (Rack 2) - adjust to the arrow if needed.
12. Turn on the lower hardware alarm box (Rack 1). The AC switch is on the back of the box.
13. Turn on the power for the SCXI input/output crate (Inside Rack 1)
14. Turn on the power for the temperature controller MUX box (Inside Rack 1). AC switch is on top of the box.
15. Turn on the power for the three Hastings mass flow controllers (Rack 1). The AC on is a rotary dial on each controller.
16. Plug in the water meter M2 (inside Rack 1)
17. Turn on the control computer and monitor and allow it to boot up.
18. Log into the control computer and start the gas system control program - double click on the icon labeled “Star_New”.
19. Using the control program close SV12 if it is open. (Closed = red)
20. Open SV13 (open = green). This is the inlet valve for the small compressor SC1
21. Open SV6,SV7, SV8, SV17
22. Using the control program, start Small Compressor 1 (SC1) and Small Compressor 2 (SC2).
23. Check the output pressure for SC1 on PI2 (Rack2). Adjust the pressure to be between the marks using the bypass valve MV16.

24. Check the output pressure for SC2 on PI8a (back of Rack 2). Adjust the pressure to be on the indicator line using the bypass valve MV17.
25. Check the flow for M2 on FI3 (back of rack 2). See the checklist for flow range.
26. Check the flow for M4 on FI2a (front of Rack 2) and adjust if needed.
27. Check the flow for M3a on FI4 (front of Rack 3) and adjust if needed.
28. Adjust the flow for M1 Oxygen meter by turning the input valve for M1 (inside Rack 3) - set the flow between the marks on FI2. (This is very sensitive!)

This next section starts the meters and pump for the gap gas (N2):
During the summer shutdown, ~ 10 lpm N2 goes to the gap through FI10 (Rack 3).

1. At Rack 4, open MV52 and close MV54 - this path selects fresh gas for the meters.
2. Plug in M7 (H2O) (inside Rack 4) and turn on M6 (O2) (AC switch on back of the meter.)
3. Check that FI10 (Rack 3) reads ~ 10 lpm.
4. Turn on the sample pump (switch on the control panel in Rack 4)
5. Check the sample flow (FI55) - it should be ~ 2 lpm.
6. Let the meters warm up for a few hours.
7. Open MV52 and close MV54 - this will sample the return gas from the gap.
8. After a few hours, check the meters readings. H2O < 10ppm, O2 < 20 ppm.

If this startup is in preparation for a new run, then you can also do the following steps:

1. If Leonid has already regenerated the purifier and dryer and the run will start in a week or so then turn the Purifier on using the computer control, The purifier will come on and heat up to the set point (~ 210 degrees C). Check after a few hours that it is regulating at this setpoint. For normal running the dryer is OFF.
2. Check that the computer data is being written out to slow controls. In the lower task bar (right side) find and left click on the icon "EPICS communicator". If the data is being successfully written you should see the message "Data saved to files" with a date and time stamp. The box next to "File writing to" should be checked and the path should be \\sc.starp.bnl.gov\gas_sys_data\ The box labeled "Direct connection to Epics channels" should NOT be checked. This process writes the gas system data to SC. You should also check the gas system GUI on CHAPLIN (accessible from the Top Level GUI) - the data should be refreshed every ~ 1 minute. If the data is not being written to SC or is not being updated on the GUI contact Wayne Betts and a slow controls expert. Also see page 148 in the gas system logbook.
3. If this is the start of a new run you also need to create a new local database on the gas system control PC. In the task bar (lower right) left click on "dbwriter". You should see the message "Data saved to database" with a date and time stamp. Click on the "Create New Database" button and create a new database identified by the year's run number (currently Run8). Close the window. Then from the desktop open the program dBviewer and click on "Change database". Select the new database that you just created (should be in the folder "databases"). After a

few minutes , check that the dBviewer program is displaying data from the new database (i.e. there should not be any data before the current day.)

Go to the "Procedure to start 100 lpm Argon Purge in TPC".

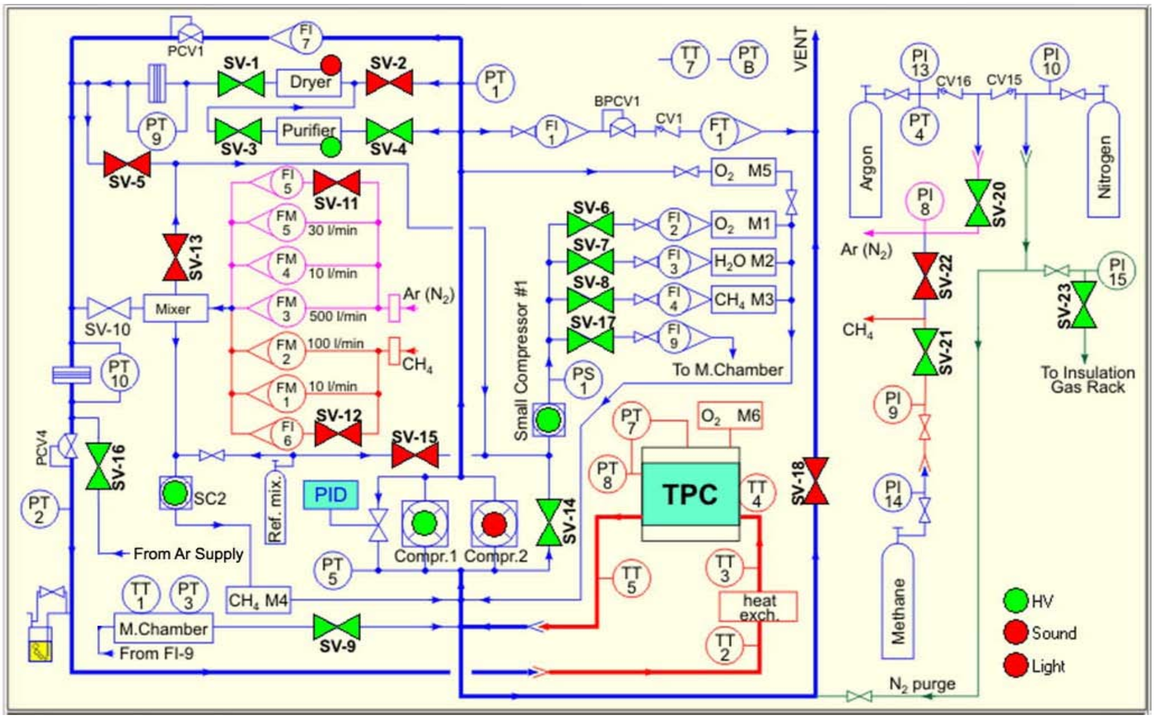


Figure 1: Gas System Schematic Diagram: Normal Circulation Mode Shown

11/19/2007
BCS

Procedure to start 100 lpm Argon Purge in TPC

1. Open MV30 (Ar inlet) located on the wall in mixing room. As Ar pressurizes the line you should hear the opposing check valves (CV15 & CV16) click - this stops the N2 flow and lets the Ar start flowing to the chamber.
2. Reduce the N2 regulator PCV2 to ~18 PSIG (located on the wall.) This further seals the check valves.
3. Open MV6 (Inlet valve for FM3 on rack 2)
4. On right Hastings controller (Rack 1) select FM3 (Channel 3)
5. Using computer, set FM3 to 100 lpm The Hastings response is sometimes ~slow.
6. Close SV11 (use computer) - stops the maintenance purge flow - red light means closed.

Note: Always stop the maintenance flow by closing SV11. NEVER close the manual valve on the flowmeter FI5 itself - this manual valve should remain open to provide the purge flow if the system shuts down automatically during running.

7. Check FM3 command/flow - command should be 100, flow should be 98 - 102. If flow is < 100, increase the delivery pressure for the Ar on PCV5 on the wall.
8. Close MV9 fully - this stops Ar from back-flowing through the compressor bypass valve.
9. To purge the supply stub that goes to the bubbler, open MV14a (bubbler bypass)
10. Read level at Ar tank
11. Note time in logbook.
12. If N2 has been in the chamber, flow Ar at 100 lpm for six volume exchanges. TPC volume is 50,000 l, so this takes ~ 50 hours.

At various times during this purge open MV9 all the way and run each of the big compressors for a few minutes (one at a time!). Leave SV18 OPEN. This gets N2 out of the nooks and crannies. Be sure and close MV9 fully after this or the Ar will short circuit out the vent.

The day before the P10 purge calibrate the methane meters. (Zero and span).

Go to the “Procedure to start high flow P10 purge in the TPC”

Procedure to start high flow P10 purge in the TPC valid 7/14/2009

This procedure is used to flow P10 gas into the TPC before turning on the recirculation.

1. Make sure the TPC is filled with AR - see the Ar purge procedure. Typically you should flow Argon at 100 lpm for 50 hours to exchange 6 volumes of gas. This will remove all of the N2.
2. Obtain a copy of the “STAR Flammable Gas Procedure Checklist” from the CAD web pages (http://www.c-ad.bnl.gov/ESSHQ/SND/OPM/Ch11/11-4-1-c.pdf) or obtain a copy from the TPC Operations page (listed as “Checklist for Flammable Gas Startup and Blue Sheet”). Fill out this checklist as you go through the remainder of the P10 startup procedure. When the checklist is complete, keep it on file as proof that the blue sheet was signed (see below).
3. STAR is not allowed to flow methane until the safety systems have been certified for the year. If this has been done (contact Bill Christie and the STAR liason engineer), call the RHIC MCR and ask for the operations coordinator. Tell the operations coordinator that you are ready to start flowing flammable gas (methane) and ask them to send the CAS watch down to STAR with the “blue sheet”. As TPC system manager, sign the blue sheet in the areas indicated by the CAS watch - this certifies that the TPC has been readied for methane etc.
4. Confirm from the STAR shift sign-up page that there is a 24 hour watch in place for STAR (at least one shiftleader and one detector operator.) Tell the current shiftleader that you will be starting methane flow. Make sure the TPC alarm box on the wall is plugged in and active. Make sure the contact numbers for the gas system expert are posted in the STAR control room and in the gas mixing room.
5. In the gas room, confirm that there is 100 lpm Ar flow in FM3.
6. On the gas pad, connect the flexible hose from one of the methane 6-packs to the wall mounted methane manifold. CGA connections are LEFT handed threads.
7. Open the bottle valve for each of the 6 bottles.
8. Open the 6-pack outlet valve which is connected to the flexible hose.
9. Using a wrench, crack open the fitting where the flexible hose connects to the manifold - this will purge the line. Let gas flow for ~ 10 seconds. Tighten the connection.
10. Open the manifold inlet valve, (MV26A or MV26B) and turn the two way valve MV26 so it selects the attached 6 pack. Confirm the delivery pressure on PI14 - it should be ~2000 PSIG for a full 6 pack.
11. In the gas mixing room open the manual valve MV25, behind Rack 3.
12. Using the control PC, close SV22 and open SV21.
13. Confirm the methane delivery pressure on PI9 (Rack 3) Should be ~ 15 PSIG.
14. Open the manual valve MV7 on rack 2. This is the inlet valve for FM2.
15. In Rack 1, select FM2 on the left hand Hastings controller. FM2 is the high-flow methane flow meter that is slaved to FM3. Check that the command value for FM2 is ~ 10.7. Switch to flow and confirm methane flow of 10.7.
16. Confirm on methane analyzers (M4 and M3) that input gas is now ~ 10.0 %. If needed, adjust the slave pot on the FM2 controller to get 10.0% methane in.

Note: Before starting P10 purge flow, the methane analyzers M3 and M4 should have been calibrated. However, the methane reading will vary with barometric pressure, so this needs to be taken into account. The variation is ~0.1% per mbar. Use the Excel spreadsheet on the TPC operation web page to create a calibration plot.

The purpose of this initial purge is to get close to 10% methane in the chamber. The final (constant) percentage will be set by setting the mass flowmeters during normal running. This process will take a few days.

17. Record the time, Ar level in the tank and the methane bottle pressure (PI14).
18. Since the system is in purge mode the alarms are still not active. During the P10 purge we have the STAR shift crew check the system every 2 hours through the night. So put post-it notes with canonical values and ranges on the following gauges: M4, M3, FM2, FM3, PT8, PI8, PI9, M1. The crew should call the expert if readings deviate from the posted values over night. Let the system purge 18 hours.
19. Send an email to the following people informing them that you have started flowing P10 in the TPC: ingrassia@bnl.gov, sampson@bnl.gov, pendzick@bnl.gov, chrisite@bnl.gov, soja@bnl.gov
20. Confirm that MV3A and MV3B are directed to "P10 to SV16" position
21. Open P10 cylinder and set 22PSIG pressure on PI52 using PCV50 pressure regulator(Gas Pad)
22. Open SV16 to purge the line for 20seconds and then close SV16 using PC

After the 16 hour purge we need to make sure P10 gets to all parts of the system and also check the return methane percentage and oxygen level.

1. Open SV1, SV3, SV4 using the PC. This opens the purifier/dryer path.
2. Open the bubbler bypass valve MV14a for ~ 1 hour.
3. Open MV9 (the big compressor bypass valve) fully.
4. Make sure SV18 is open.
5. Turn on the circuit breaker for the big compressor 2 (BC2) at the bottom of rack 2. Using the PC turn BC2 on and run for ~ 1 minute.
6. Turn BC2 off and turn BC2 breaker off.
7. Turn BC1 on. Running in this mode (SV18 open, MV 9 open, PID controller OFF) allows for purging and recirculation simultaneously.
8. With BC1 on, check the return gas. Open SV14 and close SV13.
9. Read the return O2 on M1 (should be ~ 10 ppm) and the return water on M2 (should be < 20 ppm).
10. Check the return methane content on M3. It will probably read low (<9.5%).
11. Leave the system in recirculation/purge mode. At this point, you can raise the input methane content to ~11% by adjusting the FM2 slave pot.
12. Continue like this until the return methane content is 10.0% adjusted for barometric pressure.

(continued on next page)

When the return methane content is ~10.0%, prepare the system for normal operation.

1. Open SV13 and close SV14.
2. Turn off BC1
3. Set the FM2 slave pot back to ~10.7.
4. Close the bubbler bypass valve MV14a.
5. Close MV9 fully.
6. Go to the recirculation startup procedure "Procedure to put TPC gas system into normal operation (recirculation mode)". The final adjustment of the methane ratio will be done during normal recirculation and takes a couple days.

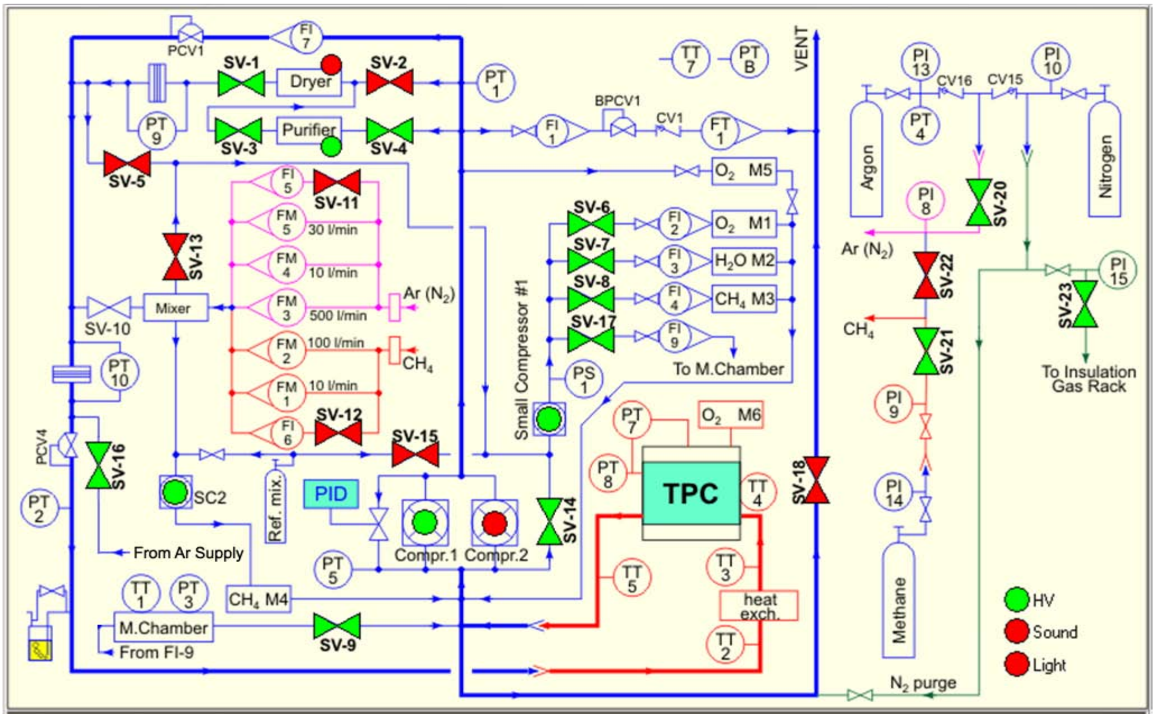


Figure 1: Gas System Schematic Diagram: Normal Circulation Mode Shown

11/21/2007

Procedure to put TPC gas system into normal operation (recirculation mode).

This procedure assumes that the system in is P10 high purge mode (i.e. 100 lpm Ar and 10 lpm Methane flow rates).

1. Open MV4 (manual valve for FM5). Open MV8 (manual valve for FM1.)
2. On the computer, set FM3 to 0 and set FM5 to 16.0 (this is the fresh gas makeup flow for recirculation mode). The course setting for Flow Meters is done with the mouse and the slider. Fine adjustment can be done with the right arrow to increase the flow by a small increment.
3. Close the manual valves MV6 and MV7.
4. On the right hand Hastings controller, select FM5 and confirm the command and flow are set to 16.0. If the reading are unstable, adjusting the argon or methane pressure in step 6 will help.
5. On the left hand Hastings controller, select FM1 and set the slave pot to a command of 1.55. This sets the canonical methane percentage for the run.
6. Reduce the Argon regulator PCV5 to ~18PSIG. On Rack 3 confirm that the Argon delivery pressure (PI8) is ~ 2 PSIG greater than both the methane pressure (PI9) and the N2 pressure (PI15).
7. Confirm again the settings for FM5 and FM1. Also check the methane content reading on M3 and M4 - they should be ~ equal, within the calibration accuracy.
8. Make sure MV10 (Rack 2) and the bubbler bypass valve are closed.
9. Confirm that SV11 and SV12 are closed (red) and that SV1, SV 3, and SV4 are open (purifier path).
10. Open MV9 (compressor bypass valve, Rack 2) ~ ¾ of a turn.
11. Turn on the PID controller (power supply inside Rack 1 at bottom right.) If not done before- check power for flowmeter FI7 and Hydrometer(M2) on rack1.
12. Open the PID controller display program (PID_NEW) and click on “Start”. The program should start to scroll and show the set point (red line) and reference pressure (yellow line).
13. On rack 2, clear the latch for both SV18 and the big compressor (push buttons).
14. Close SV18 (bang!).
15. Watch pressure rise - when TPC pressure (PT8) reaches ~ 1300 microbar, start BC1.
16. On the PID display the yellow reference pressure should slowly rise up to the setpoint. At the setpoint the PID controller should start to regulate by pushing gas to the vent through FI1a. For normal operation, FI1a should vary around ~30 and PT8 should vary around 1850 microbar. The stable yellow line should be a little bit below setpoint line and it’s position is regulated by manual MV9 valve. Sometimes it could takes 10-15 minutes to stabilize. Closing MV9 pushes the yellow line down.
17. Let the system run for 5 minutes to check for stability. Then open SV14 and close SV13 - this will sample the return gas. Record the O2 and methane levels.

18. Check the hardware alarm box in Rack 1 - all of the red lights in the top row should be out - i.e., no alarms. If this is the case, enter 79 on the keypad and push unblock. All the lights on the bottom row should go out. Alarms are now active.
19. In Rack 2, adjust the redlines for PI7 to the marks on the face of the gauge.
20. Using the PC, click the HV button to change it from red to green. Confirm on the Allen-Bradley PLC panel in rack 4 that the top row of lights are all green. Push any buttons on the bottom row of green buttons that are not lit - this sets the permissive for the anode, cathode etc. There now should be NO red lights on this panel unless a key is in the over-ride position. To reset flashing button that has been in over-ride, you have to insert a key and move it to the vertical position, then remove the key.
21. Finally, on the PC, click the "Enable Alarms" button - the program should acknowledge that the alarms are active.
22. After one hour, fill out the two page check list to make sure all parameters are within normal limits.
23. Confirm that the "Flammable Gas" signs on the two access doors into the WAH are turned around.
24. Make a STAR shift log entry that P10 is started and alarms are active.
25. At the first opportunity (no beam or stable beam) turn on the TPC HV and do a laser run - for good gas the flash off the central membrane should be in ~time bins 345 to 350.

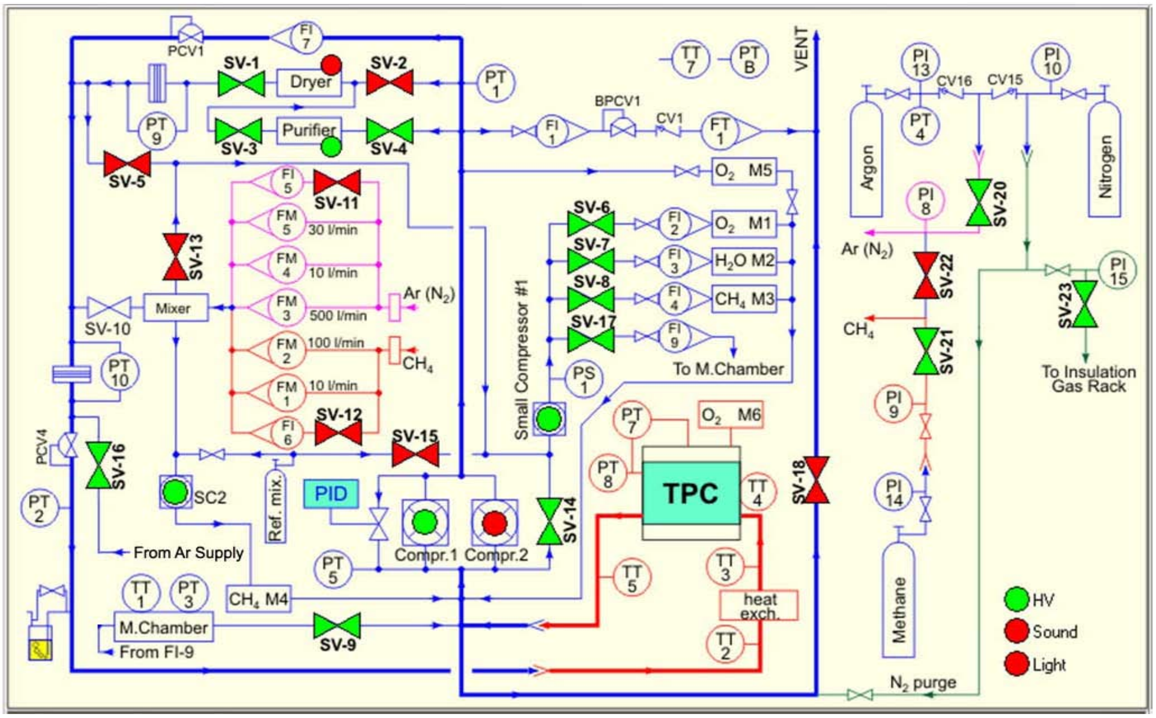


Figure 1: Gas System Schematic Diagram: Normal Circulation Mode Shown

Unanticipated shutdown and recovery of the TPC gas system.

valid 7/14/2009

Gas Room (631) 344-3122
Alexei Lebedev Cell (631) 255-4977

TPC Desk in Control Room (631) 344-8243
Jim Thomas Cell (510) 759-4936

If you have a gas alarm and you hear a recurring sound in the gas room that sounds like a person hammering on the pipes, look to see if M4 is oscillating. If so, go to the gas room computer and close SV21 immediately. This will close off the methane supply lines.

Recovery From a Re-circuation Fault

This procedure is meant to get the system back to a state where you can start a high flow P10 purge or the normal P10 recirculation mode, depending on how long the system was shut down. See the discussion at the end of this document for more information.

1. Silence the alarm (if not already silenced by the shift crew).

2. Block the hardware alarm box (enter 79, then "block alarms).

3. On the PC control screen, disable alarms. Also look at the gas system log window on the computer for clues to what might have happened.

4. If the system was shut down by SGIS then make sure SGIS is cleared and the problem fixed. Turn on the power for Rack 2; if it is off. If it is off then go to the TPC AB alarm panel and push the left-most green button on the lower row of buttons. This should turn the power back on Rack 2 by energizing the solid state relay on the wall of the gas room. You should hear the small compressors start up, and see the temperature controller for the purifier light up etc. While you are at it, check that the power is on for all 4 racks. Use appropriate personal protection to turn breakers on/off.

5. On the PC control make sure BC1 is set to "off" (i.e. red).

6. Open SV13 and close SV14. This makes SC1 sample fresh gas.

7. The Ar mass flowmeter should still be set to the recirculation value (16.0 lpm) - confirm this. If not, set it to the canonical value using the PC.

8. Close SV11 and SV12 to stop the purge flow. Confirm again that the mass flowmeter is giving 16.0 lpm

9. Close SV22 (cross-connect valve) and open SV21 (methane). Wait a bit and confirm that you have methane flow on the methane mass flowmeter (~1.55 lpm). Watch for variation of flow meters and it should be stable.

10. Check and open, if necessary, SV23 to allow nitrogen flow to the gap (it may be closed to protect the TPC. It closes when we have a PT-7 low alarm … the pressure between gap and TPC chamber goes out of range and then shuts to prevent N2 into TPC).

11. Wait a bit more and confirm that M4 and M3 read ~ 10% and M1 reads < 10 ppm.

12. Look at the dB plots around the time of the shutdown to see what might have happened while you wait for the methane content to rise inside the TPC.

13. At this point the system is stable and flowing P10 again. Go to the "Procedure to put TPC gas system into normal operation (recirculation mode)". Skip the initial steps of this

procedure (but check that all conditions are true) and start at about bullet 13. Note that you will have to lower the orange lower limit line on PI7 to zero so you can reset the interlock (red button on rack 2) and start BC1; when needed.

Once you get to normal recirculation mode, you can leave the system in this configuration and the methane concentration will slowly recover to its nominal value (10%) over a period of several days.

14. Or, alternatively, you can proceed to the instructions for starting the high rate P10 purge flow (100 lpm) by using the high flow mass flowmeters etc. The high rate P10 purge will recover the methane concentration in about 6 hours.

Go to the "Procedure to start high flow P10 purge in the TPC". Once this procedure is complete, and the high rate purge flow has started, check the return gas for the methane content and O2. To do this: open MV9 all the way, turn on the PID controller, leave SV18 open and start BC1. Make sure that SV14 is open and SV13 is closed (if they are not already in this state). Once you have a stable readings for CH4 and O2, turn off BC1, turn off the PID controller, and close MV9. The methane level you measure at the beginning of the purge will tell you how long you'll need to purge before restarting recirculation. Clearly, the longer the system was shut down and on Ar purge, the longer it will take to get going again. (It takes about an hour for every 0.1% below 10% if FM3 is set at 11.2).

When you are back to P10, start the system like you normally would with normal P10 makeup flow using the "Procedure to put TPC gas system into normal operation (recirculation mode)". Don't forget to unblock the hardware alarm box.

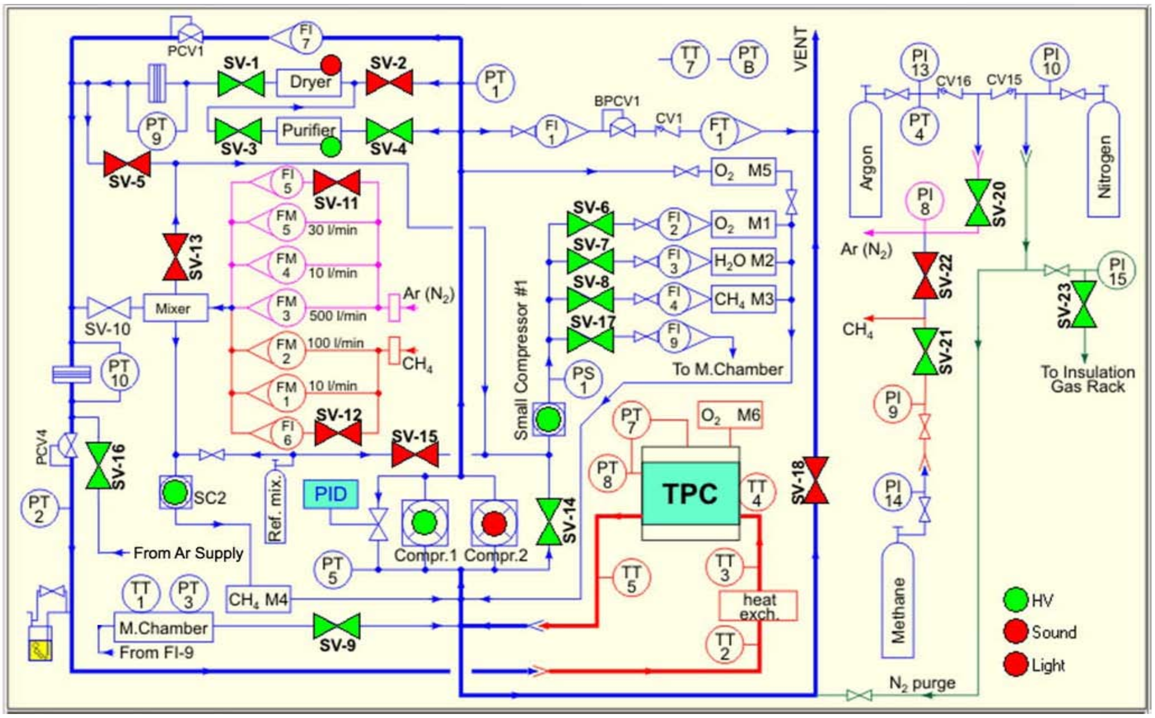


Figure 1: Gas System Schematic Diagram: Normal Circulation Mode Shown

Additional thoughts and notes from BCS 2/24/2009

I'll try and cover some of the past unplanned shutdowns of the system and the recovery procedure I used. The most probable reasons for shutdown are a valid (rare) or false shutdown signal from SGIS, a rapid RISE in the atmospheric pressure, excursions in the methane percentage above or below the alarm limit, an increase of O2 in the return gas above 80 ppm, pressure imbalance or oscillation in PT5 or PT8.

SGIS shutdown:

SGIS will send a kill signal for various reasons (high methane in the hall is the major one). This signal is passed to Jim's AB interlock system and turns off the AC power for rack 2. This shuts down BC1, SC1 and 2, the purifier, shuts off the methane (SV21) and starts the Ar purge through FI5. The chamber is in safe mode since SV18 is open and the purge flow keeps the O2 from increasing. Clearly, the methane percentage in the chamber is being spoiled from the time the shutdown occurred, so the longer the system is in this state, the longer it will take to recover to P10.

Atmospheric rise or fall:

The most common shutdown is due to a rapid rise in the barometric pressure. It is a characteristic of thunderstorms that roll through BNL that the barometric pressure will fall until the front arrives and then there always seems to be a rapid rise - the most violent I remember was ~ 3 mbar rise in < 5 minutes. The system is referenced to barometric pressure (PTB) and tries to stay 2 mbar above PTB. Unfortunately, in recirculation mode we are only putting a maximum of ~ 16 lpm of fresh gas in (if none is going out F1 or F1a) and this is not sufficient to maintain 2 mbar above PTB if the rise in PTB is too rapid or goes on too long. I'm assuming this is what happened when you had a storm last Sunday, 2/22. If you look at the dB for PTB and PT8 during that time you should see what I've just described. If the rise is too great and PT8 falls too much the system will alarm and shutdown BC1, open SV18, close the methane and start the Ar purge. Power to rack 2 will stay ON, however, so the small compressors and the purifier will stay on. (Note that an attempt was made last year by Leonid, Peter and I to have the PC control program sense the drop in PT8 and send a command to increase the fresh flow to 30 lpm until PT8 recovered. Unfortunately, when this was tried, there was a lag in the slaved methane flowmeter which is slaved to the Ar one and the fresh gas mixture deviated quite a bit from 10% - this also caused an alarm that shut the system down. So, at the moment. we have no automatic protection against these rises - pray for no thunderstorms!)

However, the system IS protected against a rapid drop in PTB. Normally, the TPC vents gas through F1 or F1a during recirculation mode. If PTB drops rapidly it could happen that F1 is not enough and PT8 will start to rise. In this case Leonid added a red-line gauge (I believe PI4) that will open a valve that vents more gas to the stack. This will continue until the pressure drops back below redline and the normal recirculation process takes over again. Since this was installed I have not seen a shutdown due to PTB fall.

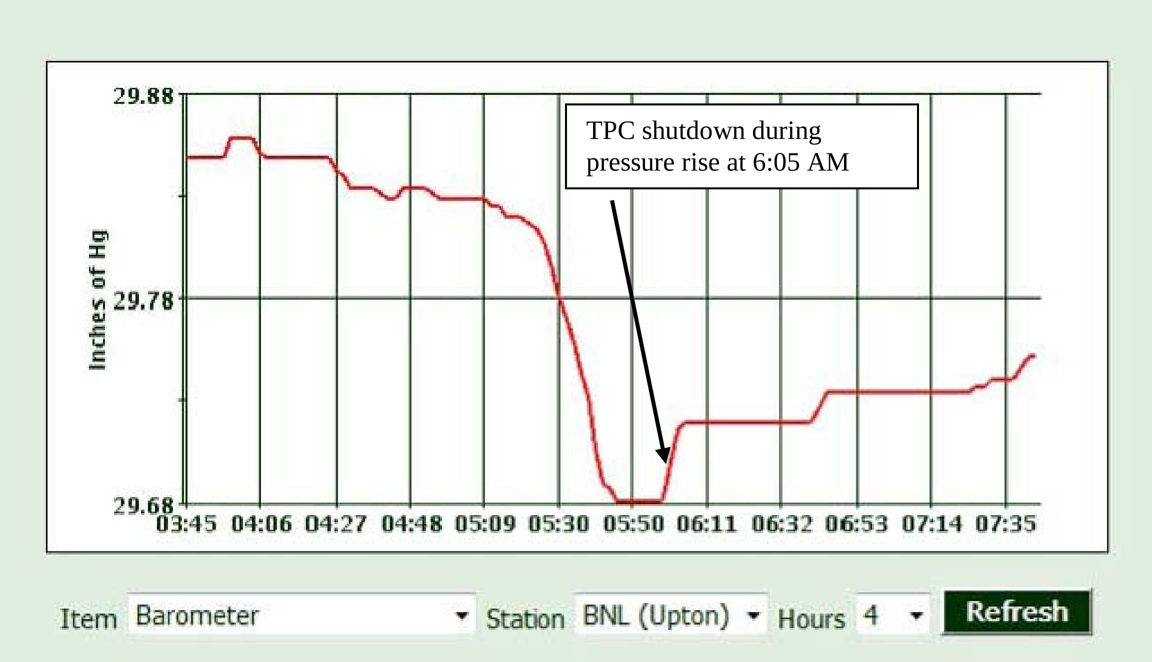
Methane excursions or O2 rise

These alarms will also cause the system to shutdown - the alarm limits are listed on the truth tables posted in the gas room. If either M4 or M3 goes too high or too low or the O2 goes above 80 ppm the system will shutdown - essentially BC1 will stop, SV18 will open, the methane is stopped (SV21) and the Ar purge is started. Everything else stays on (I believe). There are various obvious reasons for these alarms (running out of gas, methane analyzer malfunction, leak etc.) Note that when the methane bank is getting low there will be an informational alarm (no action) from PI14, at around 100 PSIG. Usually if I planned to swap banks when I came in the next morning I would warn the overnight shift that they might get an alarm - this saves getting called at 3 AM. 100 PSIG of methane should last 12 hours or more.

Pressure imbalance or oscillations in the PID controller

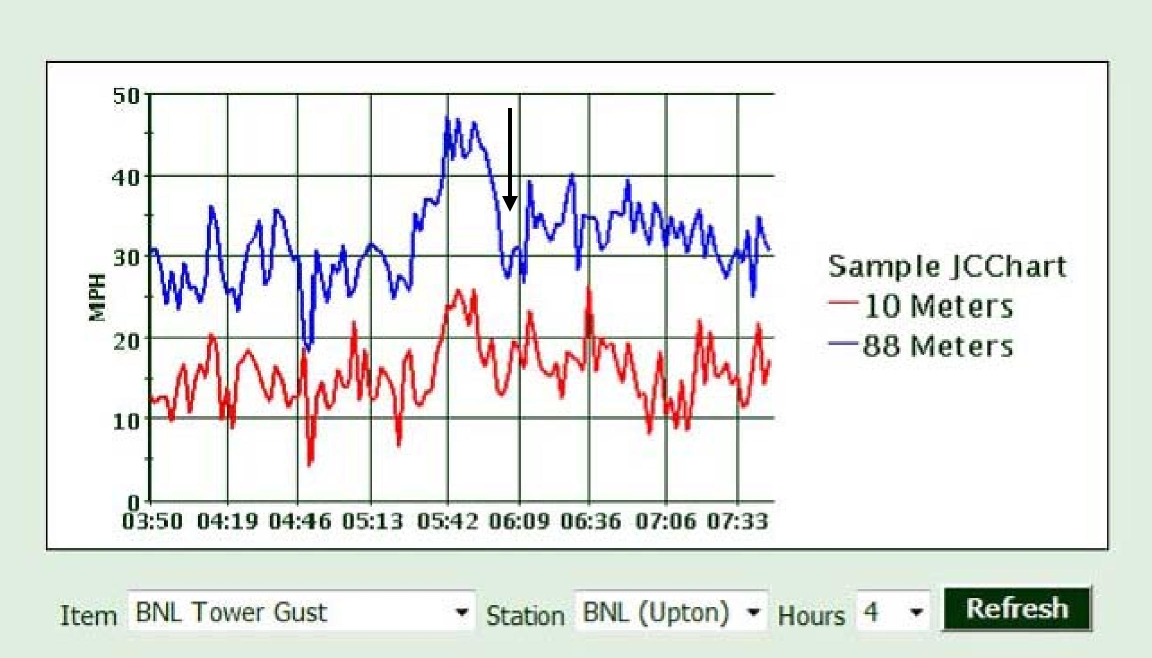
Usually, once the recirculation is started and the PID system is correctly adjusted the system will operate very stably. It even copes with high winds, although the excursions from the set point become somewhat greater. It can happen, however, that the system will go into rather violent oscillations, with rapid swings in the pressure before BC1 that is the reference for the PID controller (PT5). This happened to me last year after we had run smoothly for weeks(!?). I spent some time fiddling with the system, but never found a smoking gun as to why it has decided to become unstable. I finished out the run by further adjusting the PID parameters in order to decrease the gain and damp out oscillations - the system response became slower, so lazy excursions from the set point became the norm, but the oscillations did stop. I should point out that Leonid and I differed somewhat on the PID setup - his engineering instincts wanted a "properly" tuned system but I just wanted some peace and quiet.... You can find your own way in this parameter space.

If the oscillations are not too violent the system can usually recover itself without shutting down, but if the PT5 variations are too great it will trip the limit and shut down.



TPC shutdown during pressure rise at 6:05 AM

Item Barometer
Station BNL (Upton)
Hours 4



Item BNL Tower Gust
Station BNL (Upton)
Hours 4

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July 4th, 2009

Procedure to stop recirculation mode, start Ar purge, in preparation to shut the gas system down for the summer.

STOPPING RECIRCULATION MODE

1. Make sure all TPC high voltages are ramped to zero and turned off.
2. In the mixing room, in Rack 1, input 79 into the hardware alarm keypad and push the * button (block alarms). The bottom row of red LEDs should now be lit - all alarms are blocked. [Top row indicates alarm – bottom row indicates if blocked]
3. On the PC control GUI, click on the “Alarms Enabled” button. The button should now read “Alarms disabled”.
4. On the PC GUI click on SV13 (should turn from red to green.)
5. On the PC GUI, click on SV14 (should turn from green to red.) This switches the input gas for the meters from return gas to fresh gas. (Oxygen should drop to ~5.)
6. If SV16 is green, first click on SV17 (red to green) then click on SV16 (green to red). This switches the monitor line from recirculation to fresh gas. (The plumbing has changed. Is this still correct?)
7. Click on BC1 (big compressor) and immediately click on SV18 (red to Green). This stops the recirculation pump and opens the main vent valve. PT8 will drop.
8. Click on the “HV” button (green to red). This drops the HV interlocks at the AB panel and sets off the alarm. Silence the alarm by pushing the acknowledge button in rack 4.
9. Raise the lower redline for PI7 (Rack 2) until it trips the indicator needle - this will latch the BC1 off. Lower the redline back to the set point. Push the red button on SV18 to unlatch BC1. This will allow computer control of BC1.

At this point the system is in P10 purge mode with the normal 16 lpm refresh flow. If the plan is to purge the TPC and shutdown for the summer, proceed as follows:

STARTING ARGON PURGE

1. On the PC, kill the PID control program (scrolling display).
2. Turn off the PID power supply (inside Rack1 on the bottom right, silver toggle.)
3. Turn off the purifier using the GUI.
4. On the gas pad, close the 6 bottle valves for the methane 6-pack that is currently in use. Check the other 6 pack and close these valves if necessary. Do not close main valve, yet.
5. In the mixing room, wait for the methane line to bleed down - M3 and M4 will eventually go to zero. This will take several minutes.
6. When the methane reads zero, go to the gas pad and close the main output valve on the 6 pack, and close the corresponding input valve on the manifold.
7. Using the GUI, open SV22 and close SV21 - this puts Argon into the methane line.

8. Close the manual methane input valve (MV25, behind rack 3)
9. Close manual methane inlet valve MV8 (Rack 2)
10. Open manual Ar inlet valve MV6 - this is the inlet valve for the 500 lpm flowmeter.
11. On the PC, set FM5 to 0 and set FM3 to 100 and click on “Set flowmeters”.
12. Close inlet valve MV4 at Rack 2
13. On the Hastings mass flowmeter controller select FM3 - confirm that the setpoint is 100 and that the flow is some value other than 0.
14. Once flow starts in FM3, raise the Ar delivery regulator pressure (PCV5) on the wall of the mixing room. Maximum pressure on this regulator should make the flow reach 100 lpm.
15. Open the bubbler bypass valve (MV14a). This will purge the supply stub that goes to the bubbler. Close MV9, fully, to prevent purge from going backward.
16. We typically run this purge flow until ~ 6 volumes have been exchanged. TPC volume = 50,000 l, so 6 volumes is ~ 48 hours. Since this is for the summer shutdown, you can probably switch to a N2 purge after 24 hours.
17. CAD mandates that we maintain a gas watch as long as the methane is > 8 %. To check the return flow from the chamber during purge:
    1. Open manual valve MV9 fully (Rack 2)
    2. Lower the PI7 red line to zero.
    3. Reset the BC1 latch (red button, Rack 2)
    4. Using the GUI start big compressor 1 (BC1). Make sure SV18 is OPEN!
    5. Using the GUI, open SV14 and close SV13. This will sample the return gas - M3 will measure the return methane percentage.
    6. The system can run in this mode stably so you can watch the methane drop. Caution: the system is stable but no alarms are active – no automatic actions will be taken to protect the system.
    7. To go back to straight purge mode, open SV13, close SV14, stop BC1 and fully close MV9.
18. Once the methane percentage is < 8%, call the RHIC MCR and ask for the operations coordinator. Tell him that the chamber is purged of P10 and ask him to send the CAD watch down with the STAR bluesheet. When the watch comes, sign the bluesheet in the appropriate box (chamber purged).
19. Turn over the two flammable gas signs on the doors to the WAH, and remove the signs that are posted in the WAH. Unplug the TPC gas/water alarm box in the STAR control room.
20. Send emails to Bill Christie, Bob Soja, Al Pendzick, Peter Ingrassia and Paul Sampson stating that the chamber is purged and the gas watch is cancelled. Make an entry in the electronic log and also send mail to star-ops mailing list.
21. Turn the bubbler valve MV14a back off after 24-48 hours of purge.

Go to the procedure for the “Complete Shutdown of the TPC gas system and setup of summer N2 purge”

July 6th, 2009

Complete Shutdown of the TPC gas system and set up of summer N2 purge

Assumes gas system is in 100 lpm Argon purge mode (ie no methane in the chamber) and that you have executed the “Procedure to stop circulation and start Ar purge”.

1. Using the PC GUI, open SV11 and SV12.
2. Using the PC, set the flow for FM3 to zero (slider) and click on “set flowmeters). Confirm that flow through FM3 goes to zero.
3. On rack 2, close MV6 (manual valve for FM3)
4. Reduce the Ar regulator pressure (PCV 5 on the wall) to ~ 18 PSIG
5. Close the Ar inlet valve MV30 at the manifold on the wall. This allows N2 to flow into the Ar line.
6. Adjust the N2 pressure regulator (PCV2) and the flowmeter valve for FI-5 so that the N2 pressure increases and the flow is set to the arrow on the flowmeter - this is the standard shutdown maintenance flow for the TPC.
7. Confirm that the power for the purifier is off (TIC1 on Rack 2 should be off and the purifier control on the GUI should be red. If purifier is still on, turn it off.
8. Close SV4, SV3 and SV1 using the PC. (SV2 should already be closed). This closes off the purifier-dryer loop.
9. Using the PC, stop small compressor SC2. Turn off M4 (top of Rack 2)
10. Using the PC, stop small compressor SC1 and close SV6, SV7, SV8 and SV17.
11. Inside Rack 3, close the inlet valve first, then the outlet valve on oxygen analyzer M1 (do NOT allow the meter to be pressurized!)
12. Inside rack 3, unplug the small compressor SC3. Close the inlet valve then the outlet valve for oxygen analyzer M5.
13. Turn off M1, M5, and methane analyzer M3.
14. At rack 1, turn off the power for the three Hastings mass flow controllers. (Turn the rotary switch on the front of each meter to off.)
15. Remove the side panel of Rack 1.
16. Inside rack 1, turn off the power for the hardware alarm box, the SCXI crate and the temperature controller MUX box.
17. Unplug the water meter (M2).
18. Make sure the PID controller power supply (bottom of Rack 1) is off.
19. Put all side panels back on.
20. On the PC, kill the gas system control program and shutdown the PC. (If automatic software updates are pending, reboot once, then shutdown).
21. Turn off the breaker at the top of Racks 1, 2 and 3 (use appropriate PPE). DO NOT turn the breaker for Rack 4 off - it powers the TPC interlock system and stays on all the time.
22. At the bottom of rack 2, make sure that the breakers for BC1 and BC2 are off.
23. Turn off the “power to gas system” button on the AB interlock panel.

The next section is for the gap gas system:

1. At rack 4, open MV52 and close MV54 (selects fresh gas instead of return gas.)
2. Turn off M6 (oxygen meter) and unplug M7 (water meter).
3. Turn off the pump (toggle switch on front panel - Rack 4).
4. Confirm that there is ~ 10 lpm through FI51 - this is the summer maintenance flow for the insulation gap.
5. The N2 comes from Rack 3 - FI 10 at the bottom of that rack should also have 10 lpm flow.

Gas Pad:

Double-check the gas pad. Everything should be clean, neat, and explosive gases off.

Argon tank – Order new gas when the pressure drops to 30 inches. Full = 120 inches. This will be approximately every 2 months during the run. Every 3 months in the summer.

Methane – Order methane as needed. Use silver tanks. Red tanks are for emergencies, only. Vent the methane line whenever you install a new bottle or six pack by cracking the joint. Swith MV26 as required. Methane should last 2 weeks under normal conditions.

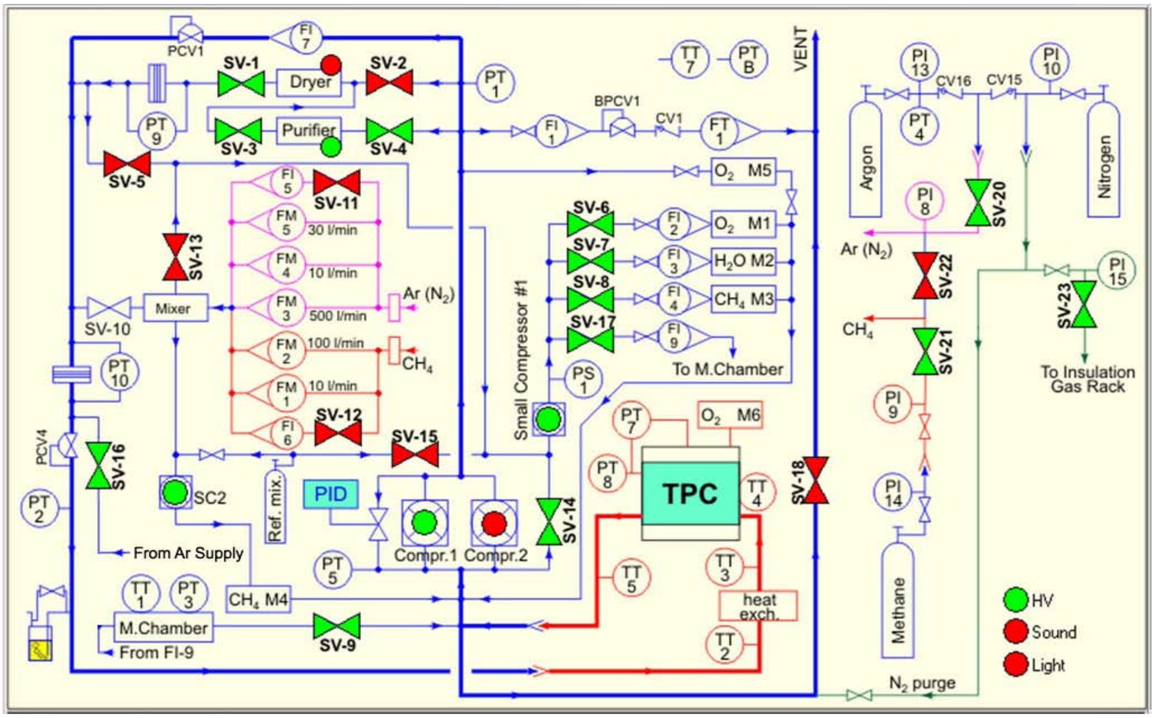


Figure 1: Gas System Schematic Diagram: Normal Circulation Mode Shown

Methane analyzer calibration AL 02.18.2009, Rev 03.02.09

The gas system has 2 methane analyzers to measure the methane concentration in the TPC gas. They are labeled M4 (for fresh gas) and M3a (return gas from the TPC). Their performance strongly depends on the pressure and ambient temperature. (An Excel spread sheet is available on the STAR TPC web page to help calibrate the meters and produce graphs for daily use.) The calibration constants for M3a and M4 should be determined before each run and anytime you suspect the calibration has been lost (not more than once/month). Choose a day with stable barometric pressure, the preferred number is 1010 mbar on PTB, which is in the middle of the TPC operating range. For other pressures there is a formula from Leonid Kotchenda:

CH4(true) = CH4(reading) + 0.012% * (Pc-P) + MeterOffset

where CH4(reading) is the current reading from the analyzer, P is the barometric pressure at the current time and Pc is the barometric pressure at the time of calibration.

Calibration is best performed with high Ar flow and for each analyzer separately. The procedure begins with Zeroing each meter. For M3a open SV13, close sv5, sv15, sv14. For M4 open mv17, close mv17a. When Ar flow is established, go to the analyzer, check the flow meters feeding the analyzers, for M4 it is FI2a(rack 2), for M3 it is FI4(rack 3). When the readings have stabilized (about 20 minutes), press ZERO, then CAL buttons. Zeroing will proceed.

To calibrate methane content we have 2 bottles with certified methane-argon ratio - P10 and P20, but exact numbers are 10.2% and 19.9% of methane in Ar. Both bottles are sitting on the gas pad outside the gas room. P10- 40 liters P20- 20 liters, both connected to a 3 way valve. Open the valves on the bottles, then manual valves MV43a, MV43b, the pressure reducers are already adjusted for ~12 PSI: see gauge on ¼" line coming to gas room.

Open the 3-way valve for P20 first, confirm ~12 PSI. Go to the gas room. On rack #1 go to the right hand Hastings meter, choose channel 4 (labeled REF P10) and request flow ~ 3.0 l/min. To calibrate M3a open sv15, close sv5, sv13, sv14, mv17a. Check flow on FI4. During calibration O2 (M1) could be high due to oxygen buildup through long ¼" line. Wait 20 minutes for the readings to stabilize. The readings for O2 should go to ~ 3-5ppm. When the readings are stable, Press SPAN, than CAL buttons. ATTENTION!! Only P20 calibration gas should be used for SPAN calibration, not the P10 gas!! Write numbers in logbook. Sometimes actual readings don't coincide with a number from reference bottle and this offset needs to be accounted in Leonid's formula. Open SV14, close SV15.

To calibrate M4, reduce the flow on the Hastings Meter down to ~ 1.0 l/min. Open mv17a, close mv17 on the back of rack2. Check flow on FI2. Proceed with a span calibration as was done for M3: see previous paragraph. When the calibration is finished, about 20 minutes, check and proceed if it is not already done: open SV14, close sv15, open mv17, close mv17a. These operations will restore flow for fresh gas to M4 and return-gas from the TPC to M3a.

Repeat proceeding operations, described earlier, with a fresh Ar to remove P20 from lines and verify ZERO for both M3 and M4.

Open 3-way valve to P10 bottle. Repeat calibration procedure for M3 and M4. Do not Zero or Span the meters with the P10 gas. At this point you are just checking the readings on M3 and M4 and comparing it with the canonical value of 10.2% for the bottle. Put a note in logbook.

Always, if possible, follows a chain: pure Ar-ZEROING ⇒ P20-SPAN ⇒ pure Ar-check ZERO ⇒ P10 check reference gas. Each step takes about 20 minutes to get an accurate reading.

If re-calibration needs to be done during the run (with TPC gas circulating), all alarms should be blocked. On alarm box press 79 on keyboard and press * button- it will block hardware alarm. At this point the lower row of LEDs will be red. Go to the gas system PC and press “Alarms disabled” button. This action will prevent all gas alarms (so don’t forget to re-enable them, later.)

After a calibration in circulation mode ⇒ remove the lock from alarm box ⇒ press 79 and # , on gas system PC enable alarms, press appropriate button “Alarms disabled” and label on button will change to “ Alarms enabled” with a recording in the log. It should say “ALARMS enabled”.

On gas pad close valves on P10 and P20 bottles. Also close the valves installed after pressure reducers. Put 3-ways valve in P10 position.

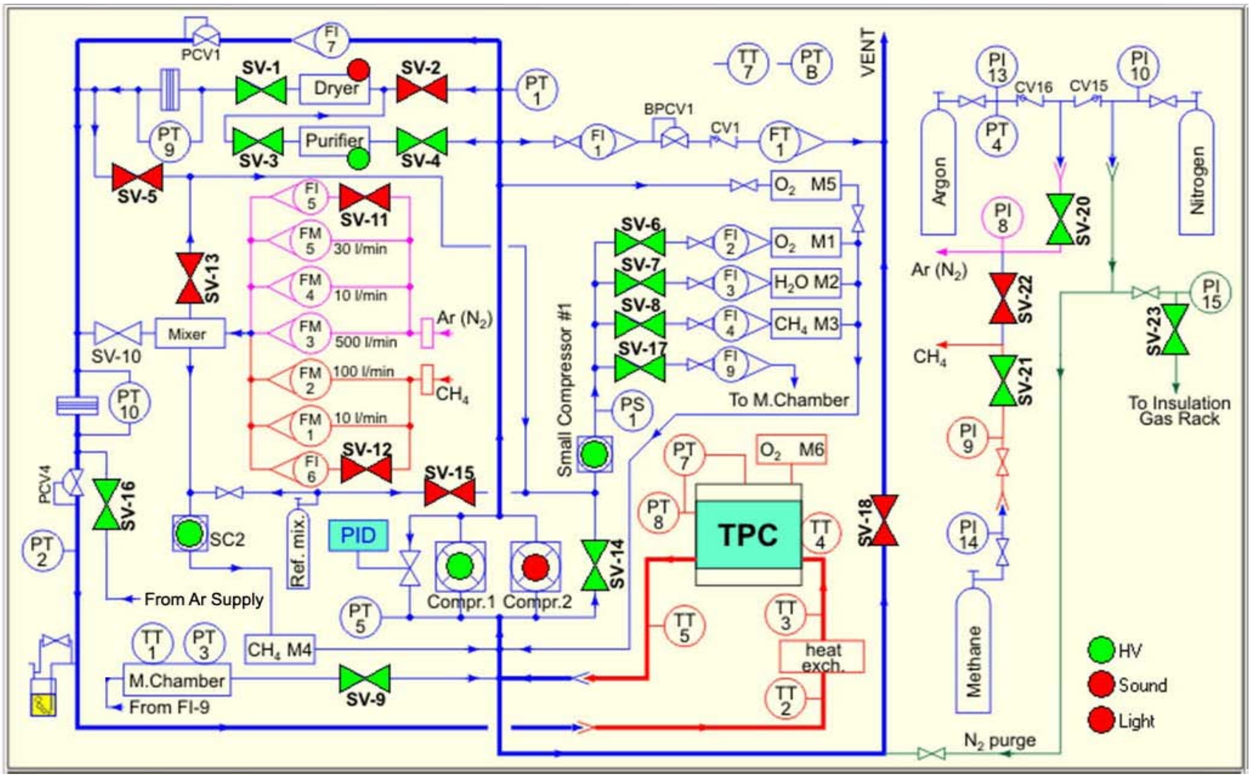


Figure 1: Gas System Schematic Diagram: Normal Circulation Mode Shown

TPC Seal and Purge Manual (Preliminary - this procedure may be incomplete) 11/19/07

Before starting the TPC circulation it is necessary to check whether it is sealed or not. This can be done by Argon or by Nitrogen. In summer TPC is kept on Nitrogen. Therefore before run starts TPC is usually on Nitrogen flow.

1. On Rack 2 open manually FM5 - (MV4 valve) (all others : FM3 (MV6), FM4 (MV5) are closed)

2. Install on FM5 - 16 l/min flow (Computer: Slide FM5 to 16 l/m and click on Set Flow Meters)

3. Close SV 11 by clicking it on Computer (Green turns to Red). This Stops a purge flow through the FI5. Clear Interlock for SV18 on Rack 2 by pushing the button (SV 18 Reset button on Rack 2, right)

4. Confirm that MV10 (Rack1 lower left) is closed and confirm that MV14a (bubbler bypass, rear end of the gas mixing room) is closed.

5. To check seal, close SV 18 by clicking on the computer (Green turns into the Red). Listen for a sound - "Bang”!

6. The pressure on Rack 1, shown by "Inside TPC Pressure (PT8) PI6" on Rack 1 starts to rise up. It should reach value 1300. This will take ~ 5 minutes.

7. After PI6 is close to 1300, open SV18 by clicking on the computer SV l8 button (Red turns to Green) and PI6 drops rapidly

8. One can start PID program to follow pressure change. Before starting the PID program, the switch at the power supply, located at the right bottom of Rack I should be switched on.

9. Start a PID program. Click on a start button. Two evolving lines will appear. The upper line is a set point value (Red) taken by a computer from DB. Lower line is yellow, which starts to rise, showing rising pressure in PT8. Watch lines, until the lower line reaches the top line. Just before reaching, click on SV18 button on the computer screen (Red turns to Green as in p. 7.)

10. During p.9, when lower line goes up, it might be some delay in rise, which is a result of outer pressure variation (wind, pressure change outside and etc.)

<u>To get gas system into a purging mode after the seal check</u>

I. Put the FM5 flow to 0 by computer

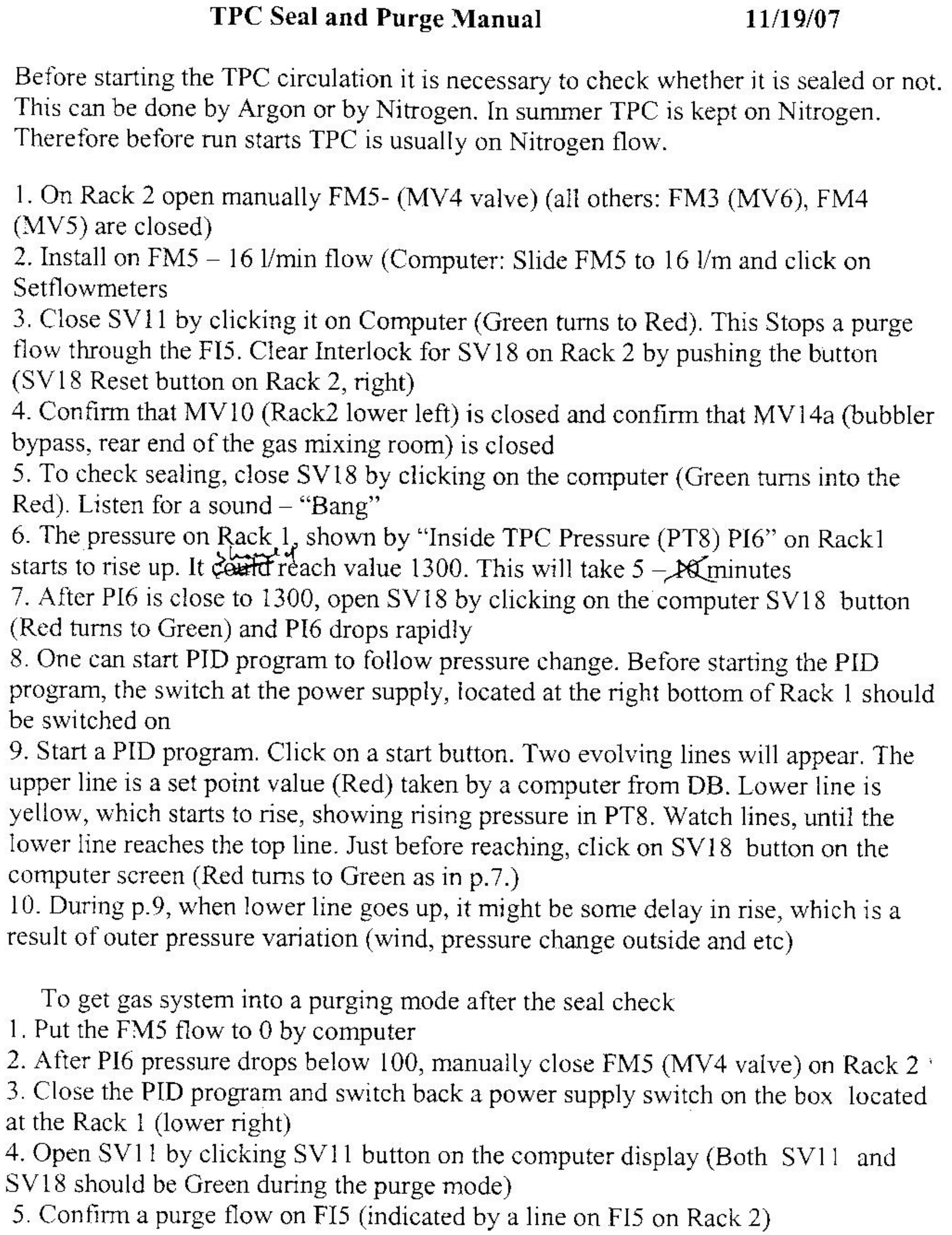
2. After PI6 pressure drops below 100, manually close FM5 (MV4 valve) on Rack 2.

3. Close the PID program and switch back a power supply switch on the box located at the Rack 1 (lower right)

4. Open SV11 by clicking SV11 button on the computer display (Both SV11 and SV18 should be Green during the purge mode)

5. Can firm a purge flow on FI5 (indicated by a line on FI5 on Rack 2)

Here is the original document as a .jpg file.



TPC Seal and Purge Manual 11/19/07

Before starting the TPC circulation it is necessary to check whether it is sealed or not. This can be done by Argon or by Nitrogen. In summer TPC is kept on Nitrogen. Therefore before run starts TPC is usually on Nitrogen flow.

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2. Install on FM5 – 16 l/min flow (Computer: Slide FM5 to 16 l/m and click on Setflowmeters
3. Close SV11 by clicking it on Computer (Green turns to Red). This Stops a purge flow through the FI5. Clear Interlock for SV18 on Rack 2 by pushing the button (SV18 Reset button on Rack 2, right)
4. Confirm that MV10 (Rack2 lower left) is closed and confirm that MV14a (bubbler bypass, rear end of the gas mixing room) is closed
5. To check sealing, close SV18 by clicking on the computer (Green turns into the Red). Listen for a sound – "Bang"
6. The pressure on Rack 1, shown by "Inside TPC Pressure (PT8) PI6" on Rack1 starts to rise up. It ~~could~~ should reach value 1300. This will take 5 – ~~10~~ minutes
7. After PI6 is close to 1300, open SV18 by clicking on the computer SV18 button (Red turns to Green) and PI6 drops rapidly
8. One can start PID program to follow pressure change. Before starting the PID program, the switch at the power supply, located at the right bottom of Rack 1 should be switched on
9. Start a PID program. Click on a start button. Two evolving lines will appear. The upper line is a set point value (Red) taken by a computer from DB. Lower line is yellow, which starts to rise, showing rising pressure in PT8. Watch lines, until the lower line reaches the top line. Just before reaching, click on SV18 button on the computer screen (Red turns to Green as in p.7.)
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To get gas system into a purging mode after the seal check

1. Put the FM5 flow to 0 by computer
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4. Open SV11 by clicking SV11 button on the computer display (Both SV11 and SV18 should be Green during the purge mode)
5. Confirm a purge flow on FI5 (indicated by a line on FI5 on Rack 2)

Procedure to Regenerate the STAR TPC Gas System Purifier

Leonid Kotchenda and Blair Stringfellow

10/07/2009

PURPOSE: To remove impurities and increase the efficiency of the STAR TPC gas purifier located in Rack 2 in the STAR gas mixing room.

BACKGROUND: To control the level of O2 and H2O contamination in the TPC ~ 10% of the gas in circulation is sent through a purifier/dryer path. (Flow through the purifier = 50 lpm.) The combination of 17 lpm of fresh gas that is introduced into the recirculation stream, and the purifier/dryer serves to hold the TPC O2 contamination to ~ 30 ppm. The current purifier has been in use since 1998 and we are starting to get evidence that its efficiency is deteriorating. We would therefore like to attempt to regenerate this purifier rather than replace it.

The purifier is installed in the TPC gas system in Rack 2. During normal operation the purifier is heated to 220 deg C using a heating coil and insulating blanket. The temperature is held constant by a TIC (temperature indicating controller.) For the regeneration procedure we will also heat the purifier to 220 deg C using the same system.

The regeneration will occur by passing a continuous flow of 95% Argon - 5% H2 gas through the heated purifier. Two chemical reactions will serve to regenerate the catalyst:

$$NiO + H_2 = Ni + H_2O$$

$$Cr_2O_3 + 3H_2 = 2\,Cr + 3\,H_2O$$

Thus, the byproduct is water. The flow rate of the Ar-H2 mixture will be 180-200 ccm and the regeneration time is estimated to be 48 hours.

The Ar-H2 mixture will be purchased pre-mixed from Spectra-Gas and the gas from the exhaust of the purifier will be either vented out the normal TPC gas stack or through an auxilliary vent line to the outdoors. The purifier already has a pressure relief valve installed to prevent accidental overpressure.

Note that this procedure is similar to the one that is used to regenerate the dryer which is done before each run. In that case the gas used is Ar only.

PROCEDURE:

1. Set MV3A to (Ar/5%H2 to Purifier) direction in Mixing Room
2. Set MV3B to (Ar/5%H2 to Purifier) direction on STAR Gas Pad

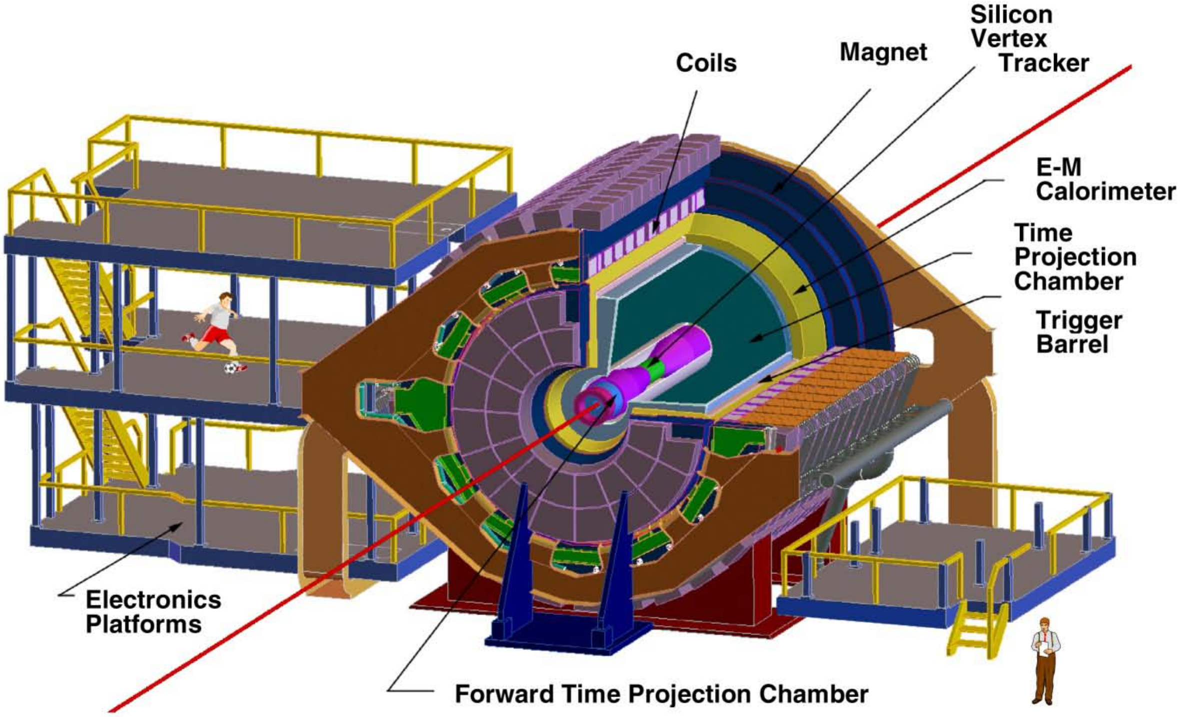
3. Open the gas cylinder
4. Set the regulator PCV50 to ~5 PSIG PI52 delivery pressure.
5. Turn on the purifier heater using the toggle switch in Rack 2.
6. Confirm that the Temperature Indicator Controller (TIC) has a set point of 220 degrees C. If not, adjust the set point using the push buttons on the front of the TIC (located in Rack 2).
7. Open MV2B inside Gas Rack 2.
8. Open MV2A inside Gas Rack 2.
9. Open MV3 inside Gas Rack 2.
10. Wait for the purifier to heat to the setpoint (usually 2-3 hours).
11. Adjust FI8A flow to 180-200 ccm
12. When regeneration is complete (estimate 48 hours) turn off the purifier heater using the toggle switch.
13. Reduce FI8A flow to 50ccm
14. Wait when the purifier will be cooled (estimate 24 hours)
15. Set MV3B to (P10 to SV16) direction on STAR Gas Pad.
16. Close the gas cylinder
17. Set MV3A to (P10 to SV16) direction in Mixing Room
18. Close FI8A manual valve.
19. Close MV3 inside Gas Rack 2.
20. Close MV2A inside Gas Rack 2.
21. Close MV2B . inside Gas Rack 2

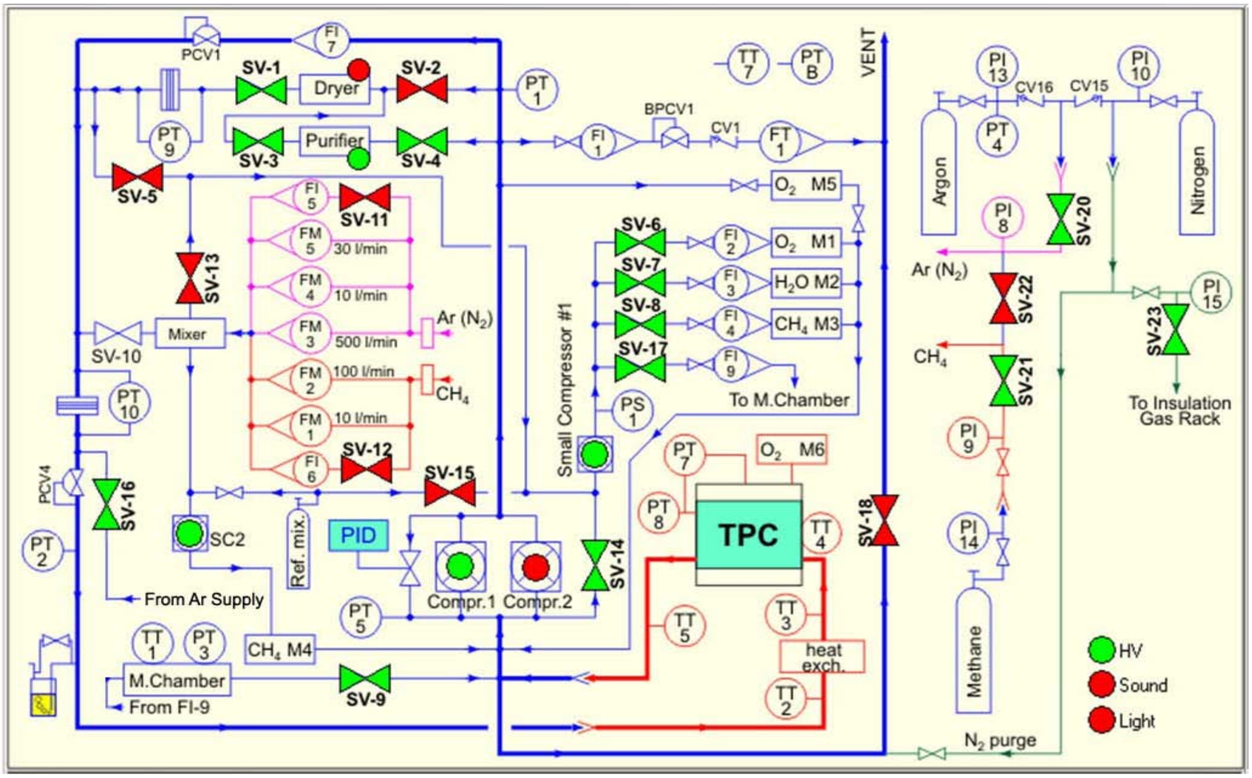
EXPERTS:

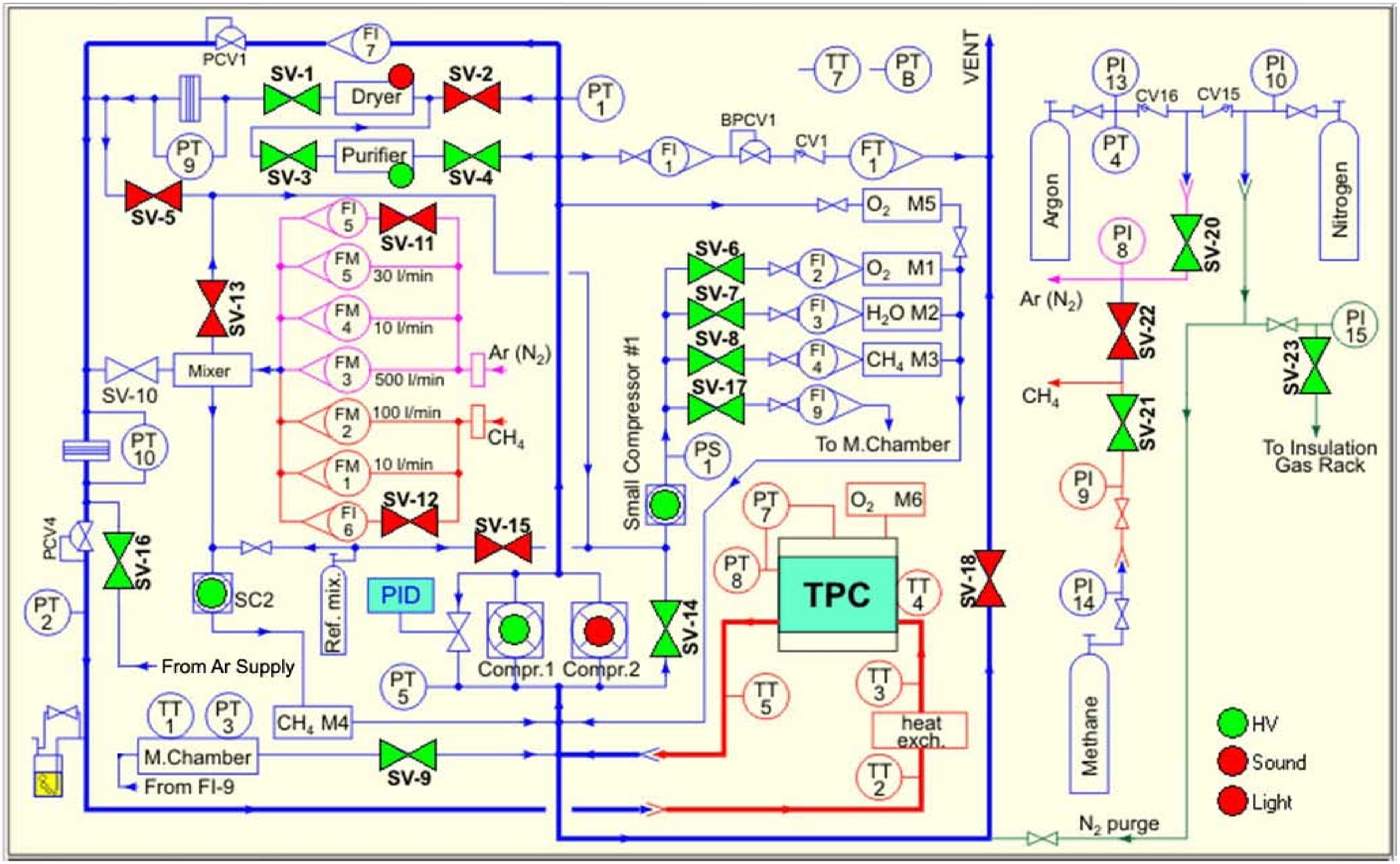
Leonid Kotchenda
STAR TPC gas system engineer
X5379

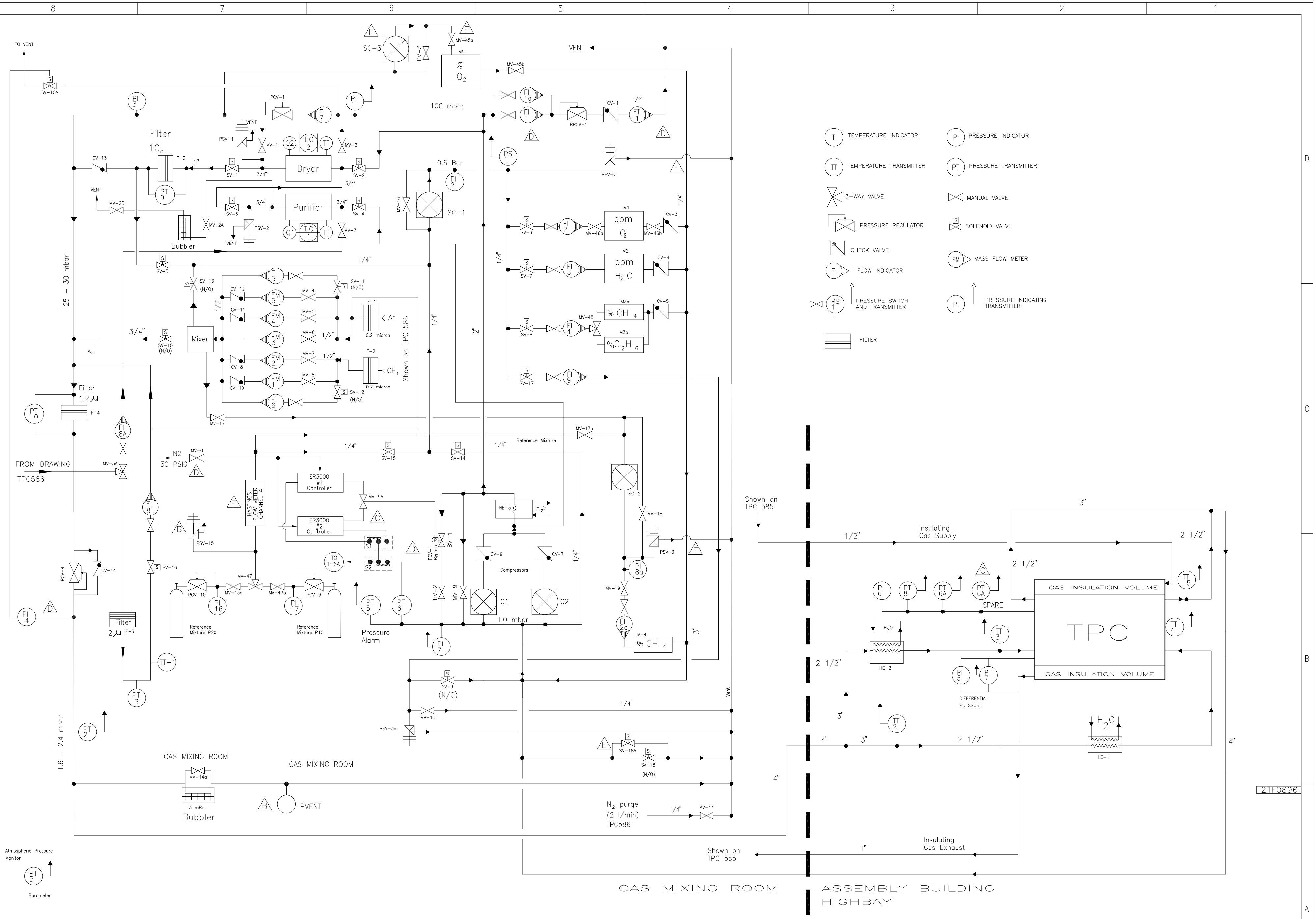
Diagrams

The STAR TPC – Simplified Schematic of the Gas System






PCV1
FI 7
SV-1
Dryer
SV-2
PT 1
TT 7
PT B
VENT
PI 13
CV16
CV15
PI 10
PT 9
SV-3
Purifier
SV-4
FI 1
BPCV1
CV1
FT 1
PT 4
Argon
Nitrogen
SV-5
O2 M5
FI 5
SV-11
FM 5 30 l/min
SV-6
FI 2
O2 M1
PI 8
SV-20
Ar (N2)
SV-13
FM 4 10 l/min
SV-7
FI 3
H2O M2
SV-22
PI 15
Mixer
SV-10
FM 3 500 l/min
Ar (N2)
SV-8
FI 4
CH4 M3
SV-23
CH4
SV-17
FI 9
To M.Chamber
SV-21
PT 10
FM 2 100 l/min
CH4
Small Compressor #1
PS 1
To Insulation Gas Rack
FM 1 10 l/min
PI 9
PCV4
SV-16
FI 6
SV-12
SV-15
PT 7
O2 M6
PT 8
TPC
TT 4
SV-18
PT 2
SC2
Ref. mix.
PID
SV-14
PI 14
From Ar Supply
Compr.1
Compr.2
PT 5
TT 3
TT 5
Methane
TT 1
PT 3
CH4 M4
heat exch.
HV
Sound
Light
M.Chamber
SV-9
TT 2
From FI-9
N2 purge



TPC P10 GAS SYSTEM
TPC584-E-1 REV. H

REV.	DWN.	CHK.	ZONE	DATE	CHANGES
H	JAS	LEONID		10-6-09	REVISIONS PER ECN #TPC584H
G	JAS	LEONID		3/14/08	REVISIONS PER ECN #TPC019
F	JAS	LEONID		11/14/07	REVISIONS PER ECN #TPC018
E	JAS	LEONID		11/14/03	REVISIONS PER ECN #TPC017
D	JAS	LEONID		5/2/02	REVISIONS PER ECN #TPC016
C	JAS	BS		10/18/00	REVISIONS PER ECN #TPC014
B	JAS	BS		4/13/99	REVISIONS PER ECN #TPC584E1B
A	RW	RW		4/7/98	RELEASED FOR FABRICATION

SHOP ORDERS
ACCT. NO.:
SER. NO.:
DATE ISS'D:
DATE REQ'D:
NO. REQ'D:
SURFACE TREATMENT: DEGREASE
IDENTIFICATION METHOD: TAG

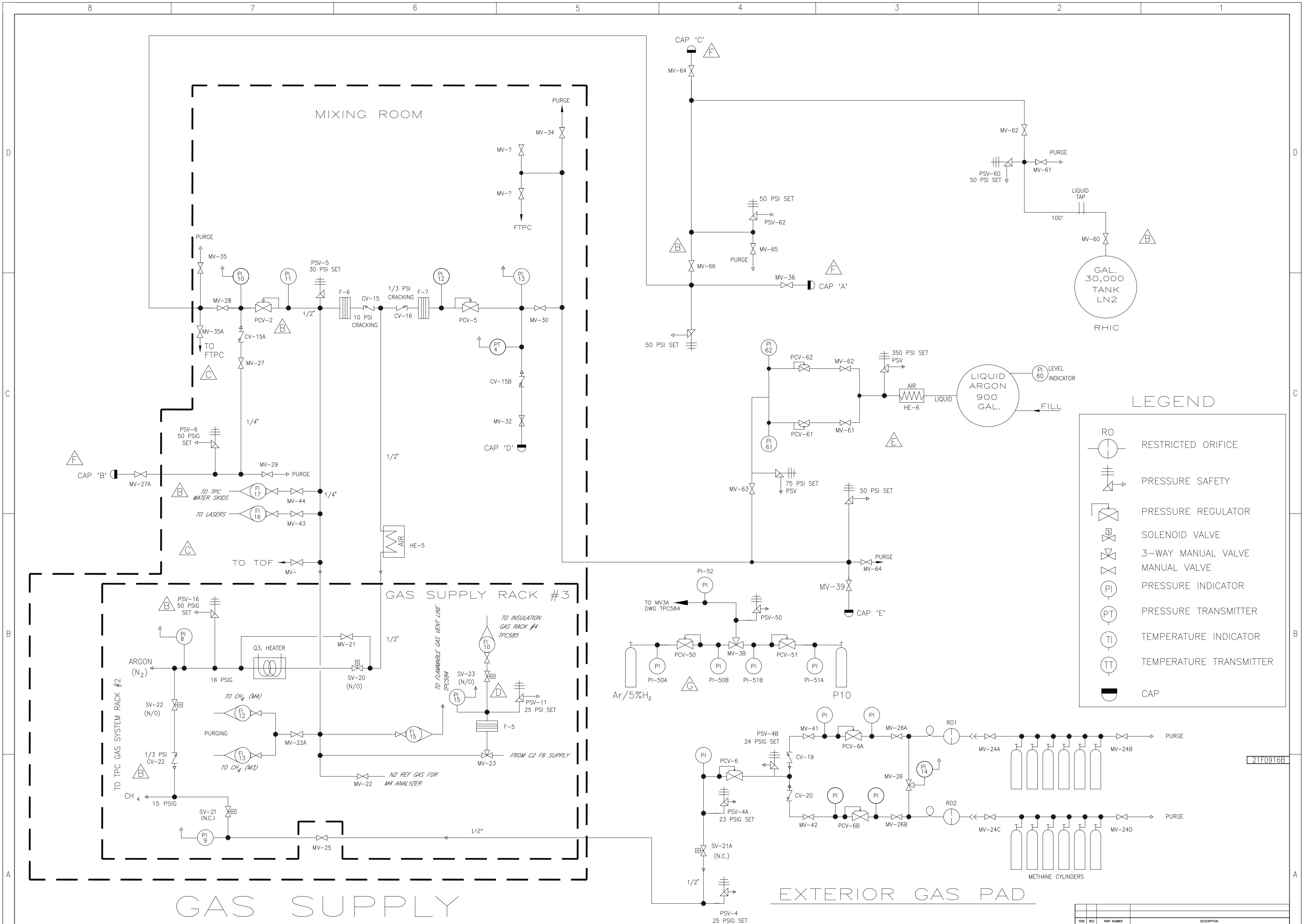
APPROVALS
DRWN BY: R. WELLS DATE 4/7/98
CHECK BY: R. WELLS DATE 4/7/98
PRODUCTION APPROVAL: DATE
COGNIZANT ENGINEER: R.WELLS DATE 4/7/98

ITEM | REQ | PART NUMBER | DESCRIPTION

STAR
WBS # 4.2.7
DWG SIZE E
STAR DRAWING NUMBER TPC584-E-1
REV. H
RHIC DRAWING NUMBER
REV. -

UNLESS OTHERWISE SPECIFIED
ALL DIMENSIONS ARE IN INCHES.
TOLERANCES
.X" = ±
.XX" = ± .01"
.XXX" = ± .005"
ANGLES ±.5°
FINISH 125
SAWED, FLAMECUT, SHEARED OR STOCK FINISH
ALL SCREW THREADS PER ANSI Y14.6
BREAK EDGES .020/.05 MAX ON MACHINE WORK.
REMOVE BURRS, LOOSE SCALE AND WELD SPATTER
REFERENCE – ANSI Y14.5 & B46.1.

LAWRENCE BERKELEY LABORATORY
UNIVERSITY OF CALIFORNIA – BERKELEY
RHIC – STAR – TPC
GAS SYSTEM
P10 GAS SYSTEM SCHEMATIC
PATENT CLEAR
DRAWING TYPE DETAIL
SHOWN ON
SCALE: NONE
DO NOT SCALE PRINTS
MICROFILMED
DESIGN ACCOUNT 8052-27
CATEGORY CODE SR-02-07
LBL DRAWING NUMBER: 21F0896
REV. H



TPC586 REV. G

REV.	DWN.	CHK.	ZONE	DATE	CHANGES
G	JAS	LEONID		10/6/09	REVISIONS PER ECN #TPC586G
F	JAS	BEAVIS		2/19/09	REVISIONS PER ECN #TPC586F
E	JAS	BLAIR		10/11/02	REVISIONS PER ECN #TPC016
D	JAS	LEONID		4/2/02	REVISIONS PER ECN #TPC586D
C	JAS	BS		10/18/00	REVISIONS PER ECN #TPC015
B	JAS	BS		4/13/99	REVISIONS PER ECN #TPC586E1B
A	RW	RW		4/8/98	RELEASED FOR FABRICATION

SHOP ORDERS
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DATE ISS'D: DATE REQ'D: NO. REQ'D:
SURFACE TREATMENT: DEGREASE
IDENTIFICATION METHOD: TAG

APPROVALS
DRWN BY: R. WELLS DATE 4/8/98
CHECK BY: R. WELLS DATE 4/8/98
PRODUCTION APPROVAL: DATE
COGNIZANT ENGINEER: R.WELLS DATE 4/8/98

ITEM REQ PART NUMBER DESCRIPTION

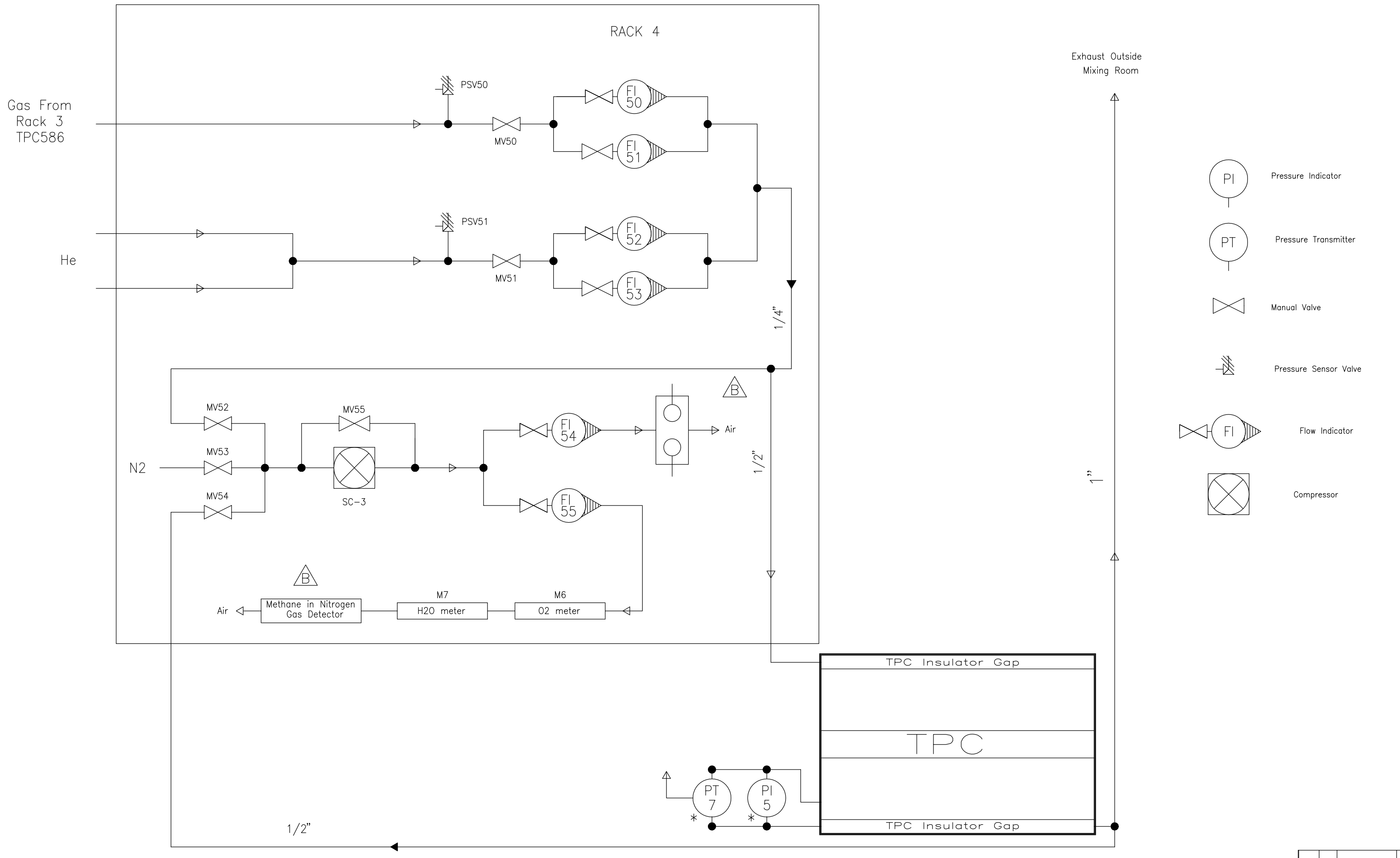
STAR
WBS # 4.2.7
DWG SIZE E
STAR DRAWING NUMBER TPC586-E-1
REV. G
RHIC DRAWING NUMBER REV.

UNLESS OTHERWISE SPECIFIED
ALL DIMENSIONS ARE IN INCHES.
TOLERANCES .X" = ±.1 ANGLES ±.5°
.XX" = ± .01" FINISH
.XXX" = ± .005" 125
SAWED, FLAMECUT, SHEARED OR STOCK FINISH
ALL SCREW THREADS PER ANSI Y14.6
BREAK EDGES .020/.05 MAX ON MACHINE WORK.
REMOVE BURRS, LOOSE SCALE AND WELD SPATTER
REFERENCE – ANSI Y14.5 & B46.1.

LAWRENCE BERKELEY LABORATORY
UNIVERSITY OF CALIFORNIA – BERKELEY
RHIC – STAR – TPC
GAS SYSTEM
GAS SUPPLY SCHEMATIC

PATENT CLEAR
DRAWING TYPE DETAIL
SHOWN ON
SCALE:
DO NOT SCALE PRINTS
MICROFILMED
DESIGN ACCOUNT 8052-27
CATEGORY CODE SR-02-07
LBL DRAWING NUMBER: 21F0916
REV. G

INSULATOR GAS CONTROL SYSTEM SCHEMATIC



21F0904B

TPC585 REV. B
4/13/99

NOTES:

* ALSO SHOWN ON TPC584

REV.	DWN.	CHK.	ZONE	DATE	CHANGES
B	JAS	BS		4/13/99	REVISION PER ECN #TPC585D1B
A	GK	RW		11/20/95	RELEASED FOR FABRICATION

SHOP ORDERS
ACCT. NO.:
SER. NO.:
DATE ISS'D:
DATE REQ'D:
NO. REQ'D:
SURFACE TREATMENT: DEGREASE
IDENTIFICATION METHOD: TAG

APPROVALS

DRWN BY:	J. ORTIZ	DATE	4/8/98
CHECK BY:		DATE	
PRODUCTION APPROVAL:	R. WELLS	DATE	4/8/98
COGNIZANT ENGINEER:	R. WELLS	DATE	4/8/98

ITEM	REQ	PART NUMBER	DESCRIPTION

STAR

WBS # 4.2.7
DWG SIZE D

UNLESS OTHERWISE SPECIFIED
ALL DIMENSIONS ARE
TOLERANCES
.X" = ±.060"
.XX" = ± 0.015"
.XXX" = ± .004"
ANGLES ±.5°
FINISH 125
SAWED, FLAMECUT, SHEARED OR STOCK FINISH
ALL SCREW THREADS PER ANSI Y14.6
BREAK EDGES .020/.05 MAX ON MACHINE WORK.
REMOVE BURRS, LOOSE SCALE AND WELD SPATTER
REFERENCE – ANSI Y14.5 & B46.1.

STAR DRAWING NUMBER TPC585–D–1
REV. B
RHIC DRAWING NUMBER
REV.

LAWRENCE BERKELEY LABORATORY
UNIVERSITY OF CALIFORNIA – BERKELEY
RHIC – STAR – TPC
GAS SYSTEM
INSULATOR GAS CONTROL SYSTEM SCHEMATIC

PATENT CLEAR
DRAWING TYPE DETAIL
SHOWN ON
SCALE: FULL
DO NOT SCALE PRINTS
MICROFILMED
DESIGN ACCOUNT 8052–27
CATEGORY CODE SR–02–07
LBL DRAWING NUMBER: 21F0904
REV. B

LBL DRAWING NUMBER	REV.	STAR DRAWING NUMBER	REV.	SHEET #	RHIC DRAWING NUMBER	REV.	ALL DIMENSIONS ARE INCHES / CENTIMETERS
24A1401	G	SIM140-A-1	G	1of1	XXXXXXXXXX	-	

DRWN BY	DATE	COGNIZANT ENG	DATE	PRODUCTION APP	DATE	CAT.CODE/WBS
Doug Fritz	8/26/93	JER	8/26/93		x/xx/xx	SR1301

REV.	DWN.	CHK.	DATE	CHANGES
D	SMH	DCF	8-27-95	UPDATED VPD GEOMETRY AND ADDED VPD LOCATION ENVELOPE, ECN TRG003
E	RES	DCF	10-13-95	INCREASED THE EMC B.L. ELECTRONICS AREA (OUTER RADIUS TO 166.395" WAS 159.307"), ECN EMC002
F	DCF	DCF	5-13-96	INCREASED CTB/TOF ENVELOPE IN "Z" (NOW 246 CM, WAS 240 CM) ECN TRG002
G	DCF	DCF	8-08-96	ADDED FTPC ENVELOPE, MODIFIED SVT GEOMETRY AND VPD MOVEMENT ENVELOPE, ECN SIM013

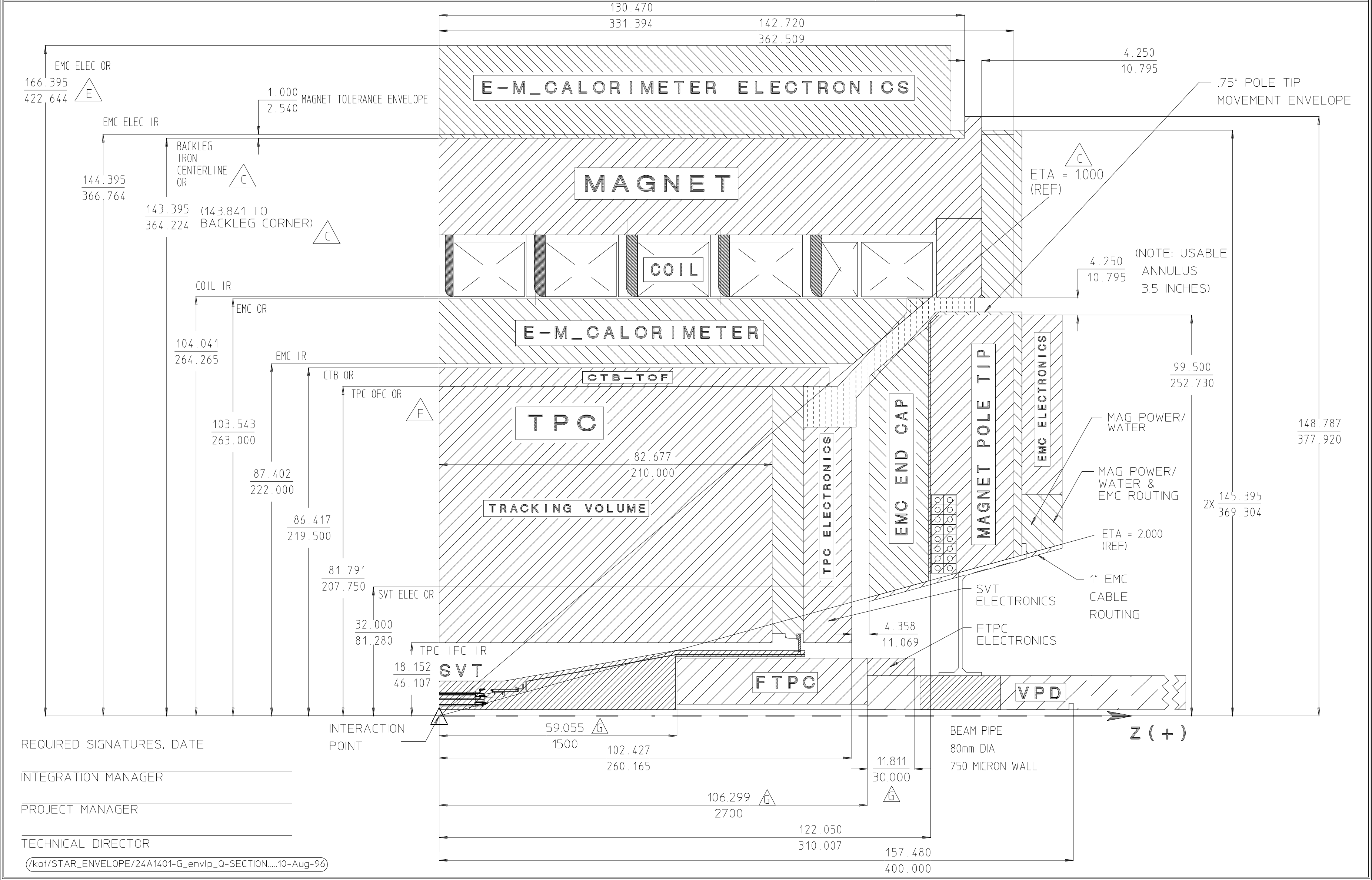
LAWRENCE BERKELEY LABORATORY

UNIVERSITY OF CALIFORNIA - BERKELEY

RHIC/STAR DETECTOR - S.I.

MECHANICAL COMPONENTS

QUARTER SECTION INTERFACE ENVELOPE



REQUIRED SIGNATURES, DATE

INTEGRATION MANAGER

PROJECT MANAGER

TECHNICAL DIRECTOR

(/kot/STAR_ENVELOPE/24A1401-G_envlp_Q-SECTION....10-Aug-96)

24A0221B

MICROFILMED	PATENT CLR		DES ACCT NO 8052-24	CATEGORY SR-04-02	SCALE: NONE

DWN BY J. BOEHM DATE 93-01-27 CHK BY J. BERCOVITZ DATE 93-01-27

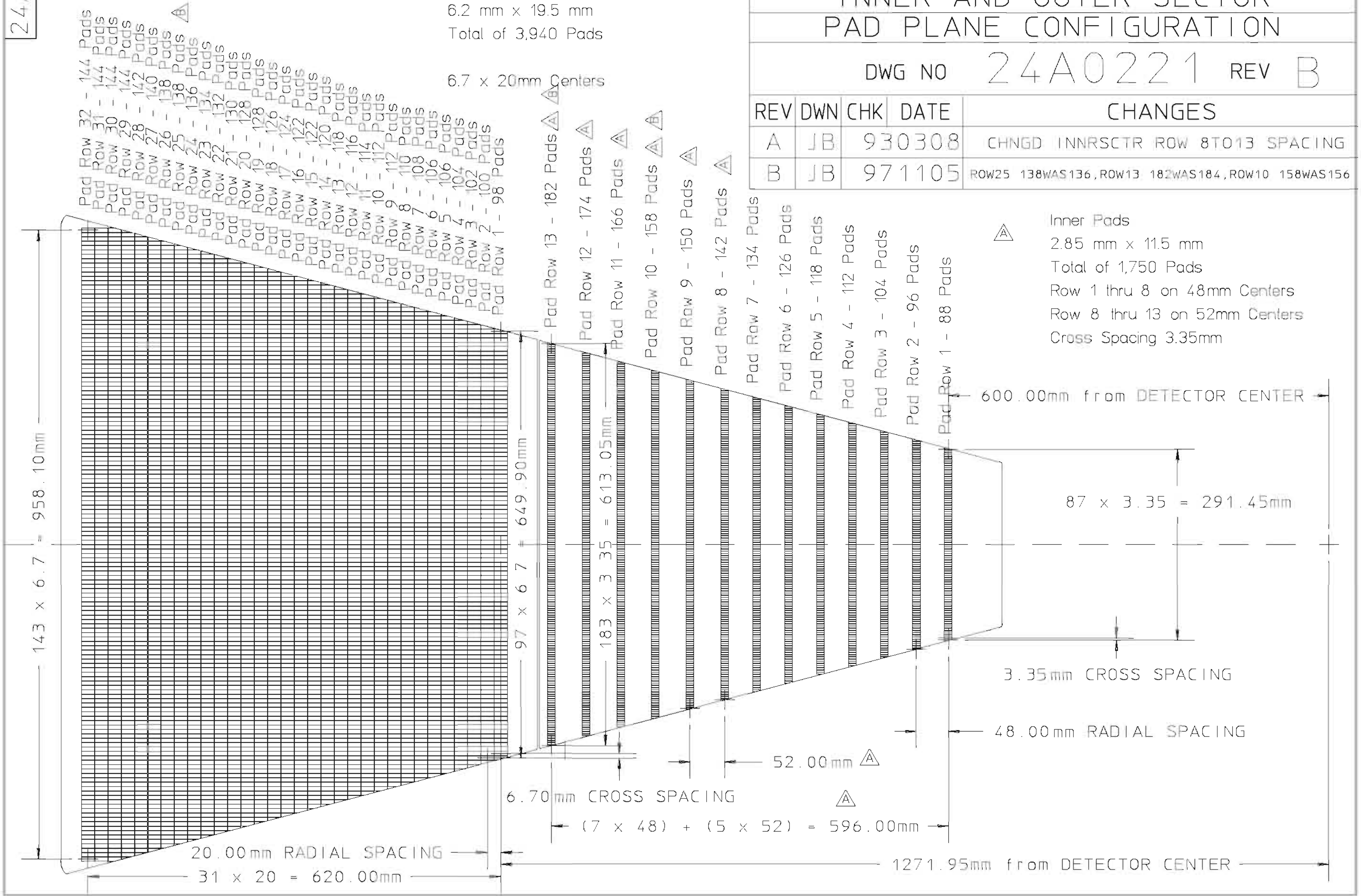
UNIVERSITY of CALIFORNIA-BERKELEY

LAWRENCE BERKELEY LABORATORY

RHIC-STAR-TPC
INNER AND OUTER SECTOR PAD PLANE CONFIGURATION

DWG NO 24A0221 REV B

REV	DWN	CHK	DATE	CHANGES
A	JB		930308	CHNGD INNRSCTR ROW 8TO13 SPACING
B	JB		971105	ROW25 138WAS136,ROW13 182WAS184,ROW10 158WAS156



Outer Pads
6.2 mm x 19.5 mm
Total of 3,940 Pads

6.7 x 20mm Centers

A
Inner Pads
2.85 mm x 11.5 mm
Total of 1,750 Pads
Row 1 thru 8 on 48mm Centers
Row 8 thru 13 on 52mm Centers
Cross Spacing 3.35mm

Lawrence Berkeley Laboratory - University of California **Engineering Note**	Code SR0210	Serial M7724	STAR Doc # SN 0373	Page 1 of 1
Author Russell Wells	Department Mechanical Engineering	Date 10/16/98	STAR WBS # 4.2.10	

Program

Solenoidal Tracker at RHIC

Sub program

Time Projection Chamber - Assembly and Test

Title

Weight of TPC and TPC Supported Hardware

Introduction:

The following table contains the weight of the Time Projection Chamber's (TPC) components, TPC supported hardware and detector subsystems. The weight categories correspond to various phases of the TPC's construction and installation. Max LBNL was the weight during transcontinental shipping, Max BNL Lift is the weight at the time of installation into the STAR Magnet, Installed Wt. W/CTB is the weight with all 120 CTB modules mounted, Installed Wt. W/TOF assumes all Central Trigger Barrel modules have been replaced with Time of Flight modules. The basis for the weights shown is listed in the right hand column. Where the weight of an item is a significant portion of the total, either a detailed accounting of the volume and density of its constituents or direct measurement was used.

Weight of TPC (lb.)

Item	Max LBNL	Max BNL Lift	Installed Wt. w/ CTB	Installed Wt. w/ TOF	Basis
IFC	107	107	107	107	close est
OFC	4991	4991	4991	4991	close est
Wheel	3100	3100	3100	3100	measured
Wheel Brkts/Adj	227	227	227	227	rough est
TOF rails	1080	1080	1080	1080	exact
Outer Sectors	2520	2520	2520	2520	measured
Inner Sectors	1752	1752	1752	1752	close est 75# ea,
Gas Manifolds at wheel	0	0	200	200	removed for lift
FEE	128	1539	1539	1539	measured
FEE Manifolds	480	480	480	480	rough
RDO	51	607	607	607	close est.
RDO manifolds	15	360	360	360	rough
RDO/FEE Cable	39	468	468	468	close est
Dist Manif/hose	240	390	390	390	rough
CTB modules (120 ea.)	0	660	3960	0	measured/ 33# ea.
TOF modules (120 ea.)	0	0	0	4800	Est, G.Mutchler 9/98
TOF cables/hose	0	0	240	240	rough
RDO elect. brkts	24	24	24	24	rough
SVT, Cone Assy &SSD	0	0	365	365	Mech Des Rev 3/98
FTPC	0	0	809	809	FDR action item 1
TOTAL	14753	18304	22409	23249	

Notes:

TPC partially populated with CTB (20 of 120) at initial installation

Anodes

ANODES

HARDWARE

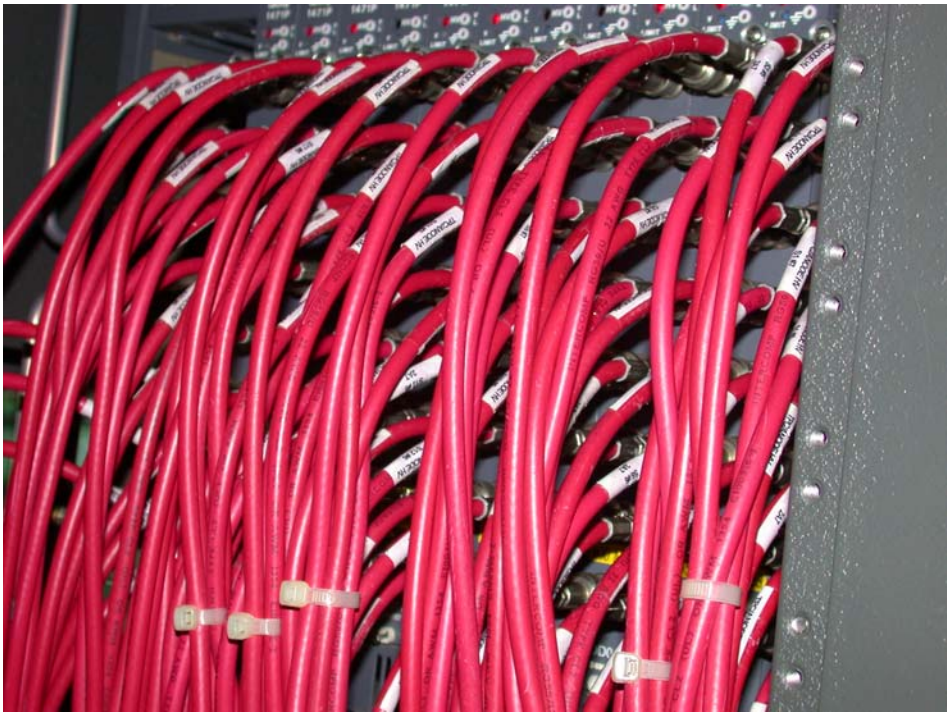
The anode controls for the TPC are separated into two parallel systems for the inner and outer sector. Each system consists of a VME crate and processor, a VME ARCNET interface card, a Lecroy 1458 mainframe and 12 (inner) or 13 (outer) model 1471 HV cards. (The outer has one extra card which was for the gain chamber, which is no longer used.) Each 1471 card has 8 independent output channels. The anode wires for each inner and outer sector are separated into 4 sections – so we need 4 * 24 = 96 channels each for the inner and outer sectors. So each 1471 card supports two sectors.

The Lecroy mainframes are mounted in Rack 2A7 – they need single phase 208 volts, so they have a special plug. To have the capability of remotely power cycling the crates they are plugged into a home made box which in turn is plugged into RPS3. The box was made by Ken Asselta. (See the section on RPS). Each Lecroy mainframe has a mini-card cage in the front which has an ARCNET card as well as an interlock/communications card. We use the "MACRO" input on the comm card as the interlock for the crate – the signal comes from the TPC AB interlock system on an RG58 BNC cable. In addition, the "Interlock" input on the comm card has a 50 ohm terminator on it. There is also an RS232 connector which is the input for talking directly to the Lecroy via serial session. The ports for the serial session are 9037 (inner) and 9038 (outer). Each Lecroy also has a three position key – off, on and remote – we run in remote.

The VME crate for the inner anodes is mounted below the Lecroys in Rack 2A7. The outer VME crate is at the bottom of Rack 2A6.

Picture showing the outer anode Lecroy front with card cage.

Inner anode VME crate – processor in left slot, also showing ARCNET card. Inner Lecroy is just above the crate.

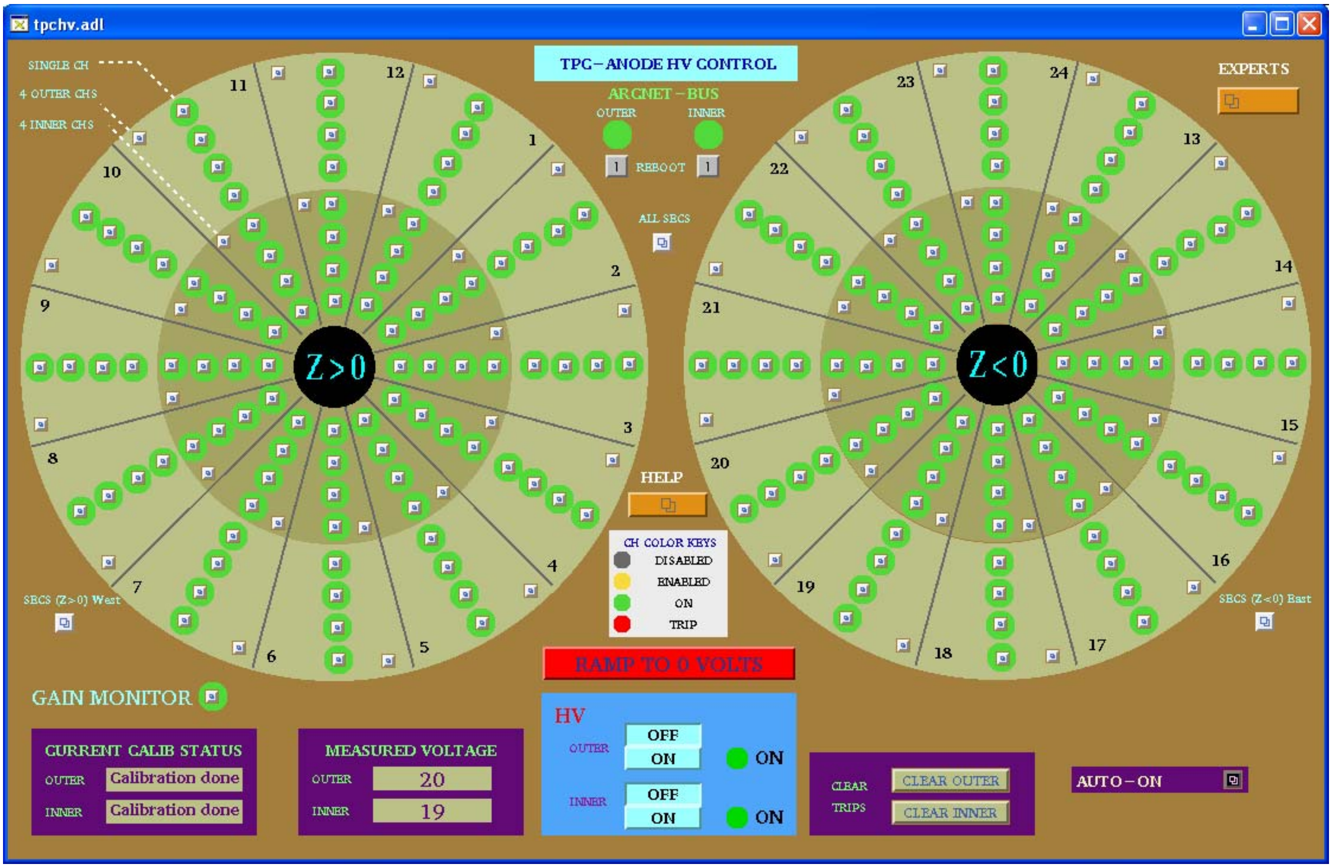


Back of Lecroy outer crate showing connections to 1471 cards.

The CANBUS address for the inner anodes is 52, and the serial port is 9006. For the outer CANBUS is 9013 with port 9013. Note that the Lecroy has its own internal memory and controls so you can reboot the VME processor with the anodes at full voltage and the voltage will not go to zero. This is useful for recovering from ARCNET hangups etc.

SLOW CONTROLS

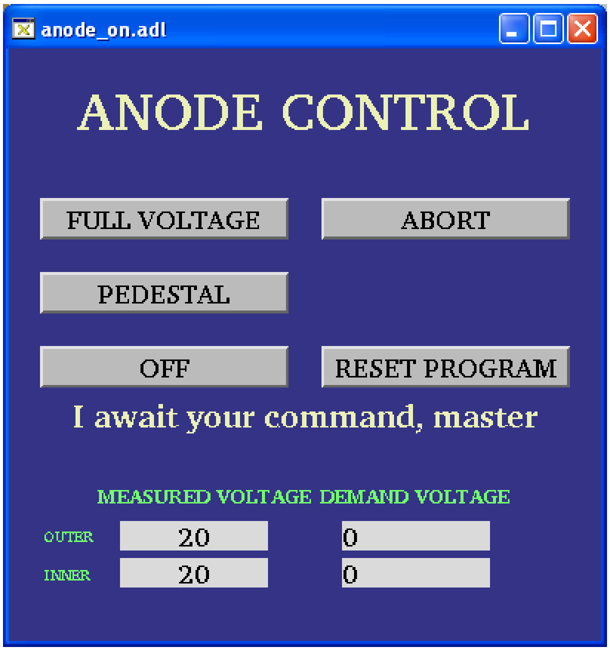
The anode control GUI is available from the TPC top level GUI:



CURRENT CALIB STATUS
OUTER Calibration done
INNER Calibration done

MEASURED VOLTAGE
OUTER 20
INNER 19

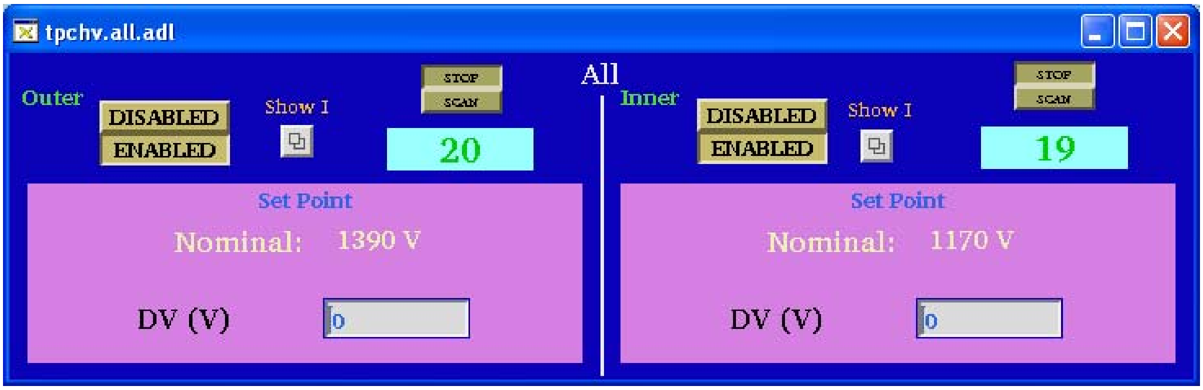
For normal operations the shift crew will use the autoramp program to raise the anodes from off to pedestal voltage (inner = 700, outer = 900) or to physics voltage (inner = 1170, outer = 1390). The autoramp is programmed to raise the voltage in steps, pausing at each level to check for high currents. If it finds a channel with high current it will ramp all channels back to zero and the crew are instructed to call an expert. If the autoramp program is not working, the crew can raise the anode voltage by typing in demand voltages – they follow the same steps as the autoramp. If the VME processor or ARCNET are down we have run for short periods in the past having the crew use the Lecroy serial session – this is less than satisfactory, of course, especially since they do not get an audible alarm for a trip.



I await your command, master

	MEASURED VOLTAGE	DEMAND VOLTAGE
OUTER	20	0
INNER	20	0

This is the autoramp GUI. This process runs on the stargate processor in the DAQ room. The program has been improved over the years by various slow controls experts. It now sends the demand voltages to the Lecroy multiple times and it has a timer that watches the progress of the ramp and times out if the Lecroy has not responded.



Outer: 20

Nominal: 1390 V

DV (V): 0

Inner: 19

Nominal: 1170 V

DV (V): 0

This is the GUI that is used to manually raise the HV if the autoramp doesn't work. It is available from the top anode GUI by clicking on the "All SECS" (all sectors) button. The crew then enters the demand voltage (DV) for the inners and anodes (you have to type in the value and then hit Enter.)

For further descriptions of the anode GUIs and the Lecroy serial session, see below. I've appended the following:

1. The anode section from the original year 2000 operator's manual – it will be somewhat out of date, but it is the longest explanation.
2. The anode section from the current (2007) manual for detector operators.
3. The current document for the detector operators to control the Lecroys by serial session.

SPARES

The Lecroy 1458 mainframes come in three flavors – low, medium, and high power. Originally, TPC owned two low power (installed) and one spare (med power). SVT also used two 1458s (med power) and those are now used for TPC spares. There are also rumored to be some 1458s floating around that were used by BRAHMS – we could probably get these in a pinch. One problem is that Voltronics (who bought Lecroy) will not repair these crates if they are > 10 years old, which ours are approaching.

At the beginning of Run 8 the low power outer crate had an interlock problem – it wouldn't turn off for a dropped interlock. We swapped in the med power crate and ran with it for all of Run 8. Ken Asselta has been working on getting this repaired – you might want to put it back in before Run 9 (test the interlock!) We also had problems with the outer anode Lecroy in 2006 – it was repaired by Voltronics. See pages 5 and 31 in my notebook II.

The spare 1471 cards are in the TPC spares cabinet. They haven't failed very often, so we should have plenty. I believe Voltronics will repair these, and they may also still sell new ones. Note that new cards have to be slightly modified (adding a resistor) to limit the HV out to 5 kV – this is a safety issue for RHIC since the connectors are only rated at 5 kV. Ken Asselta knows how to make this mod.

PAST PROBLEMS

1. One section of the TPC has not held voltage since day one. It is section 20-3 (outer sector 20, pad rows 14-21). I have tried it each year but it always trips after ~ ½ hour. I assume it's an internal problem, maybe on the ABDB board. We run with that cable unplugged at the Lecroy end – that way the GUI looks normal for the operators. The voltage for that channel ramps up as per normal – the sector is just not attached. Since this section coincides with RDO 2 of sector 20 we normally mask out that RDO in DAQ also.

2. I have a notebook where the operators record which channels trip during data runs – this is a good way of finding twitchy channels. Section 4-1 is by far the worst. Sections that trip too often should be investigated – I usually start by swapping the Lecroy output. We have had cards that go bad in one channel only. A typical sign of a bad Lecroy channel is if the baseline current goes up, or the zero point voltage (typically 20 volts) increases. The serial readout from the Lecroy will show the current for a channel down to a few nA. For more accuracy and faster response we have a homemade nano ammeter that can be put in series with the chamber to check for twitchy currents.

3. Usually, after a few days of running, if you login to either VME processor (9006 or 9013) you will see a message like "Node1 mainframe in bad status", in addition to some activity related output (read and write messages). This bad status message is generated by the program which is reading a status word from the crate. I have never figured out precisely what it is complaining about and, in fact, the Lecroy seems to operate ok even with this bad status. So I usually ignore it. It can be cleared only by power cycling the Lecroy.

Controlling the TPC Anodes with the LECROY Serial Session

Blair Stringfellow - valid from 6/4/2007

If the inner or outer VME crates go down you can still raise and lower the TPC anode voltages by sending commands directly to the LECROY mainframe.

NOTE: In this case the autoramp program will NOT work. If the outer anode VME crate is down, you will need to control the inner voltages by entering voltages by hand from the GUI on the anode desktop. (and vice-versa) There will also be no alarms for trips etc.

To control the inner or outer anodes by the direct method:

Log on to sc3.starp.bnl.gov with a putty session. (Shiftleader has the password.) There is normally a putty session open on the “other” desktop on the TPC control computer.

```
SC3> telnet scserv 9037 (inners) or 9038 (outers) (CR or Enter)
Type two CR
Type 1450
1\EDIT\1450>VT100 (CR or Enter)
```

Control screen with help screen should start up....
To see the full control screen type w (no CR)
To see the help screen again, type w (toggles between these two screens)

Using the keyboard arrow keys move the white cursor to the column headed “target voltage”.

To select all channels, type shift and > together, then up arrow. The entire column should now be white.

Type in the first voltage value and CR. After a delay the voltages for all channels should start to ramp up. Repeat this method until the anodes are at the desired voltage (pedestal or operating voltage) Raise the voltage following the steps that are posted near the control computer.

The screen shows only 2 HV cards (4 sectors). To see the other sectors page down by typing SHIFT and 2 or 4 or 6 or 8 or A. Return to the top page by typing SHIFT and 0

In the column labeled S is a symbol that shows that channels status. Normal status is indicated by a diamond symbol. (♦) A tripped channel is indicated by the symbol ⊥ Detector operators should check the status of all channels every 15 minutes to look for tripped channels.

A tripped channel can be cleared by moving the white cursor to the target voltage column for that channel - first enter 0 (CR) to change the target voltage to zero. Then type [This should change the status back to the diamond. Then ramp that channel up by the normal steps.

To exit the LECROY session, first type q, then at the prompt type quit.
Then type CNTRL and] This will get the telnet prompt. Then type quit. This will get the SC3 prompt.

To exit the LECROY session, first type q, then at the prompt type quit.
Then type CNTRL and] This will get the telnet prompt. Then type quit. This will get the SC3 prompt.

If the control screen becomes garbled with graphics characters etc just type w twice to refresh the screen.

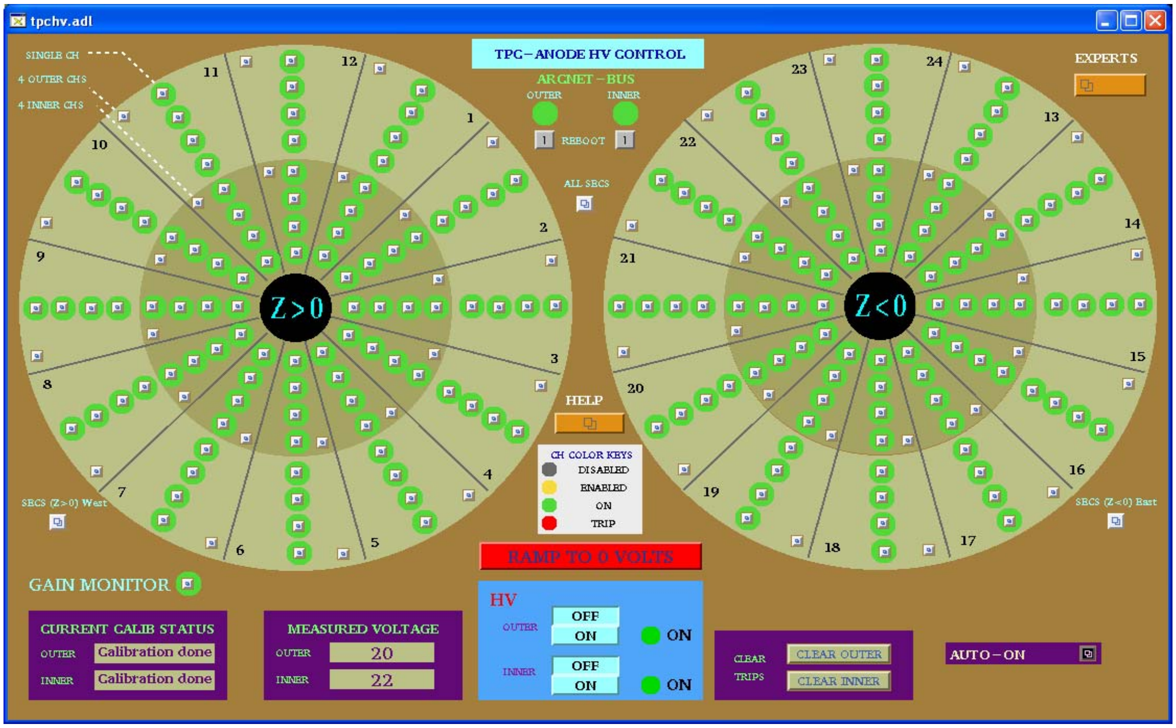
If the HV does not ramp up after entering a demand voltage, check in the top right corner of the window whether HV is on or off. If it off, type { to turn it on. If it still doesn’t turn on, call an expert.

2.7 ANODE & TRIPS

AUTORAMP

To turn the anodes on using the autoramp program:

1. Go to desktop # 1 and click on “Anode Voltage” on the top level GUI. This brings up the Anode GUI:

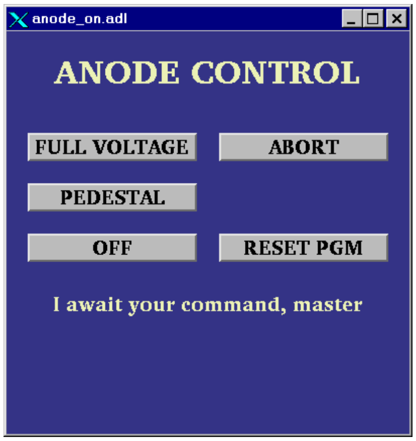


CURRENT CALIB STATUS
OUTER Calibration done
INNER Calibration done

MEASURED VOLTAGE
OUTER 20
INNER 22

2. Check the ARCNET-BUS status lights for the Inner and Outer sectors – if either or both are red, click the corresponding “reboot” button. This will reboot the processor. (The display will go white while it reboots). WAIT ~ five minutes for the reboot. The state of the anode voltages (on or off) is unaffected by rebooting the processor – the Lecroy system has local memory.

3. When the status lights have turned green, click on the “Auto-On” button. This gives the GUI:



I await your command, master

If the autoramp GUI displays the message “ARCNET connection lost”, click on the “Reset PGM” button.

4. Make sure RHIC has stored, cogged and stable beam!

5. At this point, you can go to pedestal voltage (Inner = 700, Outer = 900) or to full operating voltage (Inner = 1170, Outer = 1390).

6. To go to pedestal voltage, click “pedestal”. The program will:

Turn on the HV
Enable all channels
Ramp HV to 400 volts
Calibrate the currents (subtract out any DC offset)
Ramp to pedestal voltage

If the HV is already on, the program will just ramp up (or down) to pedestal values.

At any time the operator can stop the process by clicking “Abort”. This will ramp the voltage back to 0.

After the voltages are at pedestal values, the TPC is ready to take a pedestal run (make sure the GG is on!)

7. One can go to full voltage from either the off position or from the pedestal position.

From off, the program will repeat the pedestal procedure, and then:

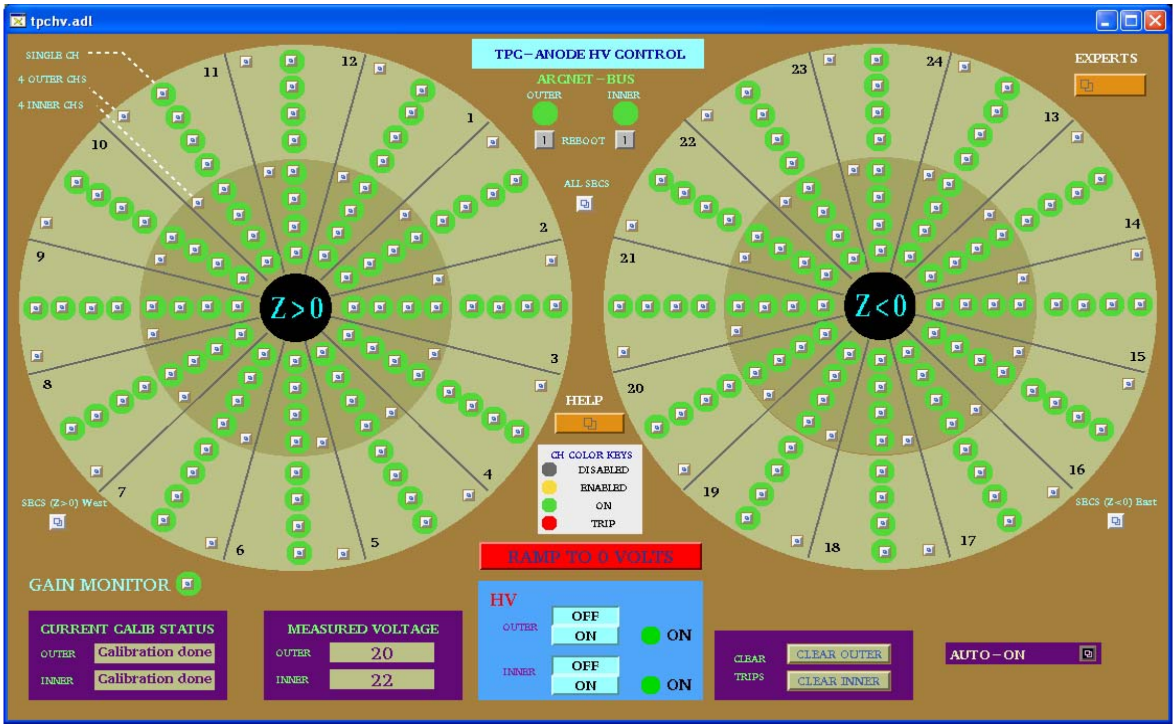
Check for tripped channels
Check for excessive currents
Ramp to Inner = 1000, Outer = 1200
Check for trips
Check for currents
Ramp to Inner = 1100, Outer = 1300
Wait for 2 minutes
Check for trips and currents
Ramp to final voltage (Inner = 1170, Outer = 1390)
Check for trips or currents.
HV ready for data

This procedure takes ~ 10 minutes.

If a trip or high current is detected during this procedure , the voltage for all channels will be ramped back to pedestal values automatically.

To turn the HV off, click on the “Off” button in the auto-on window, or click on the red “Ramp to 0 Volts” button on the main anode GUI.

MANUAL ANODE OPERATION



CURRENT CALIB STATUS
OUTER Calibration done
INNER Calibration done

MEASURED VOLTAGE
OUTER 20
INNER 22

There are 193 separate anode supplies, 1 for the gain chamber and 192 for the TPC. For each sector, the anode wires are grouped in sections, so there are four supplies per sector. The operator can control the voltage for all sectors (including the gain chamber), for the east or west end only, for a sector only (4 sections) or for an individual section (usually necessary to reset a trip.) In the main GUI above, the status of each power supply (section) is indicated by the round color field surrounding the control button. Thus:

Grey = Channel is disabled. Even if the HV is turned on and you set a demand voltage for that channel, nothing will happen.
Yellow: Channel is enabled but the HV is off or <10 volts.
Green: Channel is on at some voltage > 10 volts.
Red: Channel has tripped off due to excessive current draw. (> 2 µA)

NOTE: The Anode program is very slow. You MUST wait for each command to be acknowledged before issuing another command or it will crash!

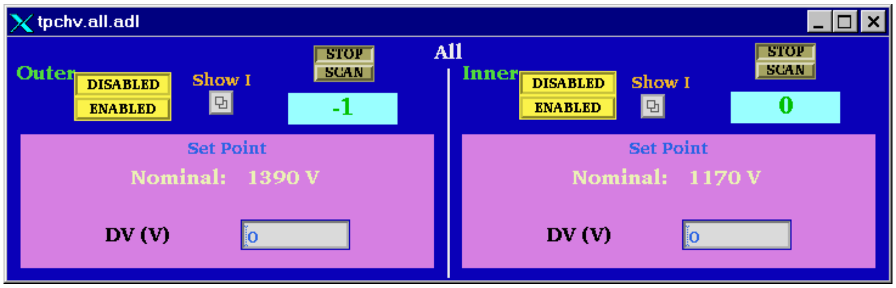
To turn on all sectors manually:

1. Check the status lights of the Arcnet-Bus. If either is red, click and drag on the reboot button to reboot the processor. Wait ~ 5 minutes. (There is a separate processor for the inner and outer sectors).

NOTE: The ARCNET link is lost frequently – you will get a TPC alarm when this happens. When this link is down the program can't get updated information from the Lecroy HV mainframe, BUT the HV is still on and the chamber is still protected. Rebooting the processor has no effect on the HV.

2. When the ARCNET lights are green, click the HV on button for the inner and outer sectors. Wait for the HV lights to turn green.

3. Open the “ALL SECS” control panel:



Nominal: 1390 V

DV (V) 0

Nominal: 1170 V

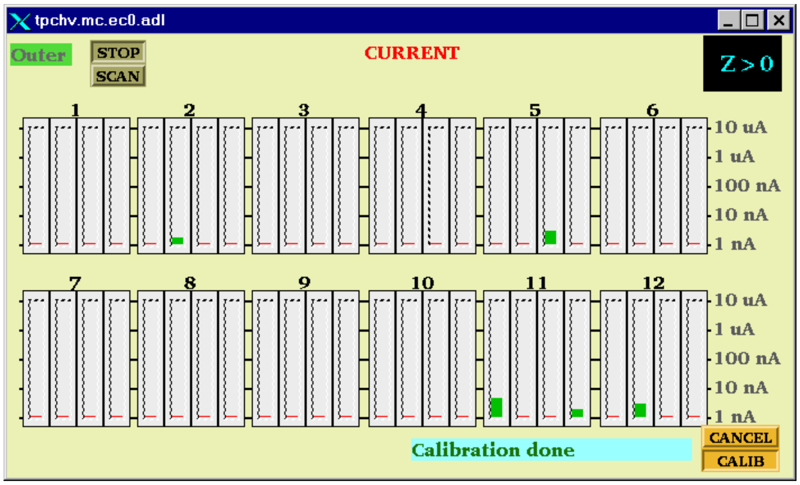
DV (V) 0

4. Check that the demand voltage DV (V) for inner and outer reads 0. If not, enter 0, CR in each window.

5. Click on “Enabled” for the inner and outer. Wait until the color circles turn green on the main anode GUI.

6. Type in a demand voltage of 400 V for the inner and outer sectors. Wait until the voltage ramps up and is confirmed in the readback window.

7.Check the Current Calibration status window in the main anode GUI. If the status is “calibrated” continue raising the voltage (see below step 10). If the status is uncalibrated, click on the Outer “SHOW I” button in the “ALL SECS” control GUI, drag down to “I (Z > 0) West) and release. This brings up the current display for all the outer sectors on the west end:



Calibration done

8. Click on the “Calib” button. The status window will say “Current is Ready” and then “Calibration in Progress”. The program will subtract the DC current offsets FOR ALL OUTER SECTORS (east and west). The status window will then say “Calibration Done”.

9. Repeat this procedure for the Inner sectors, if needed.

10. Set the demand voltage to pedestal values (Inner = 700, Outer = 900). Wait for the voltage to ramp up.

11. Continue to raise the voltage in steps, checking the currents after each step:

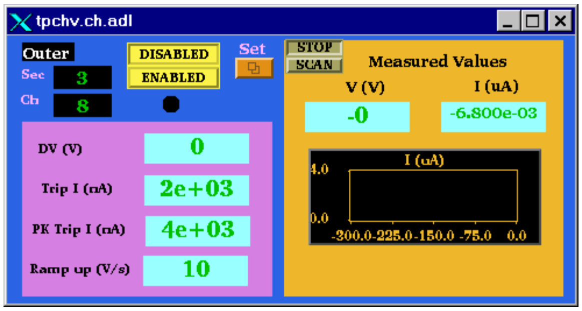
Inner = 1000, Outer = 1200
Inner = 1100, Outer = 1300
Wait ~ 2 minutes
Inner = 1170, Outer = 1390

12. To turn the Anodes off, either type in 0 for the demand voltage or click on the red "Ramp to 0 Volts" button on the main anode GUI.

RESETTING TRIPS

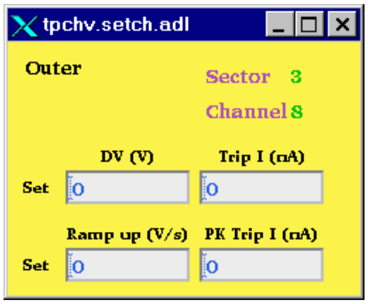
Occasionally, one or more channels will draw excessive current (> 2 μA) and automatically trip off. There will be a TPC alarm. These trips can be random or beam induced. First, STOP the current run. Then, to reset a tripped channel:

1. Click on the individual control button for the tripped channel in the main anode GUI. This brings up the channel status panel:



Outer
Sec 3
Ch 8
DV (V) 0
Trip I (nA) 2e+03
PK Trip I (nA) 4e+03
Ramp up (V/s) 10
V (V) -0
I (uA) -6.800e-03

2. Click on the "SET" button. This brings up the control panel:



Outer
Sector 3
Channel 8
Set DV (V) 0
Set Trip I (nA) 0
Set Ramp up (V/s) 0
Set PK Trip I (nA) 0

3. In the demand voltage window "DV (V)", type in 0,cr to set the demand voltage back to zero. Do this FOR ALL tripped channels.

4. In the main anode GUI, click on the "Clear Trips" button for inner or outer sectors, depending on which channels tripped. Wait – the tripped channels which were red should turn back to green.

5. If the tripped channel remains grey on the main GUI after 2 minutes, it is neccesary to enable it manually. Click the “Enabled” button for the channel on the channel control GUI shown in step 1 above. If the channel is not green, you cannot raise the voltage.

6. Using the individual channel control windows, slowly raise the voltage in stages back up to the operating point. Monitor the current for each channel. For any indication of excessive current draw, lower that channel back to 0 and call an expert. (Excessive current for constant voltage = 50 nA)

7. Record the tripped channels in the “STAR TPC ANODES” binder.

NOTE: The current limits can only be changed by the subsystem manager. If a channel will not stay on with a limit of 2 μA, LEAVE IT OFF and call an expert.

ALTERNATE METHOD FOR CLEARING MULTPLE TRIPS

Sudden RHIC beam losses can cause multple anode trips. A more efficient method for clearing these trips is:

1. If the RHIC beam is lost: Use the autoramp to run ALL anode HV down to zero. Then click on the “Clear Trips” buttons. The tripped channels should clear and be ready for the next autoramp.

2. If RHIC still has beam and the run will continue then:

First, STOP the current run. Use the autoramp program to run ALL anode HV down to pedestal voltage. Then click on the “Clear Trips” button for inner and outer, depending on which channels tripped. WAIT for the tripped channels to reset – they should automatically ramp back up to pedestal voltage. You can then autoramp back up to full voltage if the RHIC losses have stopped.

X. ANODES

OK, right up front, the most important thing with the anodes is:

PATIENCE

This won't be the last time I tell you. In addition to the normal care one needs to take with MWPC, the slow controls program for the anodes really IS slow. If you try and do multiple commands or not wait for one step to finish, it will crash and burn for sure. So…. here we go:

The HV MWPC for the TPC (anodes) is supplied by Lecroy 1471 HV cards. Each sector is segmented into four sections, each with its own independently settable HV. The Lecroy crates for the HV supplies are in Rack 2A7 (Outer sectors in the upper crate, inner sectors in the lower crate). Each Lecroy 1471 card has eight independent outputs and supplies two sectors. The Inner sections are numbered from 1 to 4 (1 = innermost radius) and the Outer sections from 5 to 8 (8 = outermost radius). The HV is controlled by a VME processor which talks to the crate via an ARCNET interface. There is a separate CPU for the inner and outer sectors. The inner CPU is in Rack 2A7, the outer in 2A6. In addition, one can communicate with the Lecroy crates independent of VME using a serial connection. (see below for details.)

COLD START

1. After a complete shutdown, the crates may be completely off. Also, after replacing a HV card it will be necessary to do a cold start. The main AC switch for the Lecroy crate is in the back. Turn this on (Both crates).

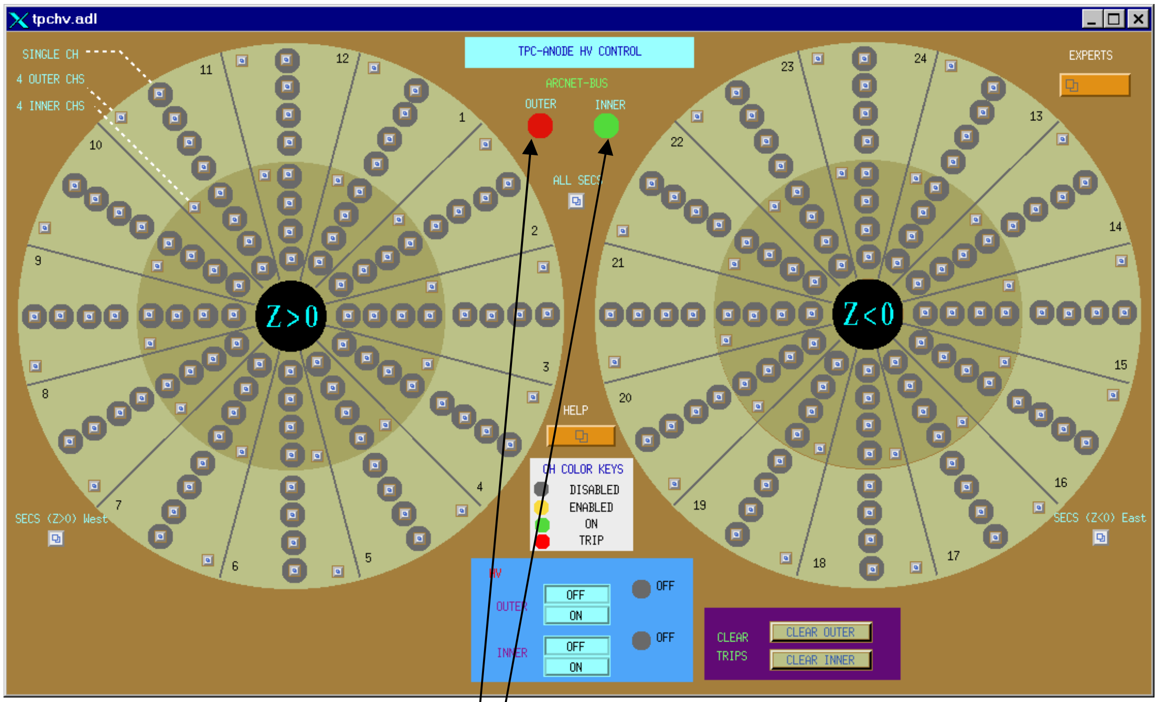
2. On the front of the crate, turn the key to "remote". (Both crates.)

WARM STARTUP

1. If the Lecroy crates are on and in remote, first check the interlock. Select Desktop # 7 and bring up the Interlock GUI. Check that the "Anode HV Enabled" button is green and not flashing. If not, contact a TPC expert or check the TPC Interlock manual.

2. Select Desktop # 8 and bring up the VME status GUI. Make sure the two VME crates are on (2A7 ANHV/Interlock for the Inner and 2A6-3 ANHV-2 for the Outer)

3. Select Desktop #1 and bring up the Anode Voltage GUI. It looks like this:



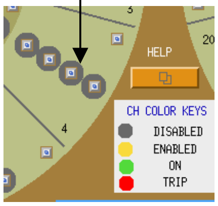
4. Check the ARCNET bus status .   Are they red? (Probably). If so you need to reboot the VME processors.

5. On the desktop, click on the Exceed shortcut “sc.session.xc”.

6. At the sc prompt, type telnet scserv 9013 (Outer sectors). This will bring up a terminal session for the VME processor. Type CR to get the prompt, then type reboot. Reboot takes ~ 5 minutes. If the processor is working properly, the ARCNET status light will turn green and debug messages will appear in the session window. (Typical messages are STARCNET: reply LS and RC_MC:RC S2 MC) These are normal. For normal running, leave this session window up – you’ll need it to reboot from time to time.

7. For the Inner Sectors, repeat step 6 except telnet scserv 9006. Leave that session window up also.

8. The status for each channel (1 channel = 1 section of one sector) is indicated by the color circle around its access button:

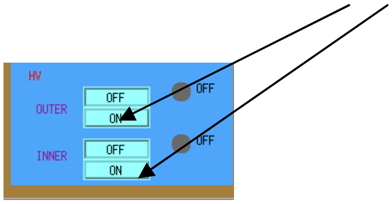


9. The color code for the status is shown on the GUI:

White: The VME processor is dead or the VME crate is off.
Grey: Channel is disabled. Even if the HV is turned on and you set a demand voltage for this channel, nothing will happen.
Yellow: Channel is enabled but HV is off or < 10 Volts. Note that a channel can be enabled even if the HV is OFF.
Green: Channel is on at some voltage greater than 10 volts.
Red: Channel has tripped off due to excess current draw.

10. Check that the status of ALL channels (inner and outer) is disabled (grey.)

11. Turn on the HV for each crate by clicking on the “HV on” buttons in turn.

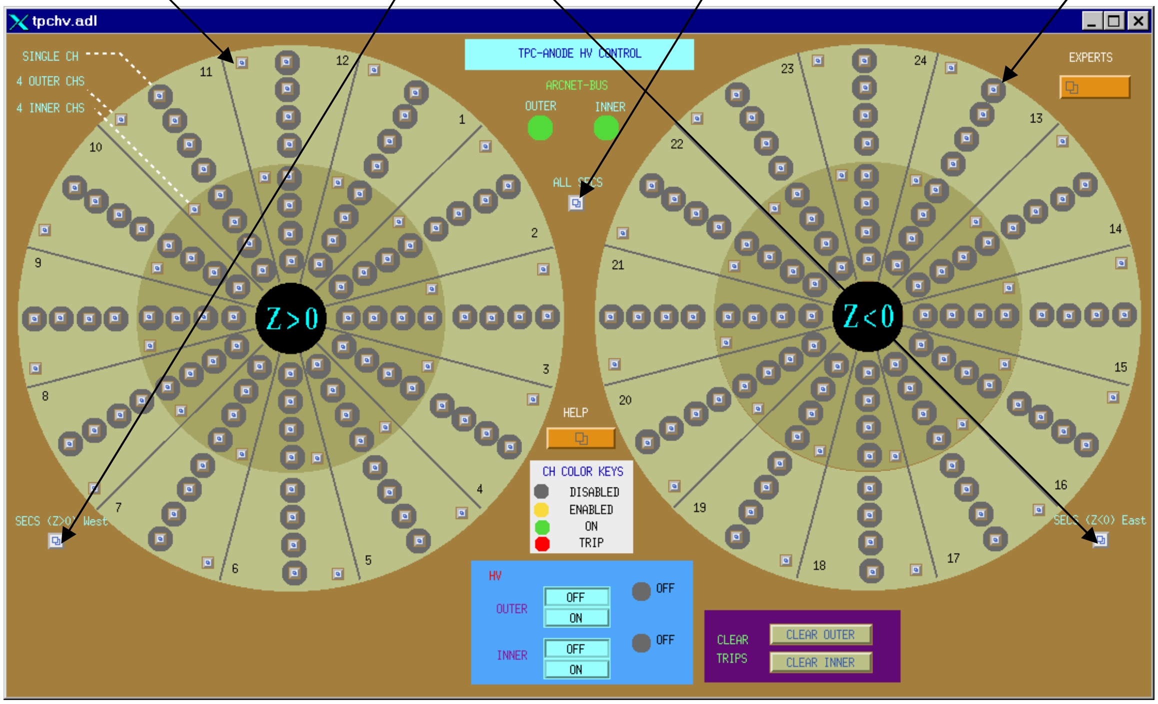


The HV status should turn from off to on and the light will turn green. (Wait for it!).

A TOUR OF THE CONTROL WINDOWS

At this point the system is ready to apply HV to the sectors.

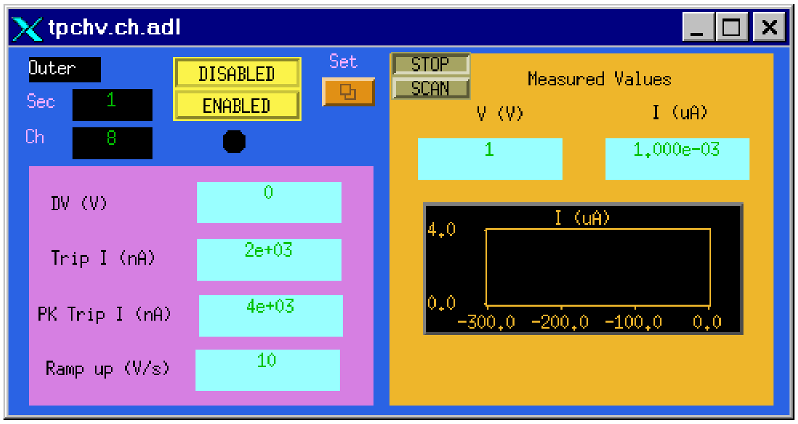
Note that there are multiple GUI entry points for each channel. One can control a single channel, 4 channels (= 1 sector), the whole west or east end or all of the TPC.



SINGLE CHANNEL

The single channel window would typically be used to reset one tripped channel or to monitor a channel that was drawing current.

1. On the top level GUI, click on a single channel button. This brings up the monitor window for that channel:



Outer
Sec 1
Ch 8
DV (V) 0
Trip I (nA) 2e+03
PK Trip I (nA) 4e+03
Ramp up (V/s) 10
V (V) 1
I (uA) 1.000e-03

All of the windows on this screen are output values. The demand voltage (DV) is shown in the first window. The next two windows show the database values for the trip current and peak trip current. A channel that draws current above these levels will automatically trip off. The trip current has a time constant of ~ 10 msec, the peak trip current ~ .75 msec. As shown the limits are set to Trip current = 2.0 µa, PK trip = 4.0 µa.

NOTE: These limits are set purposefully low in order to protect the MWPC's. They will be adjusted after we see what the RHIC operating conditions are.

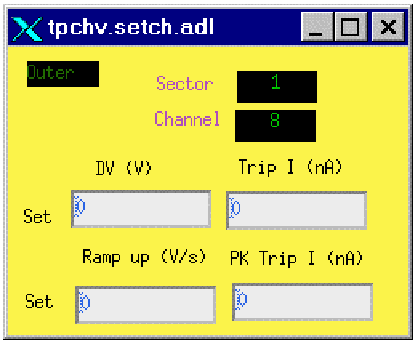
THESE LIMITS CAN ONLY BE CHANGED BY EXPERTS!!! NO EXCEPTIONS.

The Ramp up window shows the current value for the rate at which voltage is applied to the chamber. It should always be 10 V/sec.

The windows on the right show the readback parameters for this channel (Volts and Current) along with a strip chart of the current. The "Scan" button is used to force the program to read this channel more often. It can be used when the window is active, but click stop before closing the window.

To enable this channel ONLY, click on the "Enabled" button. The status light just below the button will turn to yellow (for demand voltage = 0) or green (for demand voltage > 40 V) or red (tripped).

2. To input a demand voltage for this channel, click on the "Set" button. This brings up the single channel control window:



Outer
Sector 1
Channel 8
DV (V) 0
Trip I (nA) 0
Ramp up (V/s) 0
PK Trip I (nA) 0

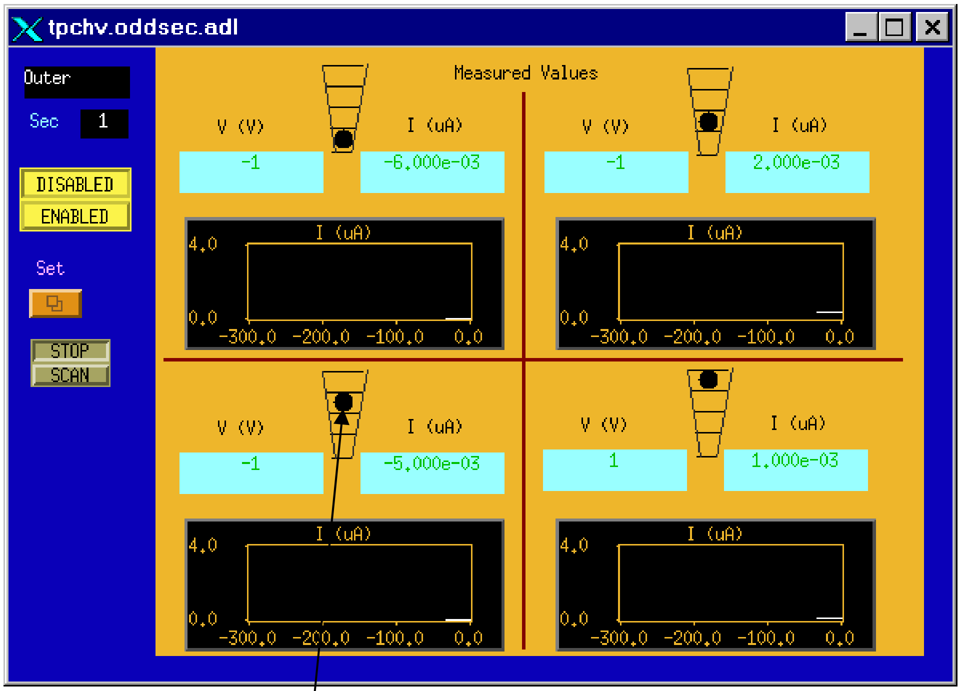
3. To set a demand voltage for this channel, type a value in the DV window and hit return. (Note: The mouse pointer has to be on the window to input a value). If the channel is enabled and not tripped, the voltage will ramp up to the demand value.

AGAIN, EXPERTS ONLY FOR THE OTHER THREE WINDOWS!

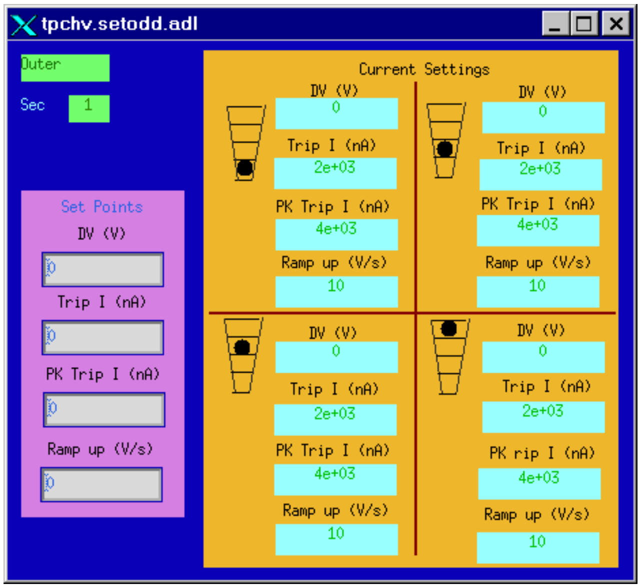
4 CHANNELS OR 1 SECTOR

This window would typically be used to reset a sector if more than one section tripped or to lower the voltage for one sector.

1. On the top level GUI, click on one of the sector buttons to get the monitor screen:



Here each section of the sector has the voltage, current and current stripchart displayed. The status of each section is also indicated. To input a demand voltage FOR THE WHOLE SECTOR, click on the "Set" button. This brings up the control window:

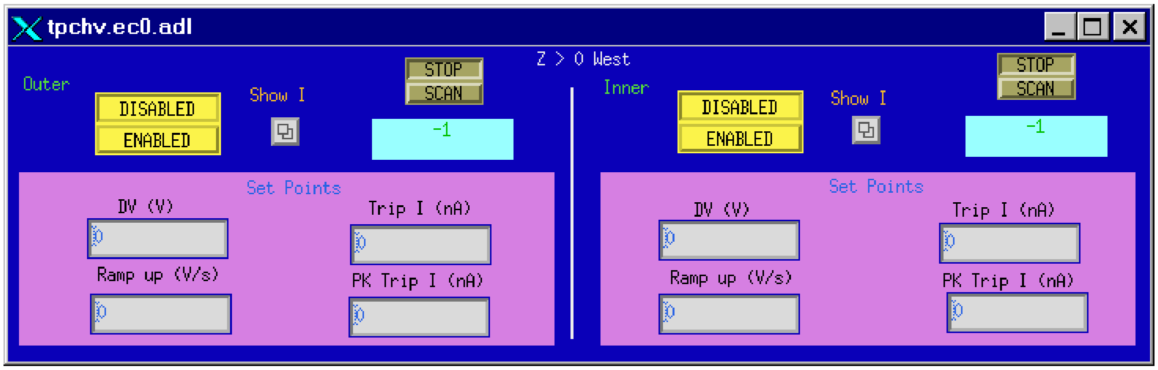


As for the single channel window, set a demand voltage by typing in the DV set point window and hitting CR. Do NOT type anything in the other three windows.

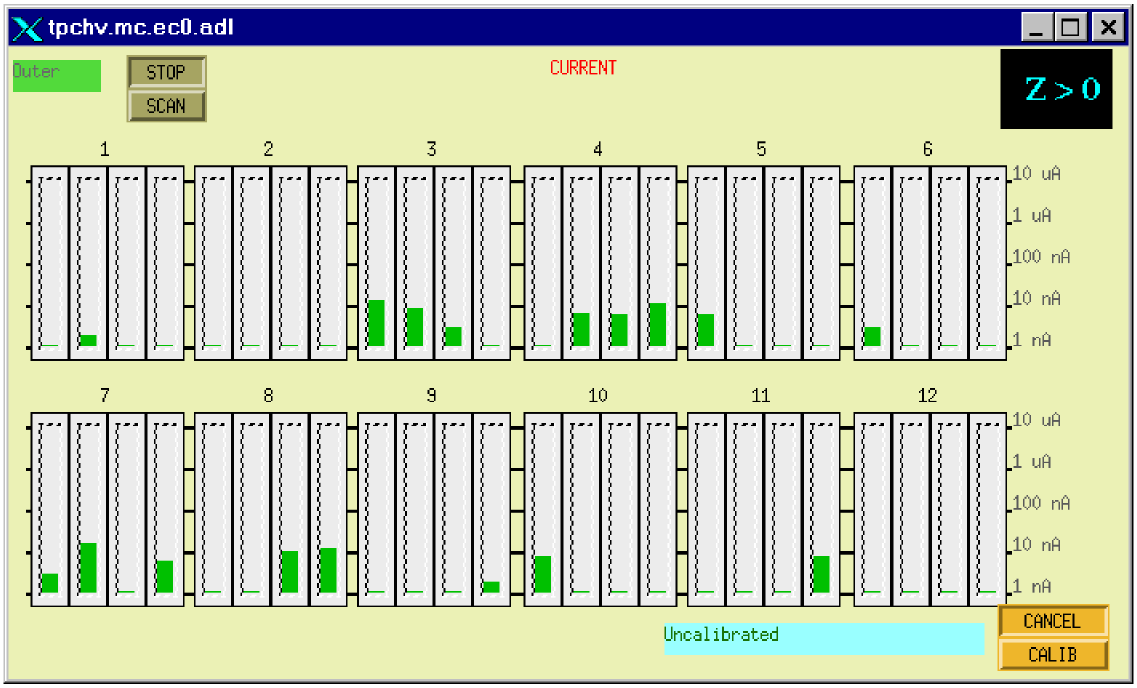
EAST OR WEST END

These windows are used to control one whole end of the TPC (12 Inner & 12 Outer Sectors)

1. On the main Anode window, click on the “SECS (Z>0) West” or SECS (Z<0) East button to bring up the control screen:



The “Enabled” button will now enable all sectors on that end. To raise the voltage, input the demand value into the Set Point DV window. NOTE: This will raise the voltage on ALL sectors of that end. To see the current for the Inner or Outer sectors, click on the corresponding “Show I” button:



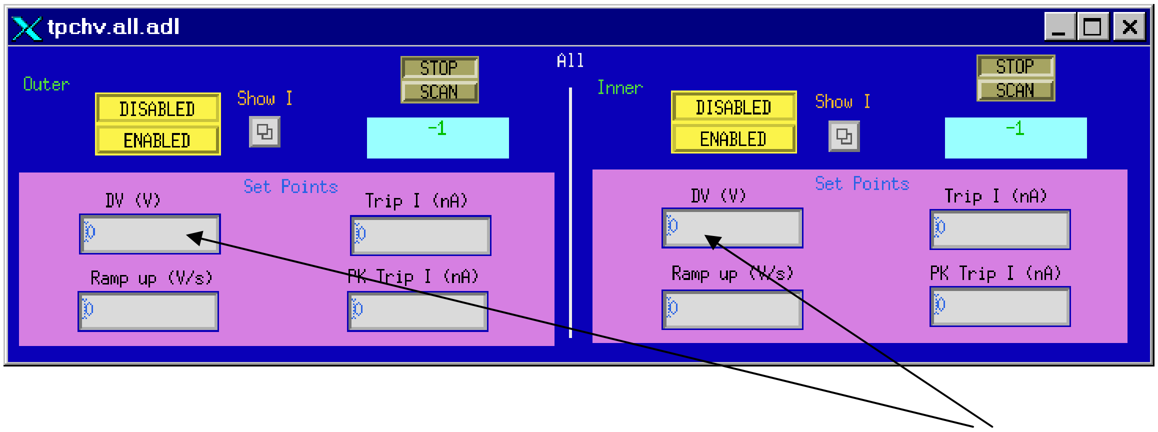
This shows the uncalibrated current for all sections of the 12 outer sectors of one end (log scale). The Lecroy modules have varying levels of DC current offsets – to do a calibration, see below.

RAISING THE VOLTAGE (WHOLE TPC)

This is the window and method that is normally used to bring the TPC MWPC's to operating voltage.

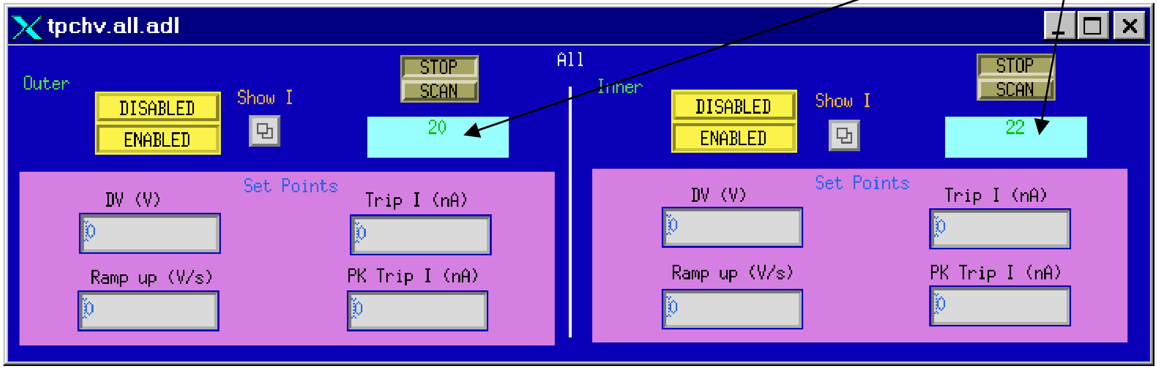
1. On the top level Anode GUI make sure both ARCNET lights are green. If one or both are not, reboot the corresponding processor and do the Warm Startup Procedure (see above).

2. On the top level Anode GUI, click on the "All SECS" button to bring up the control window:

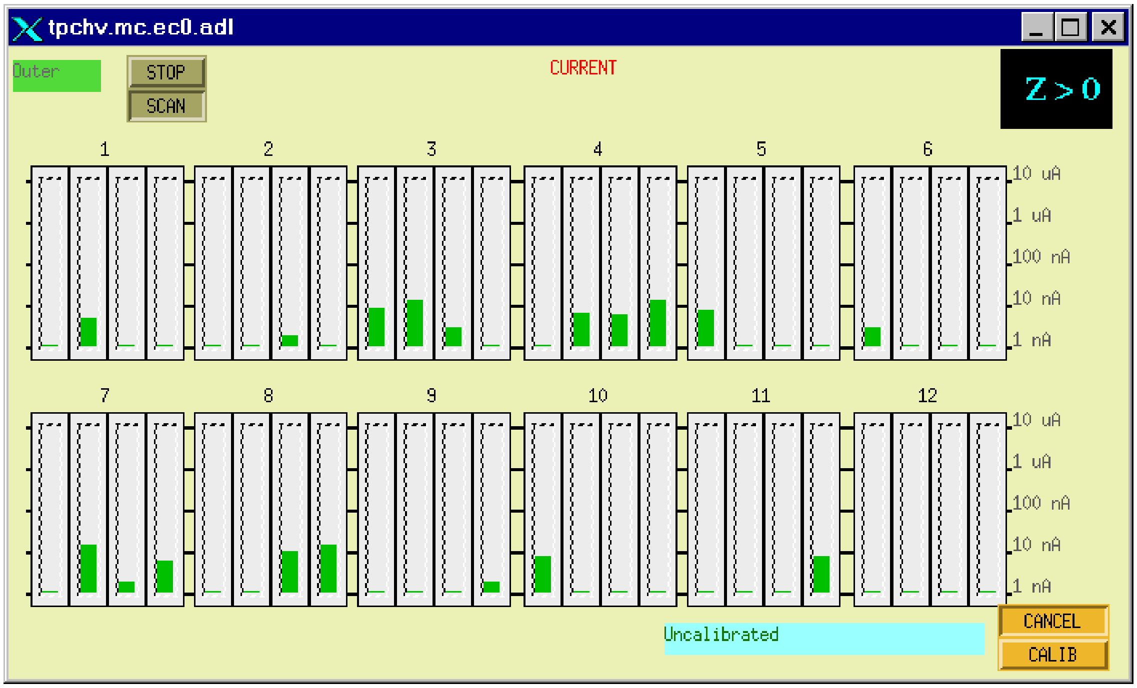


3. Check that the set point Demand Voltage for both Inner and Outer Sectors is 0.

4. Click on the Outer "ENABLED" button. All the outer sectors should turn green. (WAIT!) Do the same for the Inner sectors. The measured voltage should now read ~ 20 Volts.



5. Before raising the voltage, you need to subtract the DC current offsets for all channels. For the outer sectors, click on the "Show I" button. There will be a drop down menu – click on "I (Z > 0) West" to view the current for 12 sectors at a time. The window will look like:



6. To remove the DC offsets (some of which are negative), push the "Calib" button. The status window should read "Current is ready" and then "Calibration is in Progress" and then "Calibration done". The currents should then all read ~ zero. This calibrates ALL 24 of the outer sectors.

7. Do the same for the Inner sectors using the Inner "Show I" button.

IT’S TIME TO RAISE THE VOLTAGE!

The voltage is raised in steps up to the operating point. NEVER input the full HV from zero. It should take ~ 20 to 30 minutes to reach full voltage.

THE CURRENT OPERATING VOLTAGES ARE:

IN NER 1 170 V
OUTER 1390 V

THESE MAY CHANGE FROM TIME TO TIME – ALWAYS CHECK THE MAIN LOGBBOOK BEFORE TURNING ON.

1. In the “ALL SECS” control window, type in 400 in the Outer DV window and hit CR. The voltage should slowly ramp up to 400 V. Remember, the readback program is slow, so you may only get one or two refreshes between 20 and 400.

2. When the Outer Sectors have reached 400, then type 400, CR in the Inner Sector DV window. Wait again.

3. Continue this way up to the operating point. Recommended steps are:

   Outer: 400,800,1000,1200,1300, pause here and check currents, 1390

   Inner: 400,800,1000,1100, pause here and check currents, 1170.

4. One step before maximum, and after reaching the setpoints, open the four “Show I” windows and check for excessive current draw. Any current over 10 nA is cause for concern. Lower the voltage on that section or sector and consult an expert. NEVER let a sector that is drawing current sit at full voltage.

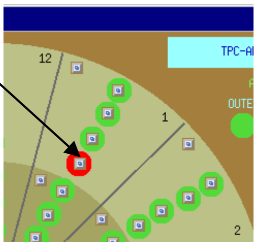
NOTE: There is an additional built in hardware over-voltage protection for each channel. If you attempt to enter a demand voltage above this limit, the Lecroy card will immediately trip that channel (or channels). The hardware trip limit is set by a pot on the front of each HV card (common to 8 channels.) The present limits are Inner = 1210V, Outer = 1510 V.

5. The TPC is now at full operating voltage – see THE SECTION ON MONITORING A RUN.

RESETTING A TRIP

HV trips due to overcurrent can be caused by a sector breaking down, excessive RHIC beam losses or bad Lecroy cards. If a channel or sector trips consistently, don’t force the issue – consult an expert.

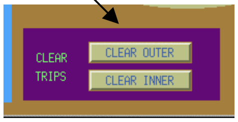
1. A tripped channel(s) will be indicated by a red status indicator on the top level Anode GUI.



2. To reset the trip, first open the appropriate control window. For a single section (as above) just click on the section button. If two or more sections of a sector have tripped, it’s usually easier to use the whole sector control window.

3. In the control window, set the demand voltage for the tripped channels to 0. (Make SURE you are entering in the right place – otherwise you will reduce the voltage on more than the tripped sector!)

4. In the top level Anode window, click on the appropriate “Clear Trips” button for inner or outer sectors:



5. In the control window for the tripped sections, raise the voltage in steps back to the operating point. Make sure to monitor the current carefully. Sections that re-trip for no known reason should be turned off and an expert notified.

6. Locate the “STAR TPC ANODES” three ring binder and log the trip. There is a separate page for each sector – log the date, time, section, the current trip limit, peak current trip limit and whether the beam was on. There is also a column for comments.

SERIAL SESSIONS

There is a parallel path into the Lecroy HV system using a serial connection for each crate (Inner and Outer). Commands can be entered from either the GUI or the serial sessions and the results will show up on both. In addition, some information is available through the serial line that is not apparent from the GUI. (Trip codes and hardware voltage limit being the most prominent). The entire system can be controlled in an emergency using the serial lines if the VME processors are down, for instance.

To open a serial session:

1. Select Desktop # 1 and double-click on the sc.session.xs shortcut located on the desktop.

2. At the sc prompt, type telnet creighton2, CR.Creighton2 is a Sun workstation located on the platform (Rack 2A8).

   username: sysuser
   password: dv4hwco8

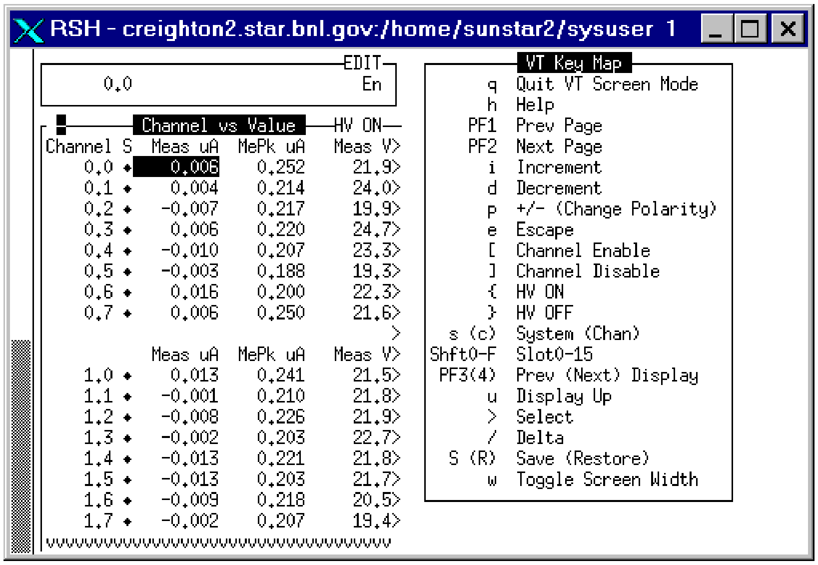
3. At the creighton2 prompt, type “tip a” for the inner sectors. For a similar session for the outer sectors, repeat steps 1-3 but type “tip b”.

4. The response should be “connected”. Hit CR.

5. At the prompt 0\ENTER “1450” to begin>, type 1450 CR

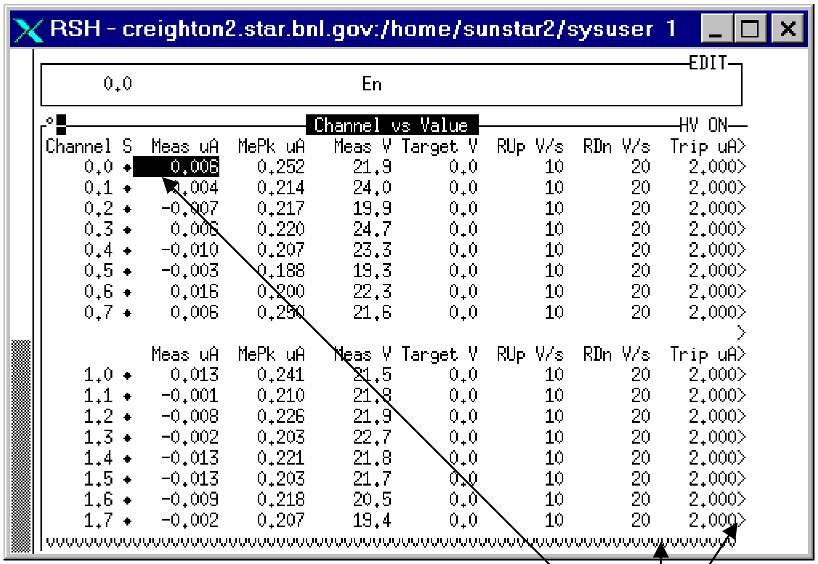
6. It will respond “Begin Serial Session” and then prompt 1\EDIT\1450>. Type VT100 CR

7. The display will change to the following:



```
                                   EDIT   VT Key Map
      0.0                            En         q  Quit VT Screen Mode
                                                h  Help
        Channel vs Value   HV ON               PF1  Prev Page
Channel S  Meas uA  MePk uA   Meas V>          PF2  Next Page
    0.0 ♦    0.006    0.252    21.9>             i  Increment
    0.1 ♦    0.004    0.214    24.0>             d  Decrement
    0.2 ♦   -0.007    0.217    19.9>             p  +/- (Change Polarity)
    0.3 ♦    0.006    0.220    24.7>             e  Escape
    0.4 ♦   -0.010    0.207    23.3>             [  Channel Enable
    0.5 ♦   -0.003    0.188    19.3>             ]  Channel Disable
    0.6 ♦    0.016    0.200    22.3>             {  HV ON
    0.7 ♦    0.006    0.250    21.6>             }  HV OFF
                                   >         s (c)  System (Chan)
           Meas uA  MePk uA   Meas V>      Shft0-F  Slot0-15
    1.0 ♦    0.013    0.241    21.5>        PF3(4)  Prev (Next) Display
    1.1 ♦   -0.001    0.210    21.8>             u  Display Up
    1.2 ♦   -0.008    0.226    21.9>             >  Select
    1.3 ♦   -0.002    0.203    22.7>             /  Delta
    1.4 ♦   -0.013    0.221    21.8>         S (R)  Save (Restore)
    1.5 ♦   -0.013    0.203    21.7>             w  Toggle Screen Width
    1.6 ♦   -0.009    0.218    20.5>
    1.7 ♦   -0.002    0.207    19.4>
vvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvv
```

8. This shows a partial display of the first two HV cards plus the help screen. Typing “w” toggles to the full display, shown below:



```
                                                                      EDIT
      0.0                                En

°                         Channel vs Value                          HV ON
Channel S  Meas uA  MePk uA   Meas V Target V  RUp V/s  RDn V/s  Trip uA>
    0.0 ♦    0.006    0.252    21.9      0.0       10       20    2.000>
    0.1 ♦    0.004    0.214    24.0      0.0       10       20    2.000>
    0.2 ♦   -0.007    0.217    19.9      0.0       10       20    2.000>
    0.3 ♦    0.006    0.220    24.7      0.0       10       20    2.000>
    0.4 ♦   -0.010    0.207    23.3      0.0       10       20    2.000>
    0.5 ♦   -0.003    0.188    19.3      0.0       10       20    2.000>
    0.6 ♦    0.016    0.200    22.3      0.0       10       20    2.000>
    0.7 ♦    0.006    0.250    21.6      0.0       10       20    2.000>
                                                                       >
           Meas uA  MePk uA   Meas V Target V  RUp V/s  RDn V/s  Trip uA>
    1.0 ♦    0.013    0.241    21.5      0.0       10       20    2.000>
    1.1 ♦   -0.001    0.210    21.8      0.0       10       20    2.000>
    1.2 ♦   -0.008    0.226    21.9      0.0       10       20    2.000>
    1.3 ♦   -0.002    0.203    22.7      0.0       10       20    2.000>
    1.4 ♦   -0.013    0.221    21.8      0.0       10       20    2.000>
    1.5 ♦   -0.013    0.203    21.7      0.0       10       20    2.000>
    1.6 ♦   -0.009    0.218    20.5      0.0       10       20    2.000>
    1.7 ♦   -0.002    0.207    19.4      0.0       10       20    2.000>
vvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvv
```

There is more information than can be displayed on one screen. The arrow (>)shows the direction where more data can be found. Use the keyboard arrow keys to move the cursor to different cells – moving all the way to the right or bottom will cause the display to shift over or down.

The rows are labeled by the crate slot number of the HV card and the output channel within the card. Each CARD controls TWO sectors (either inner or outer).

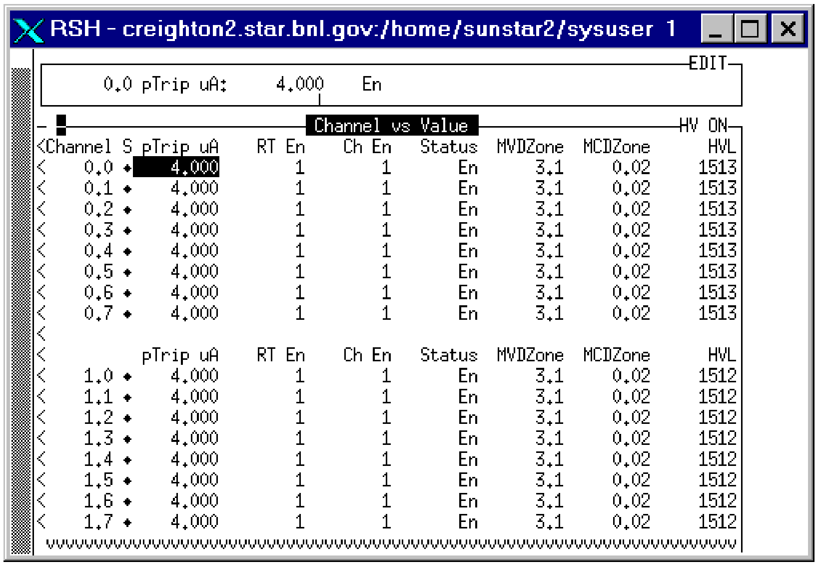
A translation table between the serial window designation (Card slot #.channel #) and the actual Sector & Section is shown below :

INNER			INNER			Outer			Outer		
Lecroy	Sector	Section	Lecroy	Sector	Section	Lecroy	Sector	Section	Lecroy	Sector	Section
0.0	1	1	6.0	13	1	0.0	1	5	6.0	13	5
0.1	1	2	6.1	13	2	0.1	1	6	6.1	13	6
0.2	1	3	6.2	13	3	0.2	1	7	6.2	13	7
0.3	1	4	6.3	13	4	0.3	1	8	6.3	13	8
0.4	2	1	6.4	14	1	0.4	2	5	6.4	14	5
0.5	2	2	6.5	14	2	0.5	2	6	6.5	14	6
0.6	2	3	6.6	14	3	0.6	2	7	6.6	14	7
0.7	2	4	6.7	14	4	0.7	2	8	6.7	14	8
1.0	3	1	7.0	15	1	1.0	3	5	7.0	15	5
1.1	3	2	7.1	15	2	1.1	3	6	7.1	15	6
1.2	3	3	7.2	15	3	1.2	3	7	7.2	15	7
1.3	3	4	7.3	15	4	1.3	3	8	7.3	15	8
1.4	4	1	7.4	16	1	1.4	4	5	7.4	16	5
1.5	4	2	7.5	16	2	1.5	4	6	7.5	16	6
1.6	4	3	7.6	16	3	1.6	4	7	7.6	16	7
1.7	4	4	7.7	16	4	1.7	4	8	7.7	16	8
2.0	5	1	8.0	17	1	2.0	5	5	8.0	17	5
2.1	5	2	8.1	17	2	2.1	5	6	8.1	17	6
2.2	5	3	8.2	17	3	2.2	5	7	8.2	17	7
2.3	5	4	8.3	17	4	2.3	5	8	8.3	17	8
2.4	6	1	8.4	18	1	2.4	6	5	8.4	18	5
2.5	6	2	8.5	18	2	2.5	6	6	8.5	18	6
2.6	6	3	8.6	18	3	2.6	6	7	8.6	18	7
2.7	6	4	8.7	18	4	2.7	6	8	8.7	18	8
3.0	7	1	9.0	19	1	3.0	7	5	9.0	19	5
3.1	7	2	9.1	19	2	3.1	7	6	9.1	19	6
3.2	7	3	9.2	19	3	3.2	7	7	9.2	19	7
3.3	7	4	9.3	19	4	3.3	7	8	9.3	19	8
3.4	8	1	9.4	20	1	3.4	8	5	9.4	20	5
3.5	8	2	9.5	20	2	3.5	8	6	9.5	20	6
3.6	8	3	9.6	20	3	3.6	8	7	9.6	20	7
3.7	8	4	9.7	20	4	3.7	8	8	9.7	20	8
4.0	9	1	10.0	21	1	4.0	9	5	10.0	21	5
4.1	9	2	10.1	21	2	4.1	9	6	10.1	21	6
4.2	9	3	10.2	21	3	4.2	9	7	10.2	21	7
4.3	9	4	10.3	21	4	4.3	9	8	10.3	21	8
4.4	10	1	10.4	22	1	4.4	10	5	10.4	22	5
4.5	10	2	10.5	22	2	4.5	10	6	10.5	22	6
4.6	10	3	10.6	22	3	4.6	10	7	10.6	22	7
4.7	10	4	10.7	22	4	4.7	10	8	10.7	22	8
5.0	11	1	11.0	23	1	5.0	11	5	11.0	23	5
5.1	11	2	11.1	23	2	5.1	11	6	11.1	23	6
5.2	11	3	11.2	23	3	5.2	11	7	11.2	23	7
5.3	11	4	11.3	23	4	5.3	11	8	11.3	23	8
5.4	12	1	11.4	24	1	5.4	12	5	11.4	24	5
5.5	12	2	11.5	24	2	5.5	12	6	11.5	24	6
5.6	12	3	11.6	24	3	5.6	12	7	11.6	24	7
5.7	12	4	11.7	24	4	5.7	12	8	11.7	24	8

The columns in the serial session window are as follows:

Channel	Output	
S (status)	Output	Blank = disabled, ♦ = enabled, ⊥ = tripped
Meas μA	Output	Measured current (not baseline corrected)
MePk μA	Output	Measured peak current (~ .2 -.3 even with 0 volts)
Meas V	Output	Measured voltage
Target V	Input	Demand voltage
Rup V/s	Input	Voltage ramp up rate (should be 10 V/s)
RDn V/s	Input	Voltage ramp down rate (should be 20 V/s)
Trip μA	Input	Current trip limit (should be 2.0 μA)

Shifting the display over reveals more columns:

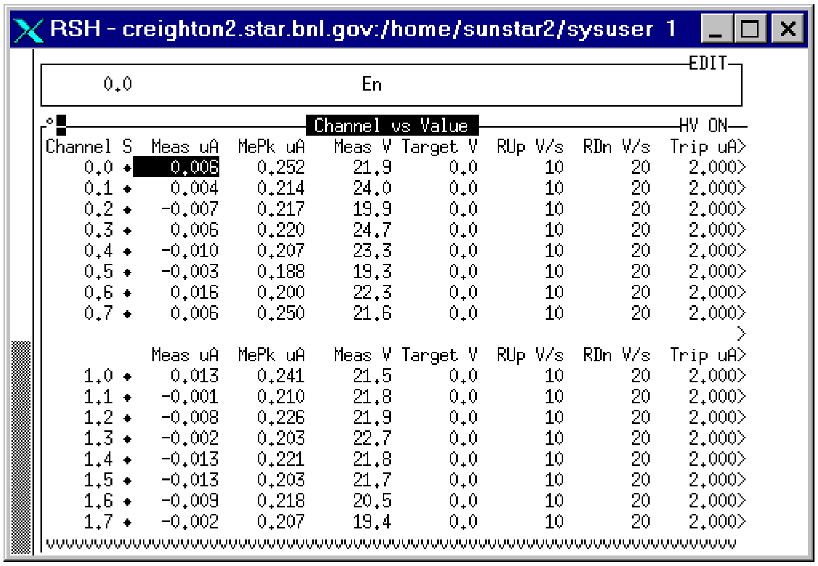


```
                                                           EDIT
     0.0 pTrip uA:      4.000     En

-                        Channel vs Value                  HV ON
<Channel S pTrip uA    RT En    Ch En   Status  MVDZone  MCDZone     HVL
<    0.0 ♦    4.000        1        1       En      3.1     0.02    1513
<    0.1 ♦    4.000        1        1       En      3.1     0.02    1513
<    0.2 ♦    4.000        1        1       En      3.1     0.02    1513
<    0.3 ♦    4.000        1        1       En      3.1     0.02    1513
<    0.4 ♦    4.000        1        1       En      3.1     0.02    1513
<    0.5 ♦    4.000        1        1       En      3.1     0.02    1513
<    0.6 ♦    4.000        1        1       En      3.1     0.02    1513
<    0.7 ♦    4.000        1        1       En      3.1     0.02    1513
<
<          pTrip uA    RT En    Ch En   Status  MVDZone  MCDZone     HVL
<    1.0 ♦    4.000        1        1       En      3.1     0.02    1512
<    1.1 ♦    4.000        1        1       En      3.1     0.02    1512
<    1.2 ♦    4.000        1        1       En      3.1     0.02    1512
<    1.3 ♦    4.000        1        1       En      3.1     0.02    1512
<    1.4 ♦    4.000        1        1       En      3.1     0.02    1512
<    1.5 ♦    4.000        1        1       En      3.1     0.02    1512
<    1.6 ♦    4.000        1        1       En      3.1     0.02    1512
<    1.7 ♦    4.000        1        1       En      3.1     0.02    1512
 vvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvv
```

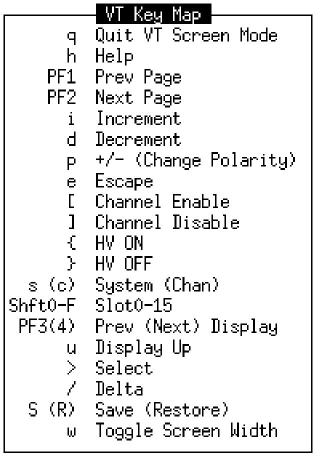
pTrip μA	Input	Peak current trip limit (should be 4.0 μA)
RT en	Input	Ramp trip enable (trips a channel during ramp up is current exceeds 40 μA (should be 1)
Ch En	Input/Output	Enable status (0=disabled, 1=enabled)
Status	Output	Channel status (Shows trip codes)
MVDZone	Input	Voltage Dead Zone – variations in measured voltage smaller than this value will not be updated on the screen (should be 3.1 V)
MCDZone	Input	Current dead zone – variations in measured current smaller than this value will not be updated on the screen (should be 0.02)
HVL		Hardware voltage trip limit – set by front panel pot on the card. Outer = 1510 Inner = 1210

9. To control the HV you only need a few commands:



```
                                                            EDIT
      0.0                        En

°                    Channel vs Value                        HV ON
Channel S  Meas uA  MePk uA   Meas V Target V  RUp V/s  RDn V/s  Trip uA>
    0.0 ◆    0.006    0.252     21.9      0.0       10       20    2.000>
    0.1 ◆    0.004    0.214     24.0      0.0       10       20    2.000>
    0.2 ◆   -0.007    0.217     19.9      0.0       10       20    2.000>
    0.3 ◆    0.006    0.220     24.7      0.0       10       20    2.000>
    0.4 ◆   -0.010    0.207     23.3      0.0       10       20    2.000>
    0.5 ◆   -0.003    0.188     19.3      0.0       10       20    2.000>
    0.6 ◆    0.016    0.200     22.3      0.0       10       20    2.000>
    0.7 ◆    0.006    0.250     21.6      0.0       10       20    2.000>
                                                                        >
           Meas uA  MePk uA   Meas V Target V  RUp V/s  RDn V/s  Trip uA>
    1.0 ◆    0.013    0.241     21.5      0.0       10       20    2.000>
    1.1 ◆   -0.001    0.210     21.8      0.0       10       20    2.000>
    1.2 ◆   -0.008    0.226     21.9      0.0       10       20    2.000>
    1.3 ◆   -0.002    0.203     22.7      0.0       10       20    2.000>
    1.4 ◆   -0.013    0.221     21.8      0.0       10       20    2.000>
    1.5 ◆   -0.013    0.203     21.7      0.0       10       20    2.000>
    1.6 ◆   -0.009    0.218     20.5      0.0       10       20    2.000>
    1.7 ◆   -0.002    0.207     19.4      0.0       10       20    2.000>
vvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvv
```

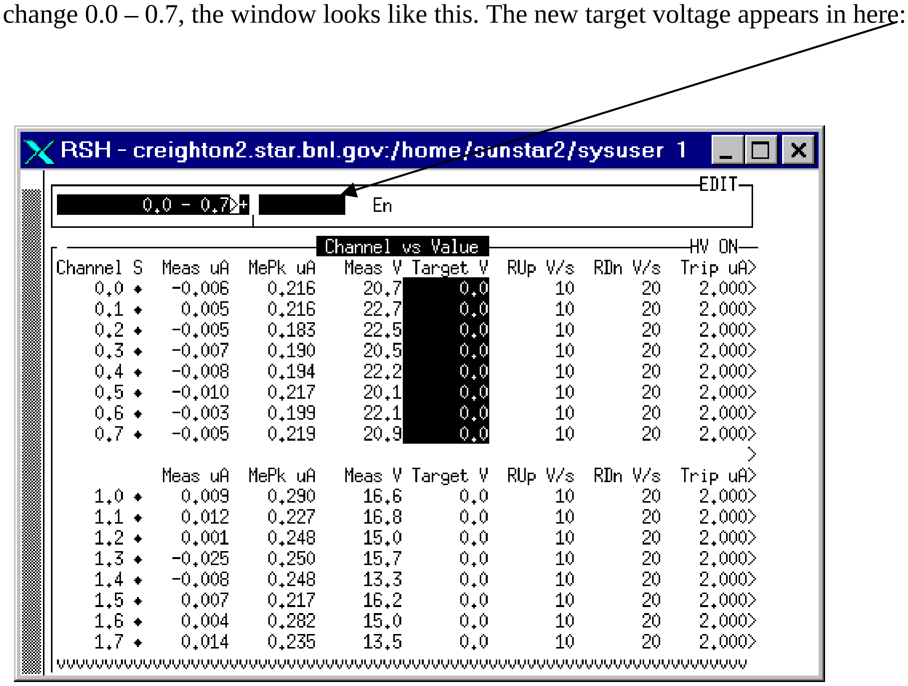


```
        VT Key Map
       q  Quit VT Screen Mode
       h  Help
     PF1  Prev Page
     PF2  Next Page
       i  Increment
       d  Decrement
       p  +/- (Change Polarity)
       e  Escape
       [  Channel Enable
       ]  Channel Disable
       {  HV ON
       }  HV OFF
   s (c)  System (Chan)
Shft0-F   Slot0-15
 PF3(4)   Prev (Next) Display
       u  Display Up
       >  Select
       /  Delta
   S (R)  Save (Restore)
       w  Toggle Screen Width
```

{	Turns the HV ON for the <u>whole crate.</u>
}	Turns the HV OFF for the <u>whole crate</u>
[	Enables the HV for the channel (row) that has the cursor (ie channel 0.0 above)
]	Disables the HV for the channel.
Shft 0-B	Scrolls up/down to slot (0 – B) There are 12 slots occupied in each crate.

To change the target (demand) voltage for ONE channel, use the arrow keys to move the cursor to the “Target V” column for that channel. Then type in the needed voltage and hit CR.

To change the target voltage for multiple channels, use the select key. First, move the cursor to the “Target V” column of the first channel to change. Then type > and use the down arrow to highlight more channels. When all channels of interest have been highlighted, type in the desired voltage and CR. Thus, to change 0.0 – 0.7, the window looks like this. The new target voltage appears in here:



```
                                                            EDIT
        0.0 - 0.7>+             En

                     Channel vs Value                        HV ON
Channel S  Meas uA  MePk uA   Meas V Target V  RUp V/s  RDn V/s  Trip uA>
    0.0 ◆   -0.006    0.216     20.7      0.0       10       20    2.000>
    0.1 ◆    0.005    0.216     22.7      0.0       10       20    2.000>
    0.2 ◆   -0.005    0.183     22.5      0.0       10       20    2.000>
    0.3 ◆   -0.007    0.190     20.5      0.0       10       20    2.000>
    0.4 ◆   -0.008    0.194     22.2      0.0       10       20    2.000>
    0.5 ◆   -0.010    0.217     20.1      0.0       10       20    2.000>
    0.6 ◆   -0.003    0.199     22.1      0.0       10       20    2.000>
    0.7 ◆   -0.005    0.219     20.9      0.0       10       20    2.000>
                                                                        >
           Meas uA  MePk uA   Meas V Target V  RUp V/s  RDn V/s  Trip uA>
    1.0 ◆    0.009    0.290     16.6      0.0       10       20    2.000>
    1.1 ◆    0.012    0.227     16.8      0.0       10       20    2.000>
    1.2 ◆    0.001    0.248     15.0      0.0       10       20    2.000>
    1.3 ◆   -0.025    0.250     15.7      0.0       10       20    2.000>
    1.4 ◆   -0.008    0.248     13.3      0.0       10       20    2.000>
    1.5 ◆    0.007    0.217     16.2      0.0       10       20    2.000>
    1.6 ◆    0.004    0.282     15.0      0.0       10       20    2.000>
    1.7 ◆    0.014    0.235     13.5      0.0       10       20    2.000>
vvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvvv
```

Since there are only 4 sectors visible in the serial session windows at a time, it is NOT recommended as a method for operating the entire TPC. It is useful for checking that the slow controls GUI is operating properly or for resetting one or two channels.

TURNING OFF

If the TPC is to be off for some time it is best to reduce the voltages to zero and close all the active windows properly. This includes the serial sessions, VME terminal server windows and the GUI. Sessions that aren't closed out can cause problems later.

SERIAL SESSIONS

1. Do the following for each window (inner and outer):

2. Type q. This gets back to the "1\EDIT\1450>" prompt.

3. Type quit CR It will say "bye bye". Type ~. (tilde, period) This will end the tip session and return to the creighton2 prompt. Type exit to get to sc then exit again to close out.

SCSERV SESSIONS (VME)

1. Do the following for both 9006 (inner) and 9013 (outer).

2. Type CTRL]. This will get the telnet prompt. Type quit to get back to sc then exit to close.

SLOW CONTROLS GUI

1. Using the "ALL SECS" control window, set the demand voltage for inner and outer to 0.

2. Wait for the voltage to ramp down. When the measured voltage reads ~ 20 V, push "Disabled" for both inner and outer.

3. When the status turns grey, return to the main GUI and click "HV OFF" for both. The HV status lights will turn grey.

4. Close all auxiliary windows and then close the main Anode GUI.

TROUBLESHOOTING

1. All the anode HV are on and one of the VME processors is spewing out error messages and the ARCNET light is red! Can I safely reboot?

YES – The Lecroy stores the setpoints locally and the HV will stay on while the VME reboots. All trip functionality is also working.

2. The TPC is up and running and all of a sudden ALL the HV go off (including gated grid and cathode) and there is a loud beeping noise. What the hell?

Gas alarm – some critical gas system parameters (methane content, TPC pressure etc) are tied into the interlock system. Under certain conditions, ALL TPC HV are turned off. To recover after the gas system is operational again, first run all demand voltages (for all systems) to zero and start from scratch.

Cathode

TPC CATHODE HV

1. Introduction

The TPC cathode high voltage is supplied by a Glassman 100 kV power supply Model # PS/WK100N6CTS30. In the model number, 100N means 100 kV negative polarity, CT means an optional current trip capability and S30 means “slow turn on” with a ramp to maximum of 30 seconds. The power supply in use is mounted in Rack Row 2A3 on the platform. The VME control crate for the cathode is mounted directly below the power supply. The canbus address for this crate is 57.

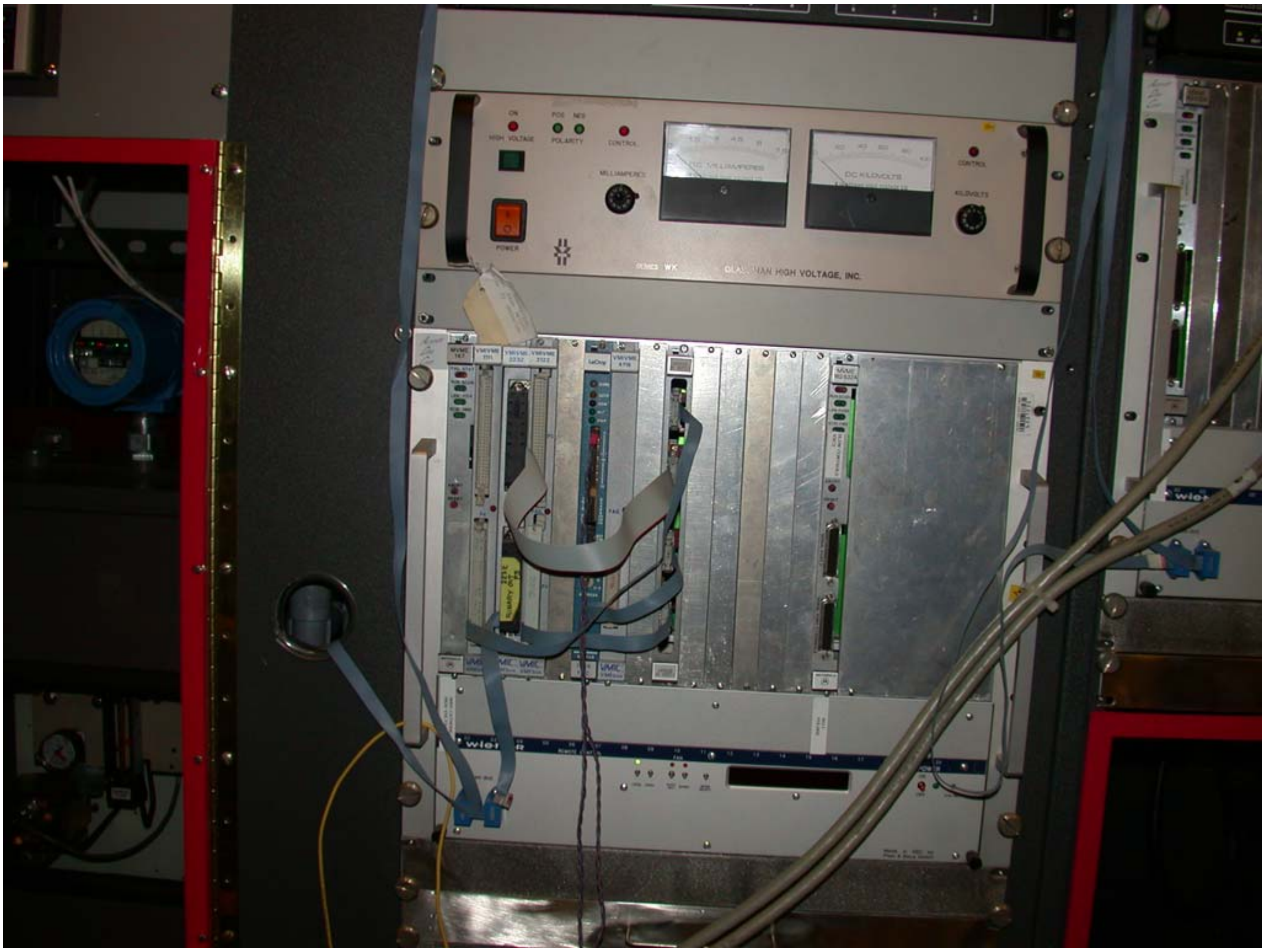


Figure 1

The back of the power supply is shown below:

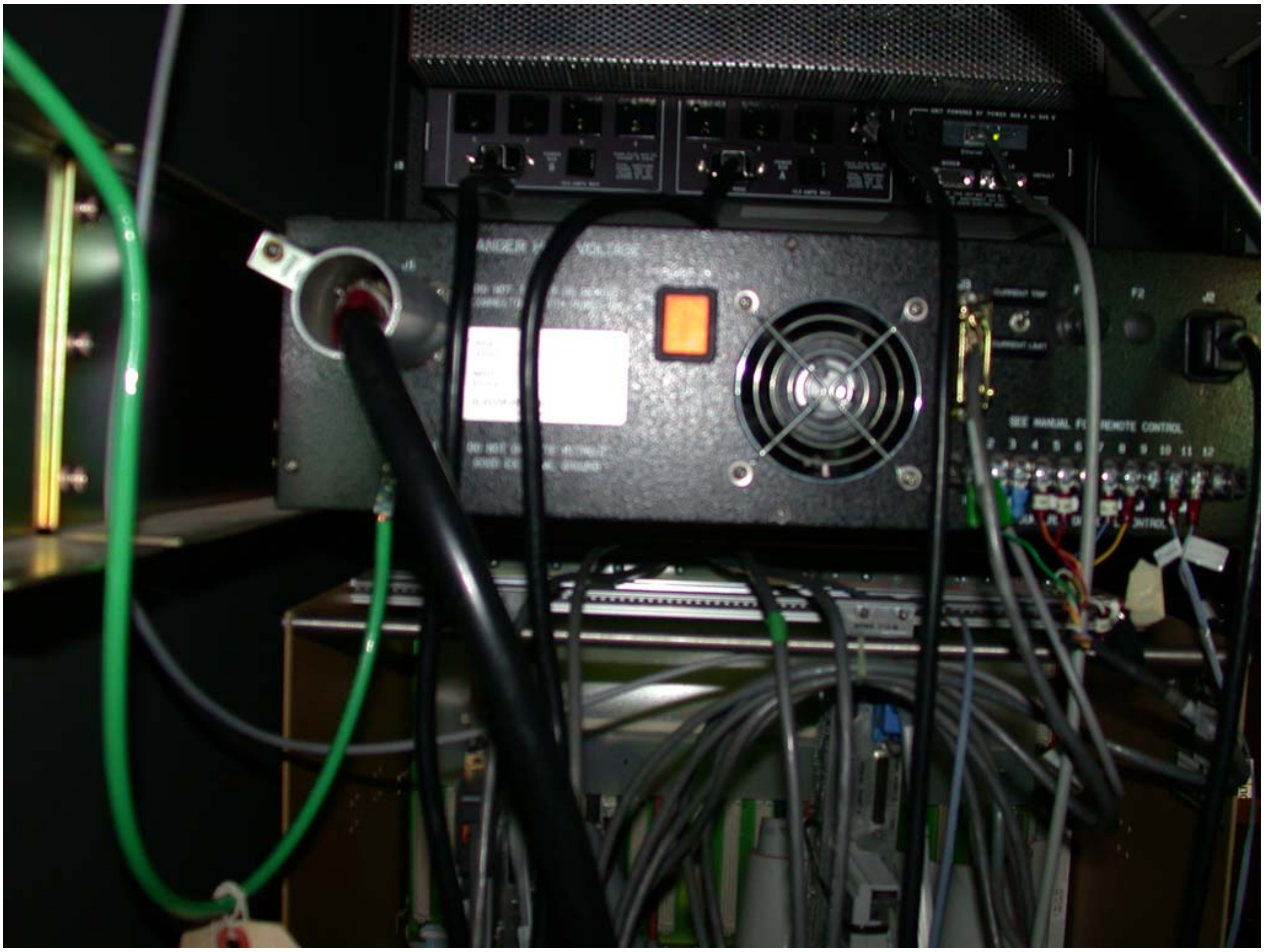


Figure 2

The slow controls for the power supply were developed by Tom Trainor and Greg Harper at the University of Washington. The power supply has been modified slightly to provide some control signals – the modifications are well documented in the schematic that is kept with the manual. We have one spare power supply that is identical to the one in use. It is kept on the platform in Rack row 2B5. The spare was used briefly a few years ago when we were checking for the source of some noise on the field cage, so it is known to work properly.

2. Hardware Connections

The main HV cable runs from the power supply through the platform cable tray up to the TPC wheel near sector 13 on the east side of STAR. The cable is a large diameter black HV cable with a red tape stripe every few feet. The cable travels down a channel at the outer radius of the field cage and makes the connection to the central membrane via a banana plug connector – the cable also has a connector that screws onto a fitting at the TPC wheel to secure it. At the power supply (see Fig 2) the cable screws into the connector on the back of the supply. The connector is covered with an aluminum tube that is also screwed to a bracket on the power supply – this is an extra safety measure which was imposed by RHIC – the theory being that it takes a “tool” to actually unplug the connector. (Don’t ask me why…). There is also a sealed transition fitting that connects the supplied Glassman cable to the long cable that goes to the TPC face. This transition piece is in the cable tray under the third floor of the platform. It is visible if you stand looking at the back of the Glassman and look up.

In addition to the power cable, a large ground return cable is bolted to the TPC face on the east side and run to the inside of the Rack 2B3. The rack is then bonded to the ground post of the power supply.

Also visible in Fig 2 are the remote control cables for the power supply: a terminal strip at the lower right, and above that a DB25? connector with a bronze hood. Just to the right of the connector is a small toggle switch – this is the selector for the current trip option (it should be up!)

To allow for a remote AC power cycle of the Glassman it is plugged into a remote power switch accessible via telnet. The RPS is mounted in Rack 2A3. The internet address is

rps2.starp.bnl.gov and the Glassman is in plug #1.

See the section on RPS for the instructions and password.

3. VME controls

The VME crate for controlling the cathode HV is shown in Fig 1. From left to right, the modules are:

1. VME processor – scserv port 9005
2. VMIVME-1111 64-Bit Differential Digital Input
3. VMIVME-2232 32 Channel Relay Output Board
4. VMIVME-3122 16 Bit A to D Converter
5. Lecroy 1176 TDC
6. VMIVME-4116 8 Channel 16 Bit Analog Output
7. Homemade connection interface board

Figure 2 also shows a second VME processor in the crate, but that has been removed to become a spare. It was for the pulser originally.

We have manuals and one spare module each for all these boards. The connections from these modules to the Glassman are well documented in the paper work that came from Greg Harper (U of Washington). In addition, the hookup of the terminal strip on the back of the Glassman is as follows: (plus see pg 54 of my notebook 1)

Terminal connector TB1 on back of Glassman:

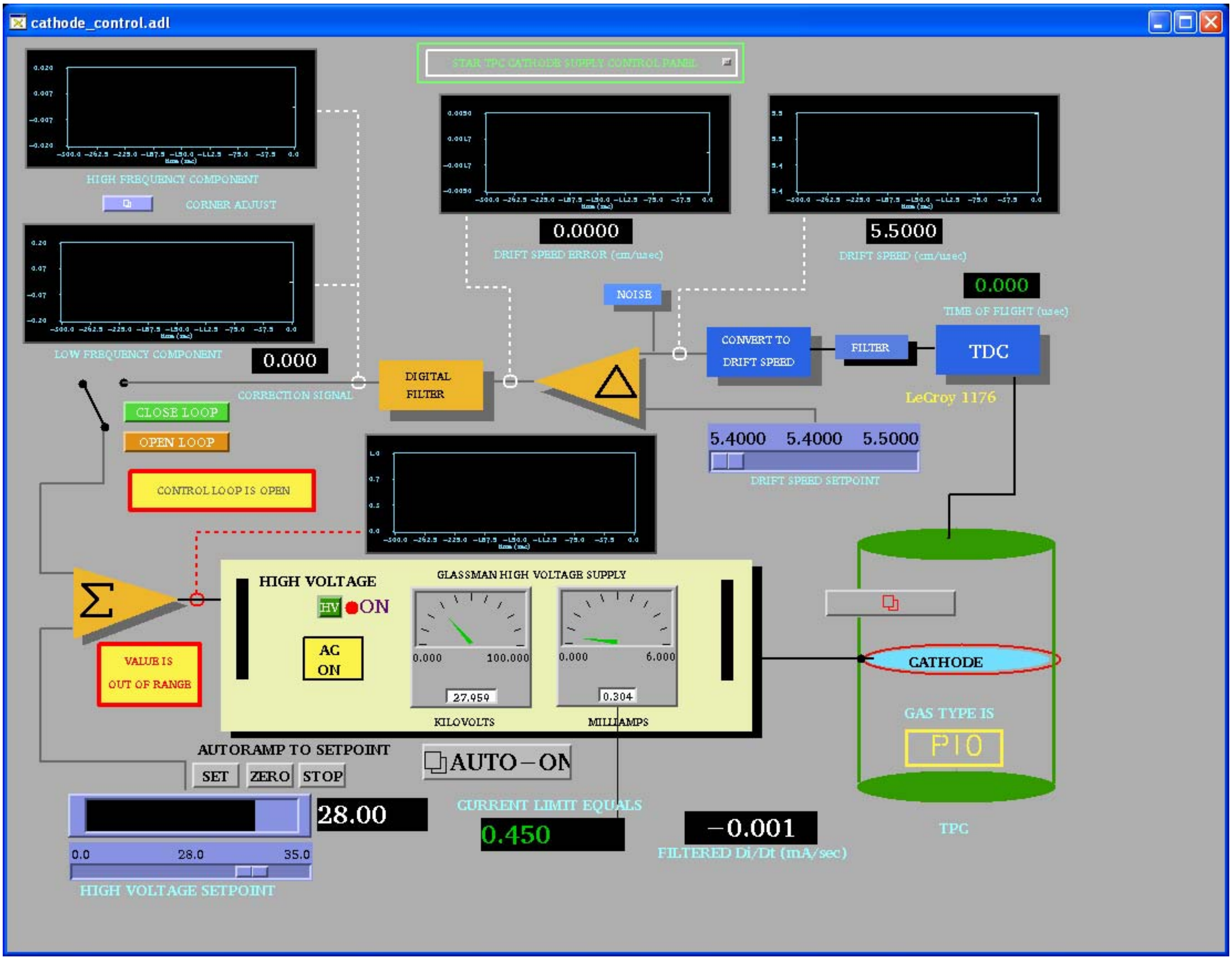
Terminal	Cable
1	#1 Green
2	Red from TPC interlock
3	Black (common) from interlock
4	#4 Orange
5	#5 Red
6	Not connected
7	#7 Blue
8	#8 Yellow
9	Not connected
10	HV enable
11	HV enable common

2 & 3 are the interlock permissive cable from the TPC AB interlock system in rack 2A8. This signal will turn off the HV in case of a STAR global alarm, or in case of a gas system problem.

10 & 11 were added by Mike Cherney and me in 1999 to allow for a remote reset of the Glassman (see below for slow controls interface.)

4. Slow Controls GUI

The main control GUI for the cathode is available from the TPC top level GUI. The cathode GUI looks like:



The picture shows the Glassman set to the canonical value of 28 kV. Note that the voltage readback shows 27.959 kV – this difference has always been there and varies between -30 and -40 volts and is probably due to a mis-calibration of the slow controls. We have run this way for many years. Note also that the total current draw for the supply is .305 milliamps and reflects the ~76 microamps down the 4 resistor chains. The current trip limit is .450 milliamps (see below for where this is set). Note also that the AC is on and the HV is “ON” as indicated by the red light. (This is really a HV enabled light.)

The rest of the graphs and indicators on the GUI are no longer used. They were developed to run the TPC in a constant drift velocity mode, not a constant voltage mode. The theory was to turn the laser on automatically every ~ hour and use a signal from the anode wires that came from the laser flash off the central membrane. This “stop” signal went to the TDC in the VME crate and the program would raise or lower the HV to bring the measured drift time back to the desired drift time (and hence velocity). The laser was then turned off automatically. This was a very elegant way of running in theory (and actually worked a few times) but it was ultimately defeated by all the other “background” signals in the chamber.

Under normal running conditions, the Glassman stays on and enabled – the detector operators merely ramp the HV up to the final value using the autoramp program after the RHIC beams are ready for physics running. The autoramp program is also used to turn the HV off before the beams are dumped. The autoramp program is a separate GUI available by clicking on the “AUTO-ON” button on the Glassman GUI:

I await your command, master

The autoramp program ramps the HV to 10 kV, checks the four field cage currents, then ramps to 20 kV, checks the currents, and then ramps to 28 kV and checks the currents one more time. If the currents are all equal, within specs, the cathode is declared ready for physics.

If the autoramp program detects a problem with the currents it will automatically ramp the voltage back to 0 and put up a “trouble” message for the operator. They should then call an expert. The autoramp program runs in a separate VME processor from the cathode processor. It currently runs in a processor in the DAQ room (stargate.starp.bnl.gov).

Note that if the cathode voltage is on and it is necessary to reboot the autoramp processor, the voltage will reset to zero.

The autoramp GUI also has a “stop” button if the operator wants to interrupt the ramp, and a reset button to bring the program back to a known state.

5. Initial turn-on of the Glassman

After a long shutdown, the cathode HV system should be turned on as follows:

1. Make sure the RPS2 is on – log into RPS2 and check that plug 1 is on.

2. Turn on the AC rocker switch on the Glassman. (Note – this AC switch can only be turned on at the Glassman. The GUI button that shows AC off or on is only an indicator, not a switch.)

3. Turn on crate 57 and wait for the processor to boot up. To be sure the boot process finished, you can watch the boot by telneting to scserv 9005.

4. Check the status of the TPC interlock – cathode HV enabled output should be green (OK) or flashing green (override OK).

5. Using the GUI or the button on the front of the Glassman push the HV on button. Check that the red “HV on” light is on.

6. Check that the green negative polarity light is on and that the red control led above the kilovolts pot is lit. (The power supply must not be in current control mode.)

7. Use the slider on the GUI to set 1 kV and push the “set” button – the supply should ramp to 1.0 kV and show some current on the readback. Set the slider back to 0 and push set. The supply should ramp to 0.

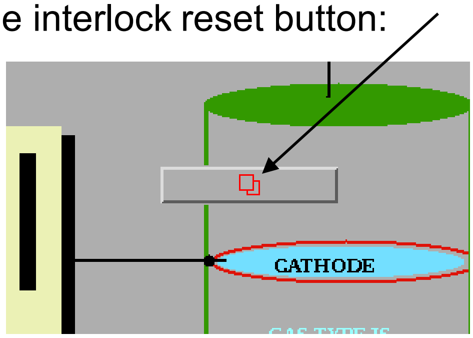
6. Interlocks and Trips

The Glassman HV is enabled by an output from the TPC Allen-Bradley interlock system. The main AB system and indicator panel are in the gas mixing room. There is also a readout of the panel available via slow controls from the top level TPC GUI. The HV enable can be dropped for multiple reasons: smoke or fire on the platform, methane detected by the platform methane sniffer, no air flow through the IFC region, TPC gas system problems or shutdown, or methane detected in the outer TPC insulation volume. In this case the green "Cathode HV enable" indicator on the AB panel will go out and the red "Cathode HV off" button will light and the HV will be disabled. To restore the HV:

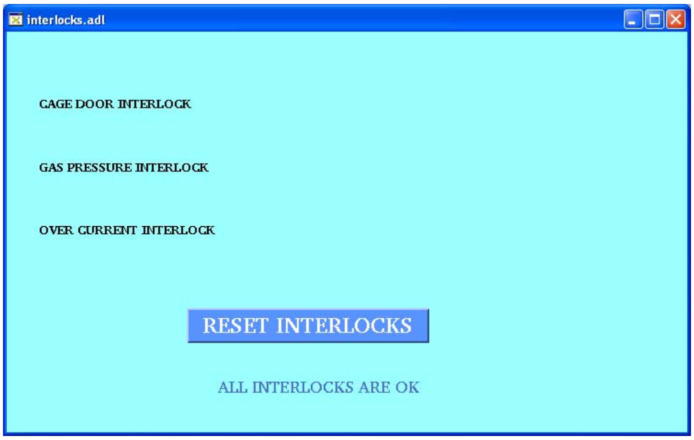
1. Find the source of the alarm and clear the problem.

2. Once the alarm condition has been cleared, go to the gas mixing room and push the green "Cathode HV Enabled" button – it should light if the reason for the alarm has been cleared. Note that the interlock will NOT clear by itself – interlocks stay latched off until operator action is taken.

3. On the Glassman GUI click on the interlock reset button:



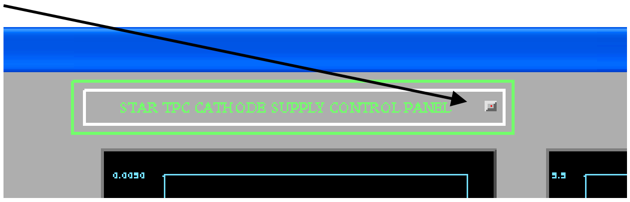
4. This brings up the interlock panel – sometimes a red box will pop up also telling you to "check the interlocks". Click on "Reset Interlocks" and kill the window.



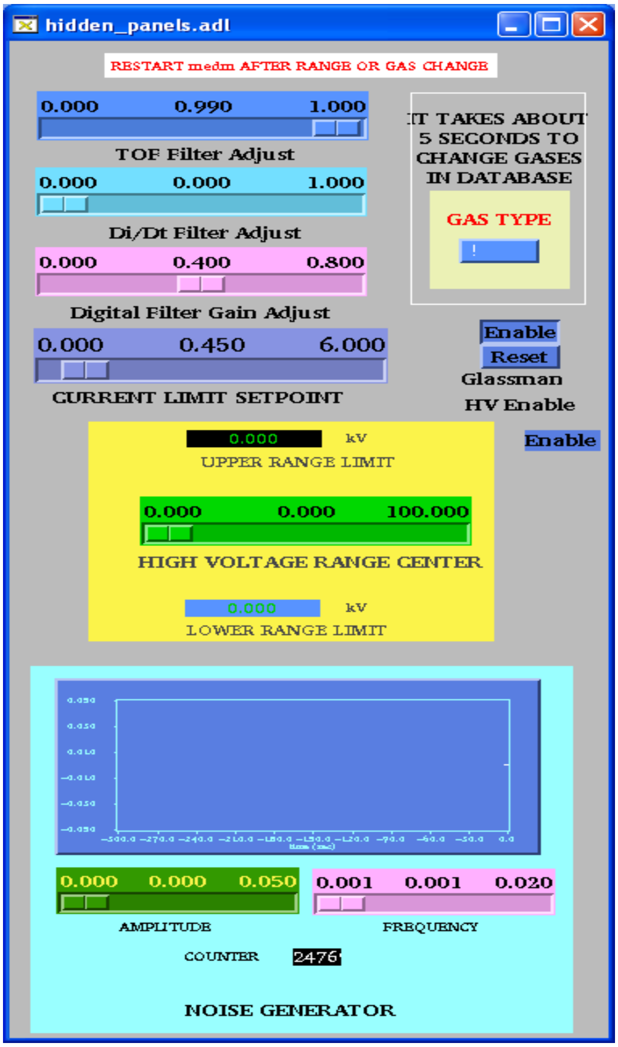
ALL INTERLOCKS ARE OK

5. On the main Glassman GUI check if the High Voltage indicator is off or on – if off, click on the green HV button to re-enable the HV. You should then be able to raise the HV again.

Rarely, usually due to a bad RHIC abort, the cathode HV will trip on current overload. (Recall the trip limit is .450 milliamps). To clear this trip you need to bring up the super secret, operators only GUI. On the main Glassman GUI find the small button labeled "STAR TPC Cathode Supply Control Panel" near the top of the main GUI:



This brings up the settings page:



Most of the settings on this page refer to the unused feedback mode. The one setting that might be used is for the current limit set point (set at 0.450). To reset a current trip, push the Glassman HV Enable "Reset" button and then push the "Enable" button.

Close this window and check the main Glassman GUI. If the HV indicator is off click the green HV button to re-enable the HV. You should then have control again. After a current trip I usually check the field cage currents at 2 kV to make sure there was no damage to the structure.

6. Troubleshooting

In general the cathode HV has been a very reliable system. I rarely have to reboot the processor during a run. Usually operator problems are connected with the autoramp processor rebooting or crashing, but for run 8 it seemed very stable. We think this may be because ITD has not scanned our systems during the run. I recall one strange episode where the Glassman got into a funny state – see pages 123 & 124 in Notebook 1.

If the cathode voltage seems to be dead, try the following:

1. Check the TPC interlock system to make sure the Cathode HV is enabled. Note that one subtle problem occurs when the methane content in the insulation gap goes above 18% LEL – the AB interlock system will drop the permissive, but there will be no alarm like when the main gas system alarms. The permissive will stay latched off until it gets reset – even if the methane goes back down. This has happened multiple times.

2. If the AB interlock is enabled, check the HV status on the GUI. If it is off, first clear the interlock on the sub-GUI and then click on the HV button.

3. If it still won't come on, go to the super secret sub-GUI and use the reset and then enable buttons. Try to turn on the HV again on the main GUI.

4. If still no, log into RPS2 and power cycle the Glassman.

5. If still no, power cycle crate 57 - wait for the processor to reboot and try again.

3/31/01) PUT ONE CARD BACK IN.

CONFIG = SAME PUPSTATUS SAME
LEAVE IT OVERNIGHT

4/1/01) STILL ON - MAYBE HV HAS TO BE ON?
TURN ON 200V (CABLES NOT CONNECTED)
2 CARDS STILL PULLED OUT
LEAVE OVERNIGHT

4/2/01) CONFIG 2274 0000 0008 0000 008B
PUPSTATUS 2 2001 1

0930) PUT 1 CARD BACK IN - 1 STILL OUT
200V AGAIN - CABLES DISCONNECTED
... ON FOR ~10 HOURS, THEN TURN HV OFF

4/4/01) PUT LAST CARD BACK IN.
200V - CABLES DISCONNECTED

4/4/01) GLASSMAN HOOKUP:

AC = RPS2 PLUG A1
TOGGLE = CURRENT TRIP
FRONT POT CURRENT LIMIT = 1.20
KV = 0.0

TB1

JUMPER [1 = #1 GREEN
2 = RED FROM AB
3 = BLACK FROM AB
4 = 4 ORANGE
5 = 5 RED
6 = NC
7 = 7 BLUE
8 = 8 YELLOW
9 = NC

10 = HV ENABLE
11 = HV ENABLE COMMON

CABLE 2, 3 NC

5007091	ALL BEAM
092	12+6 + 8 (WEST)
093	2+8
094	4+8 + 10 EAST

4] 1000) CATHODE TRIPS AGAIN - PROBABLY ON OVERCURRENT, UNCLEAR IF IT WAS BEAM INDUCED. NO BEAM NOW - TRY FULL V

	10KV	20KV	28KV	
N	27.4165	54.721	76.561	
N	27.417	54.719	76.557	
W	27.415	54.717	76.552	
W	27.569	55.021	76.979	Δ = 422

04] 0920) SPECIAL LASER RUNS TO TRY + UNDERSTAND SHORTED STRIPE CORRECTION PTB = 1011

B FIELD ON B POLARITY

SUMMED INNER ANODE CURRENT = ~.2µA

INJECTION CLOCK? 9.3411 MHZ

RUN	5012032	PED		
IN	033	ALL BEAMS	CATH = 28KV	GG = 115
RUN	034	2+8 OCLOCK	″	″
RUN	035	2+8 OCLOCK	CATH = 31KV	GG = 127
RUN	036	ALL BEAMS	″	″
RUN	037	ALL BEAMS	CATH = 25KV	GG = 103
RUN	038	2+8 OCLOCK	CATH = 25	GG = 103

/04]

ANODE TRIP : inner sector 15, chanel 2
beam was on (physics)

] CALLED IN AT 11:30PM. CATHODE WAS HAVING ~ "6 mA") SPIKES + WAS TRIPPING INTERLOCK (SOFTWARE, NOT HARDWARE). THE HV LIGHT STAYED ON + WHEN DENNIS CLEARED THE INTERLOCK - THE HV BANGED BACK ON @ 28KV. THEN WOULD TRIP AGAIN. WE CYCLE AC POWER SIMULTANEOUSLY (BOO!) ON GLASSMAN + VME CRATE. PROBLEM DISAPPEARS, THERE WERE 2 PHYSICS RUNS (OF ~2HRS EACH) OVERNIGHT W/ NO PROBLEM. CURRENT LIMIT (SOFTWARE) = .450 mA

TOTAL CURRENT @ 28KV = 4 × 77 ≅ .308 mA

GLASSMAN SUPPLY TOTAL CURRENT = 6 mA (HMM...)

1/14/04 (CON'T) READ BACK GLASSMAN CURRENT IS READ BY:

VMIC 3122 ANALOG INPUT BOARD (CURRENT + VOLT

GLASSMAN IS ALSO SUPPOSED TO HAVE A 30 SEC "SLOW START" OPTION, i.e 30 SEC TO COME TO FULL

1/20/04) DENNIS CALLED @ 1745 LAST NIGHT - OUTER L MAINFRAME WENT BONKERS. NO ARCNET, NO S SESSION. WE CYCLE POWER (RPS3) + IT LOOKS OK. I CHECK SERIAL SESSION + SETTINGS - OK.

1/20/04) DENNIS DOUBLES RAMP RATE (UP + DOWN) FOR CATHODE. HE ALSO PUTS IN A SOFTWARE FIX TO PREVENT INTERLOCK RESET FROM BANGIN 28 KV BACK ON (PG 123).

1/21/04) ACCESS: 1. REBOOT G6
2. PUT 2 MΩ IN IFCE BEFORE

MAGNET OFF	1KV	5KV	10KV	15KV	20KV	25KV	28KV	30KV
OFCW	2.836	13.766	27.414	41,670	54.714	68.356	76.555	82.012
IFCW	2.836	13.767	27.415	41.071	54.715	68.356	76.553	82.017
OFCE	2.836	13.765	27.413	41.068	54.712	68.349	76.547	82.008
IFCE	2.836	13.766	27.415	41.071	54.715	68.355	76.552	82.013
WOFC_0	1.241	6.024	11.995	17.968	22.919	29.858	33.43	35.82
WOFC_1	6.562	31.834	63.395	94.952	126.69	150.25	177.21	189.05
WIFC_0	.882	4.277	8.515	12.757	16.994	21.229	23.774	25.469
WIFC_1	6.545	31.878	63.484	95.124	126.73	150.55	177.58	190.35
EOFC_0	1.251	6.068	12.083	18.102	24.116	30.129	33.743	36.15
EOFC_1	6.577	31.907	63.544	95.135	127.00	150.65	177.66	190.33
EIFC_0	.882	4.277	8.516	12.758	16.996	21.233	23.774	25.47
EIFC_1	6.570	31.879	63.492	95.123	126.73	150.47	177.47	190.14

1/21/04) MAG FIELD OFF LASER RUNS:

MEMBRANE = 3

RUN 5021072 PED

RUN 5021080 ALL BEAMS CLOCK = 9.2159

RUN 5021081 2 + 6 O'CLOCK

RUN 5021082 8 O'CLOCK WEST ONLY + EAST MEMB (A

FEE LVPS

FEE LVPS

1. INTRODUCTION

This section describes the Low Voltage Power Supplies (LVPS) for the TPC FEEs and RDOs. Plans currently call for all of the old TPC electronics to be replaced during the summer of 2008, but the controls and interlocks for the LVPS will remain the same. So this chapter will just cover the hardware that will be carried over to the DAQ1000 electronics, but not the old FEEs and RDOs.

2. HARDWARE INSTALLATION

The LVPS are installed on the second floor platform (Racks 2B 1-4 and 2B6-9. There are 6 LVPS chassis per rack, plus a cooling blower at the bottom of the rack. In addition, there is an interface and interlock panel at the top of each rack. The VME control crate is in Rack 2B5. Each LVPS chassis has three commercial linear power supplies inside and each power supply powers 1 RDO and its FEEs. Since there are 6 RDOs per supersector (inner and outer) there are 2 chassis per supersector. The output cable for each supply connects at the back of the chassis with a latched connector. The cables then are routed to the east/west TPC face via the cable trays.

The air cooling for the LVPS chassis is supplied by the common blower at the bottom of the rack. This consists of a chassis with a squirrel cage blower inside. The cooling air exits the back of the blower chassis and is ported to each power supply chassis using flexible dryer hose. The blower is mounted with a filter and heat exchanger below the chassis - the air is pulled from below. The LVPS are interlocked so they shut off in case the blower stops – see below for the interlock scheme.

On the front of each chassis are the LED indicators and a 3 way selector switch for each LVPS. A common blue LED is lit if the interlocks for the LVPS are enabled. A green LED is lit if the supply is on. A yellow LED is lit if the PS is in remote mode. The three way switch (VERY fragile!) selects between local off, local on or remote (ie slow controls operation). We have added some plexiglas covers to the front of each chassis because people kept inadvertently backing into the supplies and switching them to local.

In addition to the main TPC supplies there are 4 more LVPS chassis mounted on the first floor platform (Rack Row 1B). These are for the MWPC FEEs and RDOs that terminate the anode wires. These will be removed for the DAQ1000 installation and the LVPS will become spares.

3. VME INSTALLATION

The VME crate that controls the LVPS is mounted in Rack 2B5 – see picture:

Some of the LVPS are also visible to the right of the crate. The crate is canbus #58 and has two VME processors: one for the control of the LVPS (scserv port 9004) and one for the HDLC readout of the RDOs (scserv port 9015). The LVPS are controlled by the processor through VME digital I/O boards (Model # AVME948x). These I/O modules are seen in the right hand slots of the crate with the ribbon cables plugged in. The I/O signals are used to send an “ON” signal to each PS, and to readback the status of the PS (ON or OFF). There is also a signal that tests the status of the interlock for each rack (see the section on the GUI.)

The other processor in the crate (port 9015) was supposed to be use for the HDLC readout of the RDOs through the Radstone boards seen in the left hand slots of the crate. This setup has not been used after the system was installed at BNL. The new DAQ1000 electronics will not use this HDLC readout, so the Radstone boards can be removed from this crate and used as spares for other subsystems. Note, however, that the processor 9015 is also used to readout the platform hygrometer and the TPC gas system parameters, so the processor will have to stay in the crate.

Above the VME crate, and barely visible in the picture, is the water interlock fanout panel. This takes the TPC cooling water skid signal from the TPC AB interlock system in rack 2A8) and fans it out to the interlock crossconnect panels in each rack.

4. INTERLOCKS

There are two interlock signals that are used uniquely by the LVPS system – TPC cooling water and a blower OK signal from the blower at the bottom of each rack. Any other global interlock signals (water leaks in the rack, smoke in the rack or on the detector etc) will kill the AC power to all of Rack Row 2B.

TPC cooling water skid – the skid is located in the second floor power supply room at STAR. The TPC interlock system measures five digital flowmeters installed in various places in this system. If these flow rates drop below a certain level, or if the STAR global interlock system detects a leak, the TPC interlock system will drive the supply and return valves closed and the skid will shutdown. A signal is also sent to the water interlock fanout panel mounted at the top of Rack 2B5. From this panel, the permissive is sent to each of the crossconnect panels at the top of the LVPS racks (including the MWPC LVPS in row 1B.

Blower permissive – each blower chassis contains a pressure switch inside. The switch compares the pressure between atmospheric pressure (measured via a small plastic tube that connects to a small port on the back panel) and the pressure in the box generated by the blower. A voltage level is sent to each blower chassis via an isolated RG58 cable - a ground isolated BNC connector is mounted on the back panel of the blower. This level goes through the pressure switch and back to the crossconnect panel which enables each of the LVPS in that rack. If the blower stops, the pressure switch will measure 0 differential pressure and the permissive will drop, turning off all LVPS in that rack.

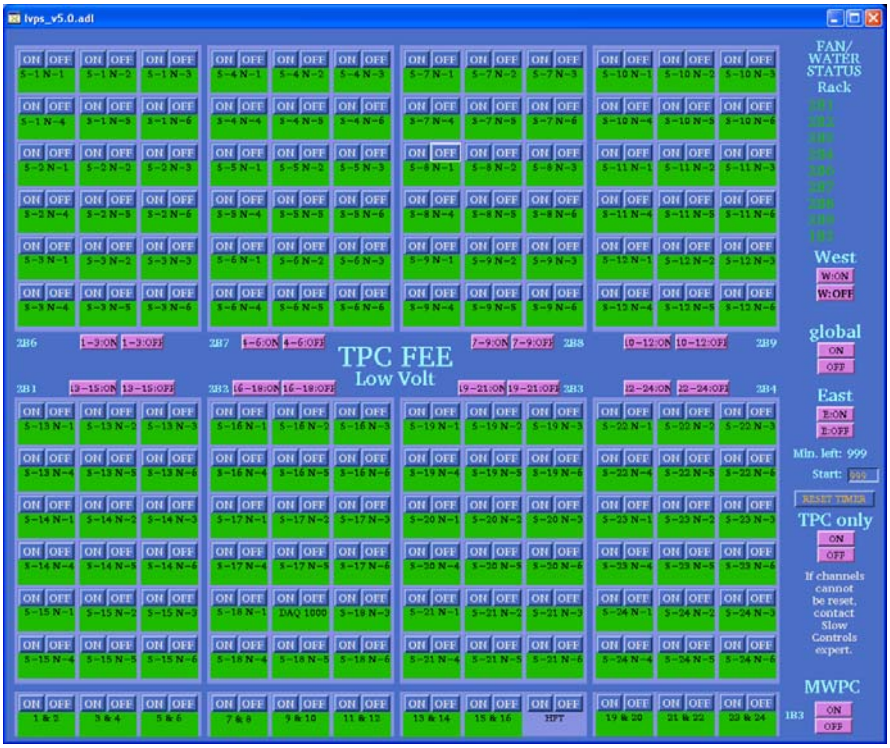
Dan Padrazo and his group have the schematics for this system and will maintain it. He has spare blowers and pressure switches and one spare crossconnect board. All of the blowers were replaced during the summer of 2006, except for one, which failed in Run 8 and was replaced during an access. Various failures of this system occurred over the years and are documented in my notebooks. Most failures can be avoided by replacing the blowers every 3-4 years.

5. GUI

The GUI for controlling the LVPS is shown below:

If channels cannot be reset, contact Slow Controls expert.

LVPS OFF



If channels cannot be reset, contact Slow Controls expert.

LVPS ON

As seen on the GUI there are various buttons for turning on the LVPS. The usual way is to click on the “Global On” button. The program then turns on each LVPS in turn, and the display turns green. You can also just turn on the east or west LVPS, each rack, or individual supplies. Note that the LVPS for the MWPC FEEs are shown across the bottom of the GUI – these supplies will not be used for DAQ1000, so a slow controls expert can remove these from the GUI.

The status of the crossconnect interlock panel is shown in the upper right of the GUI for each rack. If the blower or water interlocks are not valid the display for that rack will turn red and the supplies can not be turned on. (If the water skid is off all the racks’ status should be red.)

There is also a timer on the GUI that will turn all the LVPS off after a specified number of minutes – I usually used this for Tonko, who always forgot to turn the LVPS off when he worked late.

Note that after the slow controls sends the command to turn on the LVPS it checks a status bit to make sure the supply actually turned on. If you turn a supply on and it displays “DB Check” instead of turning green, this indicates a problem with the supply.

6. CHANGES FOR DAQ1000

During the summer of 2007 all of the old electronics for the TPC is scheduled to be replaced by the DAQ1000 electronics. Some of the LVPS system will be incorporated into this new setup. Specifically:

1. The LVPS chassis and controls will be the same – the actual power supplies inside (3 “bricks”) will be replaced.

2. The power cable from the chassis to the TPC face will be the same – a short adapter will be used to connect from the old cable end to the new RDO.

3. The old clock and trigger cable will be reused.

4. The HDLC readout will be discarded

5. The MWPC FEEs and RDOs will be removed and passive grounding cards will be used to terminate the anode wires (16 cards per supersector).

6. The interlock system will be the same.

7. The FEE and RDO cooling manifolds and TPC water skid will be reused.

8. New dual optical fibers for the RDOs will have to be run to the DAQ room.

7. PROBLEMS & TROUBLESHOOTING

The LVPS system has been stable over the years. I recall having to replace only one LVPS. The biggest problems have been with the blowers, which seem to have a ~ 3 year lifetime. The usual failure mode is for the bearings to get worn and the blower turns slower and slower and then seizes. All of the blowers were replaced in summer of 2006. Dan Padrazo has spare blowers and pressure switches.

Recently, one of the new LVPS for the DAQ1000 electronics installed this year developed a problem – in trying to turn the supply on using the GUI the supply turned green, but then turned back off, tried to turn on, turned off etc. It was then switched off. A few hours later, it was turned on again with no problem. Bob Scheetz investigated and finally replaced that supply and sent it back to the factory. It’s currently unclear what the problem was.

For past blower problems, see my notebook.

AVME948x General-Purpose Digital I/O

- **Model AVME9480:** front panel access
- **Model AVME9481:** P2 access

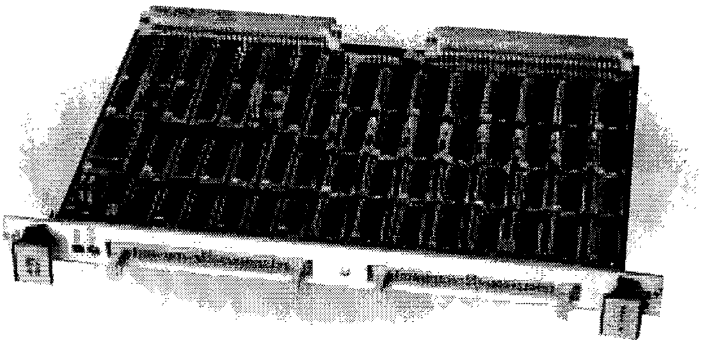
These digital input/output boards interface solid-state or mechanical control relays and other discrete industrial logic devices to the VMEbus. The interfacing is accomplished by providing 64 general purpose I/O points (or lines). Each of the 64 points is selectable as an input, an output, or both - depending on the application.

These boards can handle inputs from a low range of 0 to 5V DC to a high range of 0 to 30V DC. The host can read each of the points configured as an output.

A variety of features includes host interrupt capability and adjustable input threshold.

Features

- 64 points of bidirectional I/O
- I/O range of 0 to 30 volts
- I/O points configurable as eight 8-bit ports or four 16-bit ports
- One 8-bit port (Port 0) for handshaking with latch and interrupt capability
- Read state of points configured as outputs
- Open collector output
- Adjustable input threshold
- Status LEDs
- Built-in protection diodes for driving relay coils
- Byte or word data transfers
- Compatible with industry-standard plug-in solid-state relays and termination panels



AVME9480 and AVME9481 boards offer a price/performance balance that is ideal for a broad range of I/O applications.

Specifications

General

I/O points per board: 64; each point is programmable as an input and/or an output.

Interrupt capability: 8 level-selectable interrupt lines with programmable masks.

Digital Input

Input voltage range: 0 to 30V DC.

Input threshold:
High to low:
Internal reference supply:
V_{IL} = 1.0V DC nominal.
External reference supply:
V_{IL} = (.448 X REF) - 1.22V DC nominal.

Low to high:
Internal reference supply:
V_{IH} = 2.25V DC nominal.
External reference supply:
V_{IH} = (.448 X REF) +0.025V DC nominal.

Input hysteresis: 1.2V DC nominal.

Input current (per point):
I_{IL} = -0.2µA at 0V, V_{REF} = 5V.
I_{IH} = 61µA at 30V DC.

External reference supply: 2.75 to 27.5V DC.

Digital Output

Output type: open collector with optional pull-up resistor.

Output voltage range: 0 to 30V DC.

Output current (per point): I_{OL} = 100mA maximum.

Power Supply Requirements

Power: +5V DC +5%/-2.5% @ 1.6 A, typical.

Environmental

Operating temperature: 0 to 70°C (32 to 158°F).

Relative humidity: 5 to 95%, non-condensing.

Isolation: Non-isolated.

Connector

1P, P2: IEC Type 603-2-C096MX-xxx (96 pin DIN).

P3, P4: (AVME9480 only) 50 pin male header connector.

VME Compliance

Meets VME Specifications per revision C.1 dated October 1985 and IEC 821-1987.

Data transfer bus: A16: D16/D08 (EO) DT8 slave.

Address modifier codes: 29H, 2DH.

Interrupt request levels: IRQ(1) - IRQ(7) eight programmable vectors.

Memory map: short I/O space occupying 1K.

Ordering Information

AVME9480:
Front cable access

AVME9481
Rear cable access (P2), see warning below

WARNING: Do not plug AVME9481 into a P2 backplane slot. The middle row of P2 pins are used for I/O. Instead, use a 9921 adapter and P2 backplane with an open slot. See termination products for more information.

For software, see Page 58. For wiring hardware, see Pages 60-65. For signal conditioning, see Page 66.

5/15/03) 0900) 24-5 ANODE TRIPS 4 TIMES OVERNIGI

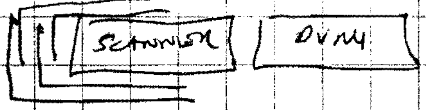
MEASURED CURRENT = -.048 (MOST NEG I'VE

BAD HV CHANNEL?

5/16/03) ACCESS - WORK ON FC SCANNER

1. REMOVE RACK SIDE RAIL - NO HELP.

2. ADD STEEL SHEETS FOR SHIELDING FROM BACK:



← RACK SIDE WALL IS MAGNETIC

AT 28 KV;

Δ=7.2	76.588	76.585	Δ=5.8	)* = FIXED
Δ=1.7	76.592	76.592	Δ=1.4	) FOR A POL

5/18/03) 2 FEE LVPS GO OUT @ ~1800. AT MIDNIGHT ALL OF RACK 2B3 GOES OUT - INTERLOCK.
ACCESS ON 5/19 - FIND BLOWER VERY HOT + 2 CIRCUIT BREAKERS TRIPPED (= 1800 EPISODE).
FIND SPARE BLOWER + INSTALL - ALL LVPS COME ON. THIS BLOWER WAS THE ONE THAT I USED TO KICK TO GET PRESSURE SWITCH ON AFTER SKID WAS OFF. KENNY REPLACED PRESSURE SWITCH ~2 MOS AGO. DANNY LOOKING AT FAN BLOWER MOTOR NOW (BEARING WAS VERY STIFF).
CHECKING ON LIFETIME OF BLOWER AND GETTING SPARES.

10/8/03) → TURN ON BEFORE ROLL-IN - 2B3 PRESSURE SWI
AGAIN DOESN'T CLEAR! KICKING DOESN'T HELP.

~~10/27/03) 1000 AFTER ROLL IN - BOTH~~

10/13/2003 TEST FIELD CAGE – DET ROLLED OUT, SVT, SSD, FT.

NO AIR BLOWER, NO MAGNET

	5KV	10KV	15KV	20KV	25KV	28KV	30KV
OFCW	13.765	27.422	41.088	54.737	68.377	76.574	82.032
IFCW	13.765	27.422	41.087	54.737	68.374	76.578	82.058
OFCE	13.764	27.421	41.085	54.735	68.381	76.577	82.036
IFCE	13.765	27.422	41.085	54.733	68.782	76.574	82.037

OK

10/13/2003 AFTER POWER OUT ON FRI, INTERLOCK FOR 2B7 FEES DIDN'T CLEAR, LOOKS TO BE WATER SIGNAL. ALSO, 2B3 WENT BAD AGAIN LAST WEEK, CROSS CONNECT LOOKED LIKE FLAKY PRESSURE SWITCH AGAIN.

PG 108

DISCOVERED THAT PRESSURE SWITCHES ARE ADJUSTABLE + WE HAVE TWO KINDS – ONE HAS LOWER RANGE THAN THE OTHER.
NOT FIXED YET – 2B3 BLOWER CABLE IS UNPLUGG FOR NOW.

10/14/03 ON TURNING OFF, BLOWER SWITCH FOR 2B6 DOESN'T SHUT OFF LVPS IN THAT RACK. ARGH!

ALSO, MEASURE PRESSURE IN BLOWER IN 2B1

$= \boxed{.7'' H_2O}$

10/27/03 1000 AFTER ROLL IN – BOTH 2B6 AND 2B7 WO. OK. THUS TURNING OFF BLOWER IN 2B6 DROPS INTERLOCK. 2B7 CROSS CONNECT CLEARS OK. SO

PHIL REPLACES PRESSURE SWITCH IN 2B3 AGAIN
PUT IN ONE WITH LOWER PRESS RANGE

SEE [illegible] 146

START REPLACING FEES

DEAD BAND ON "00" TYPE IS VERY WIDE
RANGE = .07 TO .15. WHEN BLOWER GOES ON, WORKS WELL. WHEN BLOWER TURNED OFF

'HOULD USE TYPE "01"

GAS SYST RECIRC w/

TURN ON ALL SYSTEMS TO FULL VOLTAGE
(INCL 20-5) 20-5 TRIPS AFTER ~ 20 MIN

GAIN CH SHOWS NOTHING - NO NOISE, NO Fe, NO PULSER
RESET MCA ON PLATFORM ... STILL NOTHING.
EMAIL PAUL

1640 TURN OFF HV (EXCEPT 66)

9/03) 1000) TRY A LASER RUN
66 20 OUTER STAYS AT 69.5 ALL NIGHT

1530) LASER RUN - BEAMS LOOK ~WEAK
AL CHECKING POWER METER
TIMING AT TCD LOOKS OK 106, 216, 329
Δ = 110

20/03) 0900 LASER LOOKS GOOD - IT WAS N2 IN TPC GAS.

24/03) CROSS CONNECT IN 2B7 AGAIN FLAKY. ON TURNING ON FEES NONE OF 4, 5, 6 COME ON (2B7) BUT SLOW CONTROLS DOESN'T SHOW BAD INTERLOCK. FIND CROSS CONNECT RED LED ON - CYCLE POWER ON VME CRATE - AFTER REBOOT LED ~1/2 ON & THEN FADES OUT - VERY WEIRD. OK NOW.

→ FIXED? BY PHIL - FOUND THAT MODULE HAD A BAD 10k Ω PULL DOWN RESISTOR IN FAIL SAFE MOD WE HAD MADE. HE PUTS IN GOOD 10k Ω.

26/03 FIND ONE TPCTEMP THERMOCOUPLE READING 88° (= INNER RDO 7). WE TRY & LOOK INSIDE w/ BORE SCOPE BUT NO GO. FAN BLOWING ON OUTSIDE BRINGS IT DOWN ~2°. (THIS ONE WAS ~HIGH LAST YEAR - MAYBE 82 BUT WAS NOT LOOKED AT.

TRY TURNING ON ONE BY ONE. -
IF ALL SIX OFF, T = AMBIENT ~79°
TURN ON RDO 1 - 79°
TURN ON RDO 2 - 79°
TURN ON RDO 3 - 86° (RDO 3 = OUTER MANIFOLD!
SO THEORY IS THAT SENSOR FOR INNER RDO 7 IS NOT GLUED TO MANIFOLD & IS HANGING JUST ABOVE RDO 3.

1/11/07 MAGNET WORK FINISHED - HAD 2 FAST CRASHES FROM FUL
FIELD.

CHECK FC AGAIN - CURRENTS OK, AS PER PG 7. Δ ≡
TURN ALL OFF

1/25/07 1100 LECROY 1458 MAINFRAME (FOR OUTER SECTORS) COME BACK FROM VOLTRONICS AGAIN. (REPLACED MOTHERBO
PUT IT IN + IT SEEMS TO WORK. LEAVE ON FOR 24 HR.
PUT MOD POWER 1458 IN BOX + PUT ON CLEAN ROOM ROOF. CAN BE TPC OR SVT SPARE.

1/26/07 REPAIRED 1458 STILL OK - SHUT IT DOWN.

2/7/07 DANNY REDOES THE INTERLOCKS FOR THE LVPS. PROBLEM WAS THAT IF THE INTERLOCK CABLE TO THE BLOWER WAS UNPLUGGED (BNC) THE LVPS STAYED ON - SO NOT FAIL SAFE. DANNY REDOES THE LOGIC.
I TEST THE LVPS FOR THE MWPC FEES:

1. UNPLUG BLOWER CABLE - LVPS GO OFF
2. TURN OFF BLOWER - " " "

WILL TEST WATER SKID THIS WEEK

DANNY NOW MODIFYING RACK ROW 2B LVPS (ALL)

2/12/07 1400. PUT POLARITY REVERSING CABLE IN GG FOR SECTOR 8 INNER. THIS SECTOR HAS WHAT ARE PRESUMED TO BE FLOATING GG WIRES IN 2 PLACES THAT CAUSE A GRID LEAK. REVERSE POLARITY SEEMS TO [illegible] IMMEDI CLOSE THIS LEAK.

OOPS HOULD BE OUTER MOVED 3/6/07

2/17/07 1000 PUT 1 MΩ IN IFC EAST RESISTOR CHAIN.
WAS 2 MΩ AT END OF RUN 6.
TEST FC

							10:30	12:00
	2 KV	5 KV	10 KV	15 KV	20 KV	25 KV	28 KV	28 KV
CW	5.558	13.751	27.345	41.052	54.691	68.325	76.524	76.508
OFCE	5.557	13.750	27.346	41.048	54.687	68.321	76.516	76.505
IFCW	5.557	13.750	27.397	41.049	54.688	68.321	76.515	76.505
IFCE	5.542	13.713	27.321	40.936	54.538	68.173	76.348	76.451
					Δ = 150	Δ = 150	Δ = 160	Δ = 50

REMOVE TRANSISTION MODULE -

ALSO, CAPUT INTO +12 V LOWER TRIP LIMIT DOES NOT WORK.

1/16/08) FINALLY BACK TO NORMAL FOR CRATE 59.

1630) FOUND SMALL SLOW WATER LEAK IN RADIATOR ABOVE CRATE 59 - DROPS MAY HAVE GONE INTO PS. REPLACE RADIATOR.

1ST SPARE CRATE DRAWS 20 A ON +12V, THEN TRIPS ON OVERCURRENT - PS SMOKES.

MAY HAVE BEEN DUE TO TRANSITION MODULE CONNECTOR CARD TOUCHING SIDE OF CRATE.

GET YET ANOTHER PS FROM DANNY - REPLACE TRANSITION MODULE CONNECTOR CARD (BLOWN ON BOARD FUSE).

NEW PS + CRATE LOOK GOOD - NO VOLTAGE SPIKES.

BOOT UP WITH REPLACEMENT PROC - OLD PULSER PROCESSOR (SEE PG 33).

1/17/08) 0900) CRATE 59 GOOD ALL NIGHT.

28/08) 0900) END OF DAU. ACCESS DAY

1. FOUND COOLING FAILURE ON RACK 2B3 - FIND BLOWER VERY HOT - CALL KEN FOR REPLACEMENT.

2. TOMMO PRACTICING WITH TPX FAST RO. UNPLUG 66 + TURN OFF 66 VOLTAGES.

630): TOOK ALL DAY TO REPLACE - BLOWER WAS FROZEN BUT ALSO HAD PROBLEMS W/ PRESSURE SWITCH.

2nd PRESSURE SWITCH FINALLY WORKS.

27/08) LAST ACCESS

1. INVESTIGATE TPX LVPS #6 - HAD TROUBLE 2 DAYS AGO TURNING ON - KEPT OSCILLATING ON/OFF REPLACED PS
2. CREW REPORTS SC ALARMS DIDN'T WORK FOR ANODE TRIPS - CHECKED OK
3. YURI WANTS CC PROC REBOOTED

Field Cage

FIELD CAGE READOUT

1. INTRODUCTION

The uniform electric drift field of the TPC is established by the central membrane cathode (28 kV) and the four field cages: inner and outer, east and west. The field cages consist of conducting stripes separated by a small insulation gap. The stripes are connected to each other with 2 X 1 megohm resistors. Each field cage has 182 of these stripes and hence a resistor chain of 362 megohm from the cathode to ground. During the run the currents through these four resistor chains are monitored, since any deviation from nominal current would cause distortions in the drift field. We also measure the voltage on the next-to-last and last stripes, and any current that might show up on the outer gas containment ground shell.

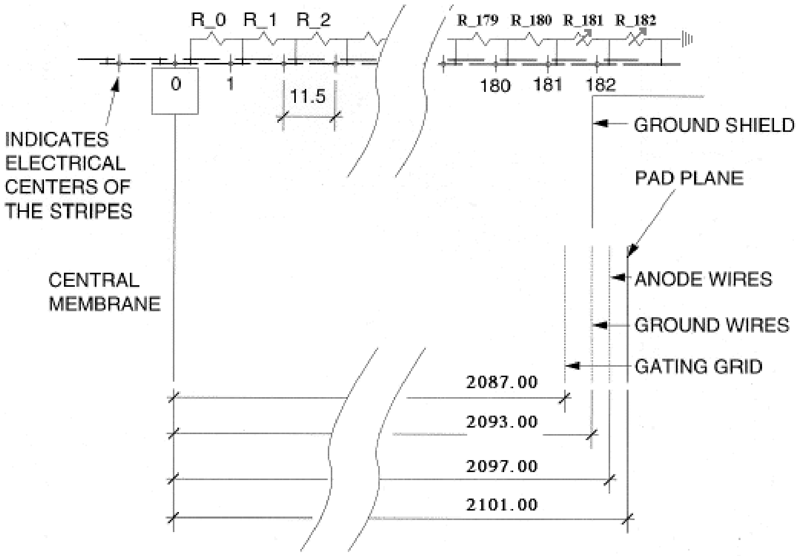
2. HARDWARE

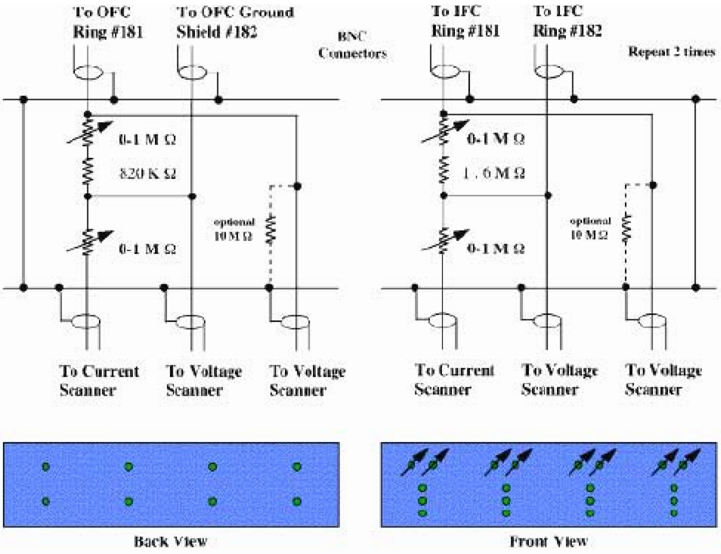
A schematic of the field cage structure and readout scheme are shown on the STAR home web page:

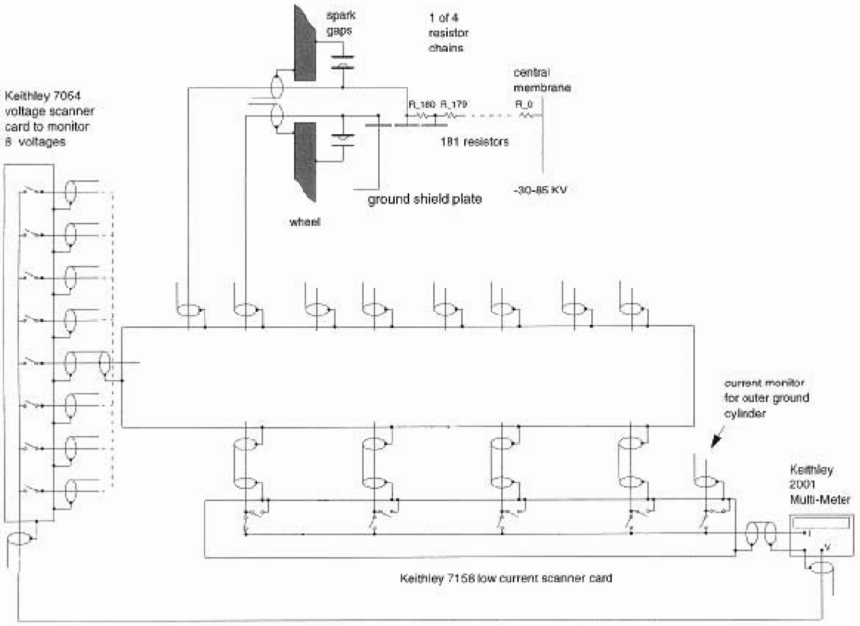
http://www.star.bnl.gov/public/tpc/tpc.html

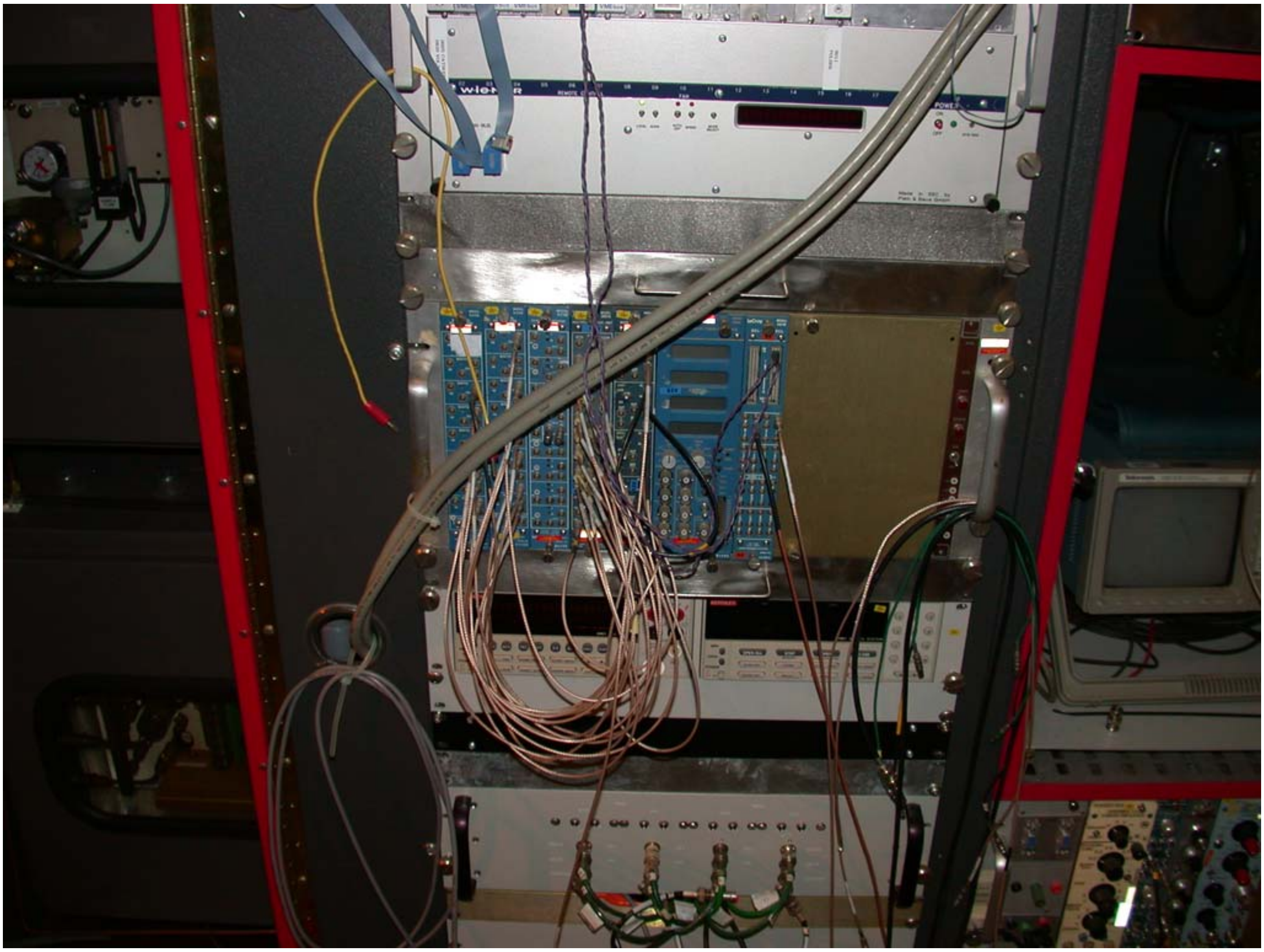
Click on “Hardware”, then “Drift-defining Hardware: E-Fields and Gas” and then “Page 5: Tuning the Field Cage”

The connections to the next-to-last stripe (Ring 181) and last stripe (Ring 182) are brought from the rings to BNC connectors mounted on the TPC end caps. A set of long RG-58 cables then bring these signals to Rack 2A3, where they terminate in the resistor box (designed and built by Jim Thomas). For monitoring purposes the signals are brought out of this box into a Keithley scanning/switcher box and then into a Keithley DVM. (See schematic below). The Keithley DVM and switcher are also mounted in Rack 2A3, directly above the termination box (see picture).




To OFC Ring #181
To OFC Ground Shield #182
BNC Connectors
To IFC Ring #181
To IFC Ring #182
Repeat 2 times
0-1 M Ω
820 K Ω
0-1 M Ω
optional 10 M Ω
0-1 M Ω
1 . 6 M Ω
0-1 M Ω
optional 10 M Ω
To Current Scanner
To Voltage Scanner
To Voltage Scanner
To Current Scanner
To Voltage Scanner
To Voltage Scanner
Back View
Front View


spark gaps
1 of 4 resistor chains
central membrane
R_180
R_179
R_0
181 resistors
-30-85 KV
ground shield plate
wheel
Keithley 7064 voltage scanner card to monitor 8 voltages
current monitor for outer ground cylinder
Keithley 2001 Multi-Meter
I
V
Keithley 7158 low current scanner card



Picture 1: Bottom of Rack 2A3. The termination box is at the bottom of the picture. The two Keithley units are rackmounted side by side just above the termination box. The DVM is on the left, switcher on the right. The two large cables are the GPIB readout cables for the Keithleys, going from the VME crate (Rack 2A4) to the back of the Keithleys, inside the rack.

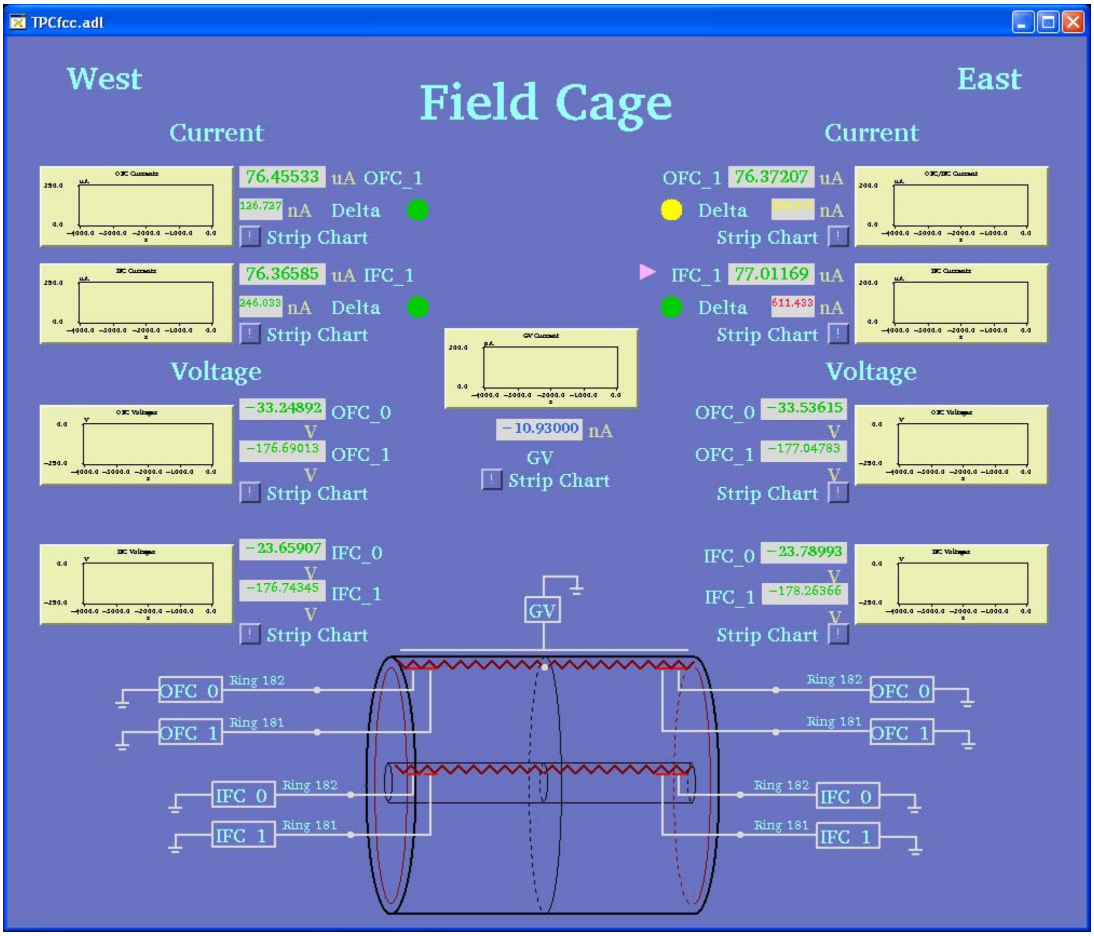
The Keithley switcher consists of a “main frame”, model # 7001 with two scanner cards installed: a model 7054 High Voltage Scanner and a model 7158 low current scanner. The DVM is a model 2001 Multimeter. Under VME program control the units switch between each of the 5 currents and 8 voltages and measures each one. Since the dwell time is ~ 1 second per measurement, a cycle is completed ~ every 15 seconds. It is probably not advisable to go faster and still expect a stable measurement.

One important thing to note about this system is that each of the four field cage resistor chains ALWAYS has a path to ground, both when it is switched to the DVM and when it is waiting. Also note that both ring 181 and 182 are connected to ground by a spark gap (these are inside at the BNC connector.) These sparks gaps have been selected to conduct at ~ 600 volts, so if the external ground is removed, the gaps will provide the path to ground and the field cage will not charge up to 28 kV. Note that this also has implications for placing external compensating resistors in the system (see section on shorts.

3. VME & GUI

The processor for the field cage readout is in a VME crate in rack 2A4. The crate is Canbus address 56 and the processor is port 9001 on the serial server. The interface card is a dual output GPIB module, one output for the DVM and one for the scanner. To turn the system on, first turn on the DVM and scanner and then boot the processor. After the boot you should see the scanner display move from channel to channel and see the DVM measure 5 currents and 8 voltages at ~ 1 second intervals.

The GUI for the field cage is accessible from the TPC top level GUI and is read only – there are no operations possible by the operator through the GUI. The GUI looks like:



This shows the 4 field cage currents, the ground shell current, and the 8 voltages from rings 181 and 182. Note that the ground shell current readout is drowned in noise when the magnet is on – it is only useful for finding outer field cage coronas when the magnet is off. (In initial tests at LBL we had outer field cage corona above 35 kV. The corona provides a separate path to ground, so current would disappear from the resistor chain and appear on the ground shell – the ratio helps to locate the corona in z)

For alarm purposes we usually don’t look at the currents themselves, which can change with temperature and especially humidity. Rather, four calculated deltas are shown – each delta subtracts each measured current from the average of the other three. Alarm levels are then placed on these deltas to warn the operator if there is a short in any of the field cages. Note that one shorted stripe would result in a change in current of 420 nA out of 76 microamps. The screen capture shown above thus shows a field cage problem. During Run 8 the 4 currents were well behaved (except for a known OFCW problem), so the alarms on delta were set at ~ 200 nA. Offline studies have shown that a delta above ~ 100nA will cause distortions in the field cage that have a measurable effect on the data. In fact, for highest precision, the limit is even smaller. The OFCW problem has been happening for a few years – the current is bistable, and varies between nominal and nominal + 60nA. The offline program now tracks this variation and attempts to correct for it.

There are also buttons on the GUI for popping up a scrolling display of the currents – I usually have one of these up for the inner and outer currents for the operators to watch during data taking and to allow me to scroll back to check for strange behavior over night.

4. FC SHORTS AND COMPENSATION

Over the years we have encountered a few one stripe shorts, especially in the inner field cage. Gruesome history can be read in my notebooks. We have usually managed to find the reasons for these shorts (foreign objects left in the inner field cage), but they sometimes only show up after things are buttoned up and the magnet is turned on. We currently have one short in the IFCE, which has been made permanent – see the documentation by Alexei. We also have the above mentioned OFCW bistable problem – we have NOT attempted to go into the insulation gap area to try and locate this problem for fear of causing more problems.

Past history shows that it is always a good idea to test the FC extensively as the detector is being brought on for a new data run, especially if work has gone on inside the IFC. Typically we test the FC daily until things are buttoned up and the magnet has been on at full field.

A one stripe short can be somewhat compensated for by adding an external resistor to the corresponding resistor chain. This is done by putting a 2 Megohm (for one stripe) resistor inline at the termination box where the cable from stripe 181 goes into the box. Small boxes with various resistors have been made in advance and are stored inside Rack 2A3.

5. SPARES

We have one spare Keithley multimeter, two spare scanner mainframes, one spare 7158 low current card and a refurbished 7054 HV card. The 7054 is no longer made by Keithley, but they sold us the encapsulated switch modules, and Ken Asselta installed them on our old card. The cards were replaced in March, 2003 when I was chasing some noise on the readout.

We do NOT have a spare dual output VME GPIB module. It is no longer made by National Instruments in the form we have. If the installed one fails we will have to do some slow controls work to either adapt a single output module by piggy backing the cables or use two singles in the same crate. Theoretically it should just be a GPIB addressing problem, but….

Given some spare time this could be worked on during shutdown times.

6. CANONICAL READINGS

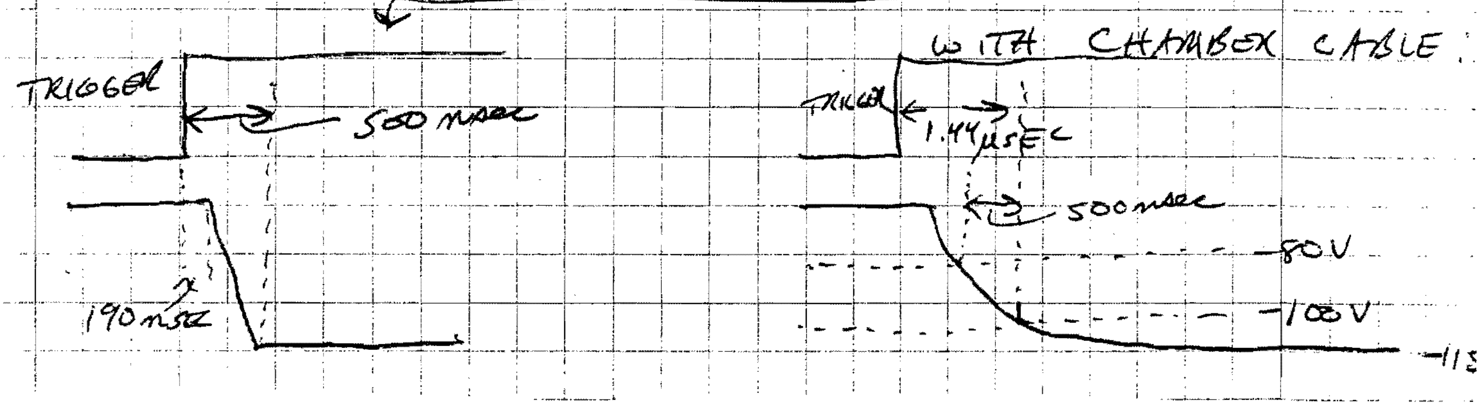
Aside from actual shorts in the field cage, the current and voltage readings will vary depending on conditions in the hall. The Keithley DVM is affected by humidity, so running in the spring and summer is difficult. (See page 21 in my logbook II). Also, the IFC readings are usually not reliable if the IFC air blower is not running and the IFC is open to the WAH air. Here are some canonical currents and voltages for ~ stable conditions:

	2 KV	10 KV	20 KV	28 KV
OFCW	5.879	27.441	54.733	76.562 µA
OFCE	5.879	27.438	54.728	76.552 µA
IFCW	5.879	27.438	54.727	76.554 µA
IFCE	5.879	27.439	54.727	76.554 µA
OFCW_0				-33.33 V
OFCW_1				-177.35 V
OFCE_0				-33.73 V
OFCE_1				-177.68 V
IFCW_0				-23.69 V
IFCW_1				-177.36 V
IFCE_0				-23.66 V
IFCE_1				-176.96 V

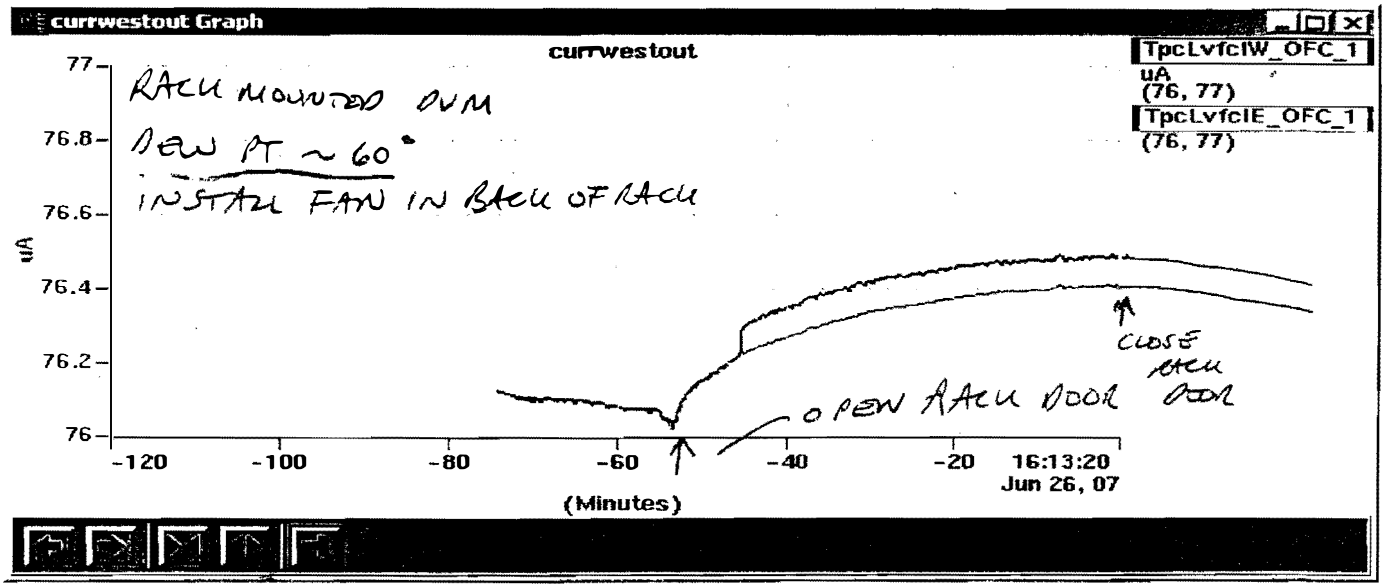
USE BREAK OUT BOX IN BACK TO SEE REAL V.
USE 10X PROBE, 10 MΩ TERMINATION

II - 21

WITH CHAMBER CABLE ~~NOT~~ ATTACHED!)



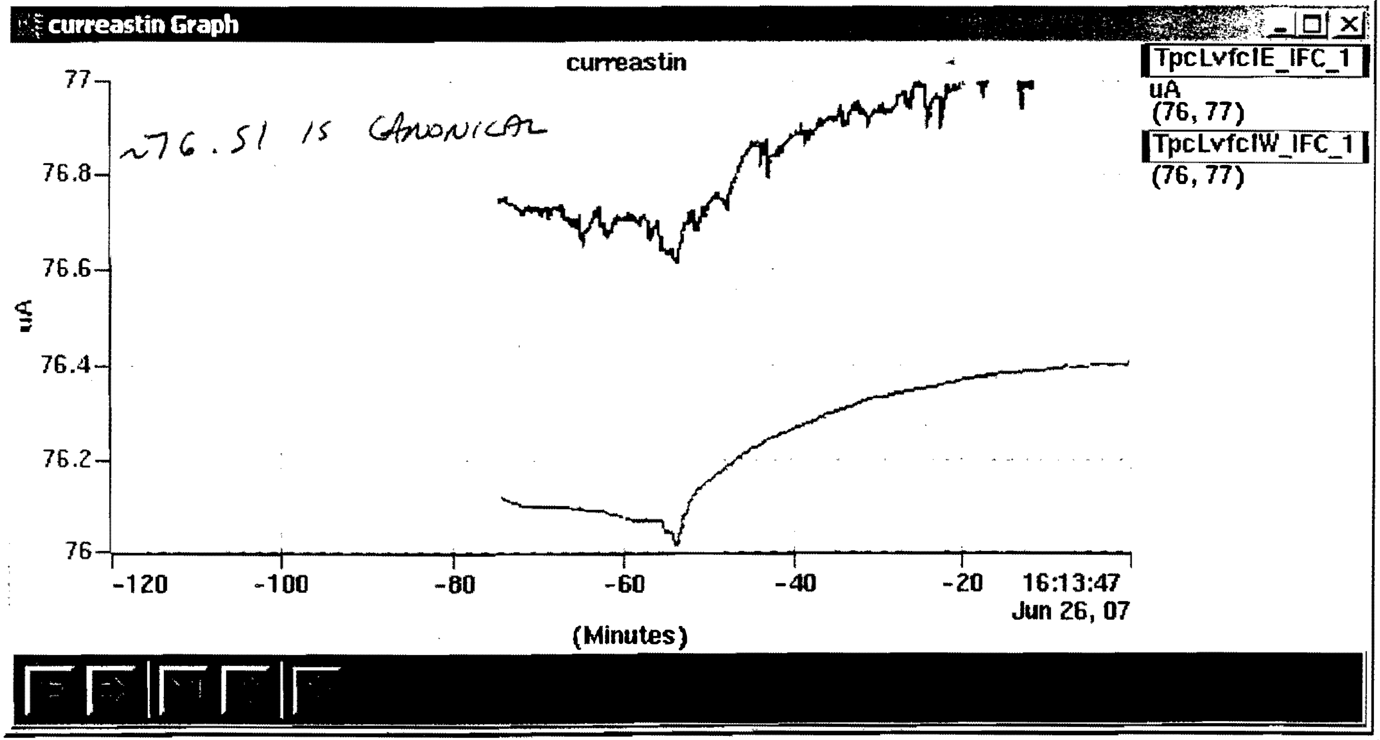
07



RACK MOUNTED DVM
DEW PT ~ 60°
INSTALL FAN IN BACK OF RACK

OPEN RACK DOOR

CLOSE BACK DOOR



~76.51 IS CANONICAL

CH6 @ 500V .471 - .481 .305
TRIP @ 1040

CH7 @ 500V .469 - .481 .306
TRIP @

0/98 | 1600) N2 PURGE STARTED - ~~X~~ 2 BROKEN SECTORS REPLACED - S
12 O CLOCK SECTOR SHORT TO STRIPE
INNER+OUTER WEST
TEST ALL ^ SECTORS (~~[illegible]~~) w/ 200 V

((Tested new sparkgaps prior to installation on field cag
nominal 600 V gaps ~~tripped at~~ 560 - 630 volts
Selected 4 606, 625, 612, 582

1700) FIND ONE SECTION NOT DRAWING CURRENT S4 #5

FIRST FIND CABLES MISLABELED S4 #5 AND S4 #8
RELABEL @ TPC END.

REPLACE PIGTAIL + LONG HV CABLE - S4 #5 STILL NO
ON RAMP UP
SWAP PS AT DISTRIBUTION BOX - STAYS WITH S4 #5.

STOP N2 PURGE + GO HOME ....

1/98) 0900 - INVESTIGATE S4 #5 SOME MORE - MEASURE
CAP ETC. SWAP WITH S3 #5 - NOW SEEMS
RESTORE ALL ORIGINAL CABLES - STILL OK. SO - ?

915) (INSTALL NEW SPARK GAPS. 600 V GAPS INSTALLED FR
STRIPES 181 + 182 TO GROUND ON EAST + WEST END OF OFC

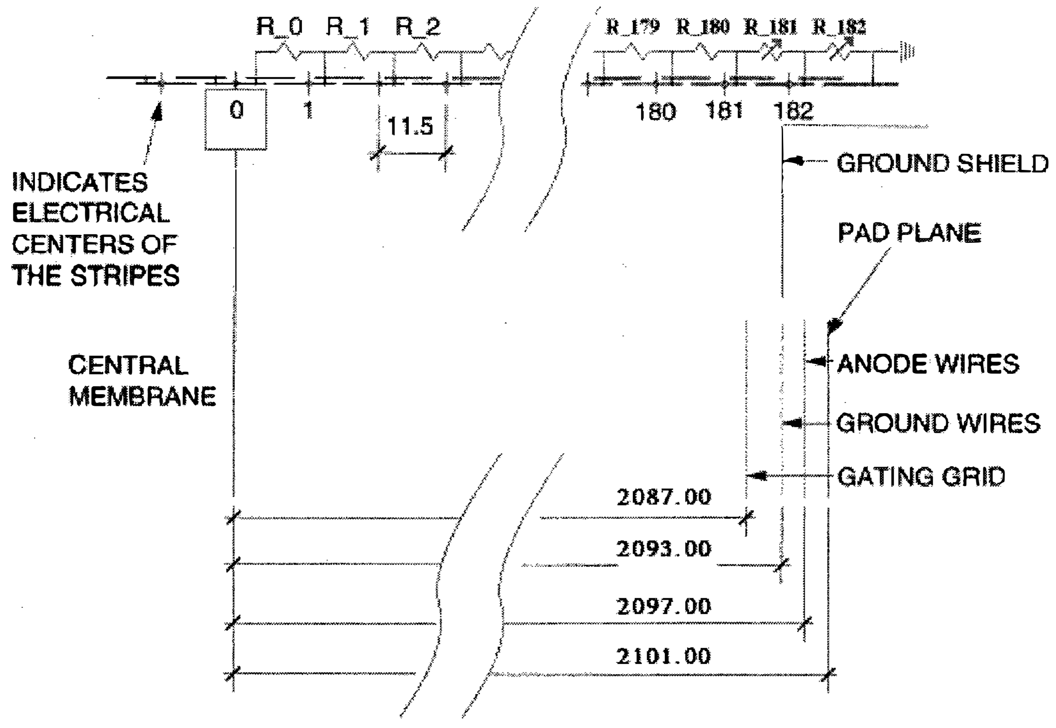
7/98 | 0945) BCS TPC SEALED + BAD SECTORS REPLACED. P10 IN
TURN ON WEST SECTORS 1-12

0950) 500 V
1055) 800 V
1110) 1000 V INNER 1200 V OUTER
1300 1100 V 1300
1330 1150 1400

2030 1.1.18 TRIP) Tripped or previously disabled, not

Tuning the Voltage Divider

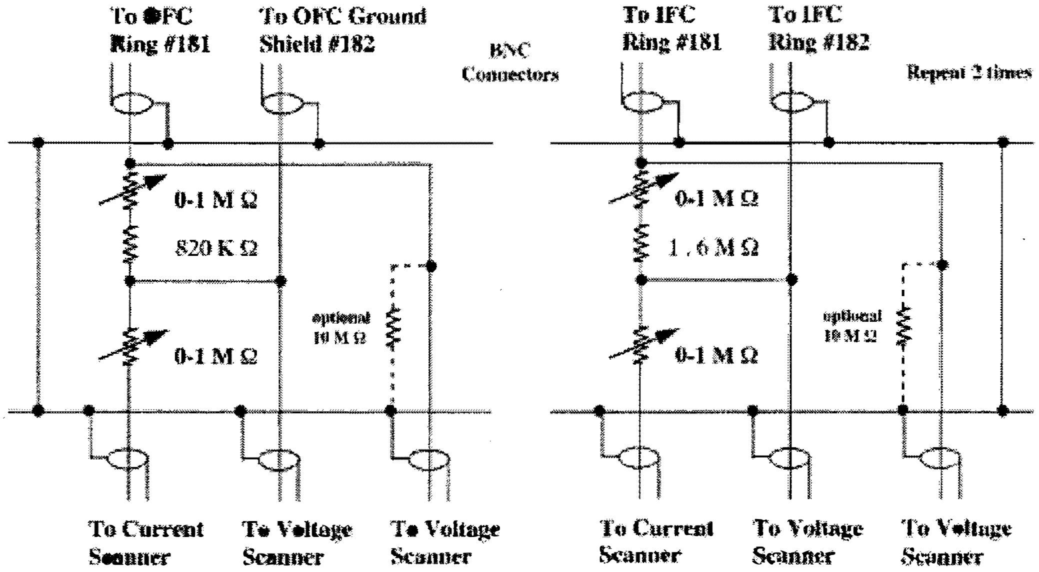
The TPC field cage defines a uniform electric field between the central membrane and the gating grid near the pad plane. The terminus of the field region is the gating grid (and not the anode wires, ground wires, or pad plane) because we are not interested in drifting electrons inside the anode sector. Either we are trying to regulate the drift with the gate or we are trying to drift and amplify the signal near the anode wires. These actions require electric fields bigger than the drift field. However, the TPC field cage extends beyond the gating grid in the region outside the anode sector and we do want the uniform field to continue in this region to prevent distortions of the tracks at the sector boundary. Resistors 181 and 182 set the voltage on the last two field cage rings and they must be tuned to achieve this goal.

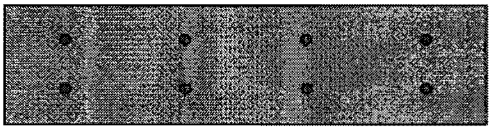


The resistor chains are different for the outer field cage and the inner field cage. The outer field cage has a "ground shield" attached to ring 182 and the shield is lined up with the "ground wires" in the anode sector. This prevents the shield from being located at the center of the ring and requires us to set the ring at the correct voltage for the ground shield rather than its own natural setting. Accomplishing this requires tuning both resistors.

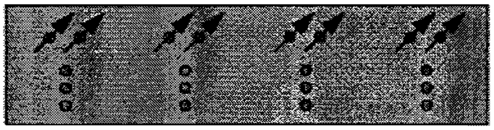
The inner field cage does not have a "ground shield" and resistor 181 is just one more step in the resistor chain. It keeps its normal value of 2 M ohms while resistor 182 is trimmed to bring the field to ground potential. Ring 182 is not necessarily set to an integral multiple of ring-to-ring voltage steps above true ground because the gating grid, which determines the overall drift field, is set independently and its value is determined by the transparency of the grid and other external factors. (See the next page).

So in order to easily adjust resistors 181 and 182, they have been removed from the TPC and installed in an external rack.



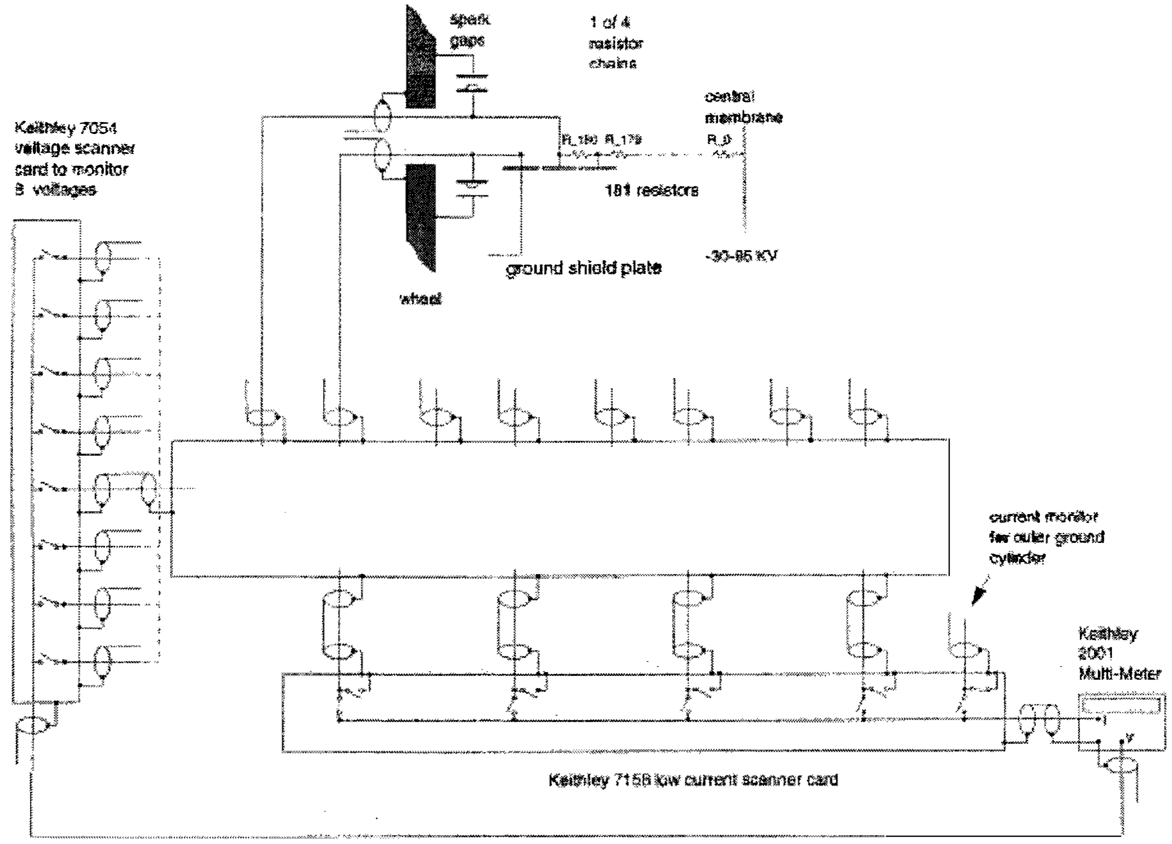


Back View



Front View

The resistor chain terminates in a scanning current meter so we can monitor the currents running down each chain. This is a useful diagnostic for helping to find short circuits in the voltage divider system. A scanning voltmeter also monitors the voltage on ring 181 and 182 to ensure that they are set properly.



To determine the setting on the variable resistors, let:

$Z_{gg} - Z_{cm}$ = the distance between the gating grid and the central membrane

$V_{gg} - V_{cm}$ = voltage on the gating grid minus the voltage on the central membrane

The drift field is then simply:

(1) $E_{drift} = (V_{gg} - V_{cm}) / (Z_{gg} - Z_{cm})$

The field cage is built of rings with equal spacing between the rings. This is true for all ring-to-ring gaps except for the gap between the central membrane and the first ring. It is slightly wider. In order to keep a uniform field gradient at the central membrane, the first resistor (R_0) must be slightly larger to represent the wider gap.

(2) $R_0 = Z_{01} * (R_1 / Z_{12})$

As long as R_0 is chosen this way, the voltage and resistances are well defined functions of Z in the region between the gating grid and the central membrane.

(3) $R(Z) = (Z - Z_{cm}) * (R_1 / Z_{12})$

(4) $V(Z) = E_{drift} * (Z - Z_{cm}) + V_{cm}$

Extending these equations to zero voltage will tell us the total resistance in the chain. Thus,

(5) $R_T = (V_{cm} / E_{drift}) * (R_1 / Z_{12})$

This is enough information to calculate the settings on the variable resistors R_{181} and R_{182}. There are several known quantities:

E_{drift} = 146.5 V/cm for P10 gas, chosen to be over the peak in the velocity curve (eg. see previous page)
V_{gg} = -125 V chosen to make the grid 100% transparent, see next page
R_1 = 2 M Ohms
Z_{gg} = 208.7 cm
Z_{cm} = 0.0 cm
Z_{01} = 1.225 cm
Z_{12} = 1.15 cm
Z_{gs} = 209.3 cm

From (1) V_{cm} = -30,700 Volts
From (2) R_0 = 2.130 M Ohms
From (5) R_T = 364.440 M Ohms

Since there are 180 identical resistors in the chain plus R_0, R_{181}, and R_{182} this means that

$R_{181} + R_{182} = R_T - R_0 - 180 * 2$ M Ohms = 2.310 M Ohms

In the special case of the inner field cage where there is no ground shield

R_{181} = 2 M Ohms
R_{182} = 310 K Ohms

R_T is the same for the outer field cage but it is split differently between R_{181} and R_{182} because the ground shield is partway between the center of rings 181 and 182 and we want to bias ring 182 so that the ground shield is at the correct voltage rather than the ring. We can easily calculate these values using equations (3) and (4).

$R_{gs} = (Z_{gs} - Z_{cm}) * (R_1 / Z_{12})$ = 364.000 M Ohms
$V_{gs} = E_{drift} * (Z_{gs} - Z_{cm}) + V_{cm}$ = -37.5 Volts

R_{gs} is the total resistance between the central membrane and the ground shield and to make better sense of this number we should subract off the fixed resistor values. Thus in the special case of the outer field cage

$R_{181} = R_{gs} - R_0 - 180 * 2$ M Ohms = 1.870 M Ohms
$R_{182} = R_T - R_0 - 180 * 2$ M Ohms $- R_{181}$ = 440 K Ohms

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Page created by Jim Thomas, send comments to jhthomas@lbl.gov.
Last modified on March 31st, 1998

Gated Grid

GATED GRID

HARDWARE

The gated grid system consists of two crates located in Rack Row 2A6: a 6U VME crate for the processor and 12 control modules and a special 9U crate for the actual GG drivers (also 12 modules). See picture:

The control crate is at the top, with the processor in the left hand slot. A set of three ribbon cables go from each control module to the corresponding driver module in the crate below. In addition there is a lemo cable that goes from each control module to each driver – this is the “gate open” signal (TTL), whose width determines the gate open time (typically 39 microseconds.) The primary gate open signal comes from the first floor platform as an output from the TPC TCD (rack 1A2). This NIM signal plugs into the left- most control module, which converts it to TTL and puts it on the VME back plane, where the other 11 control modules pick it up. Each control module then outputs the TTL signal to its corresponding driver. Note that this means that the left most control module is different from the other eleven – it has the additional NIM input lemo. We thus have two flavors of spares.

The gate open signal comes from the TPC TCD in Rack 1A2. The signal width (gate open) is set by DAQ software and is output from a front panel Lemo labeled “Grid Out”. Since we ran a mixed TPC and TPX system this year and the TPX had its own TCD I “ORed” the two Grid Out signals and then level shifted this OR to NIM. This was done in a NIM bin just above the TCD crate. If all the old TPC electronics is replaced before Run 9, this OR can be removed (but the level shifter has to stay!).

Each of the grid driver modules has four individual outputs, each of which drives one sector. The output cables are connected inside the modules on screw lugs, pass through a grommit on the back panel and then terminate after ~ 2 ft with a LEMO twinex connector. These are in turn connected to the 100 ft twinex cables which go to the face of the TPC (one cable per sector). From the front of the crate, the first four modules are for outer sectors 1-12, the next four are inner 1-12, the next four are outer 13-24, and the last four inner 13-24.

The gate open voltage (i.e., the voltage for both sets of wires when the gate is open) is determined by the TPC geometry and the cathode operating voltage. To maintain the uniform electric drift field the voltage on the gate needs to match the field cage at that point in z. Since we run the cathode at - 28 kV it has been calculated that the gate open voltage is - 115 V. For documentation on this geometry and calculation see the TPC hardware web pages:

http://www.star.bnl.gov/public/tpc/tpc.html

And click on Hardware, then “Drift Defining Hardware”, then “Tuning the Anode planes” or “Gating Grid/MWC”

Tests were made initially to determine what the swing voltage needed to be to completely close the gate 100%, with some safety margin. This swing voltage has been set to plus/minus 75 volts for all runs since 2000. Thus alternating wires have -40 and -190 volts when the gate is closed.

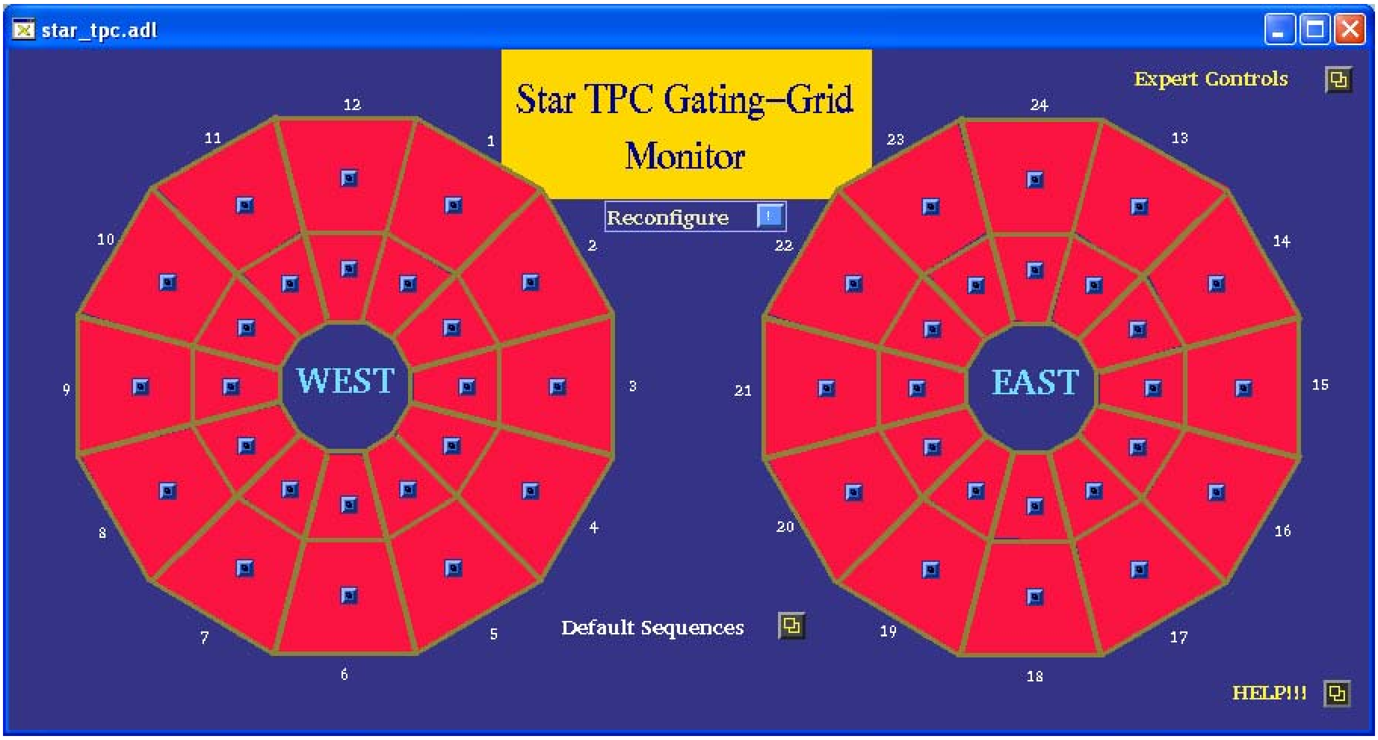
For monitoring purposes and when needed for calibration we have a breakout box which is kept inside rack 2A6. It consists of a box with female and male twinex Lemo connectors where one can plug in the cable from the driver and the cable from the chamber. It also has three banana plug test points for a DVM and two probe hoods for a scope probe. Thus the voltages can be measured safely when the chamber is still attached. Risetimes and ringing can also be viewed with a scope.

In addition, there are lemo monitor outputs on the front of each driver card for the four channels – this is useful for checking the gate width etc. The monitor output is 100:1. See pages 85-86 in my notebook #1.

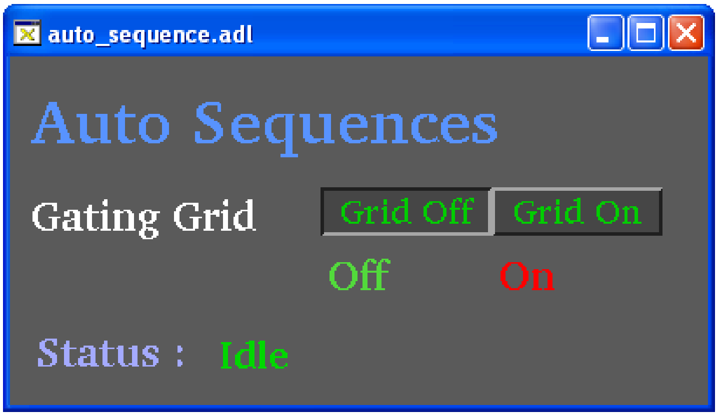
The gated grid is interlocked with the TPC AB interlock system – the GG voltage is turned off for gas system problems, water leaks etc. The interlock connection comes from the TPC AB system in Rack 2A8 and connects to a DB15 connector on the fan tray of the driver crate. This interlock can be over ridden by using a key on the main AB panel in the gas room for testing purposes if there is no gas in the TPC.

SLOW CONTROLS & GUI

The gated grid control GUI is accessible from the top level TPC GUI:

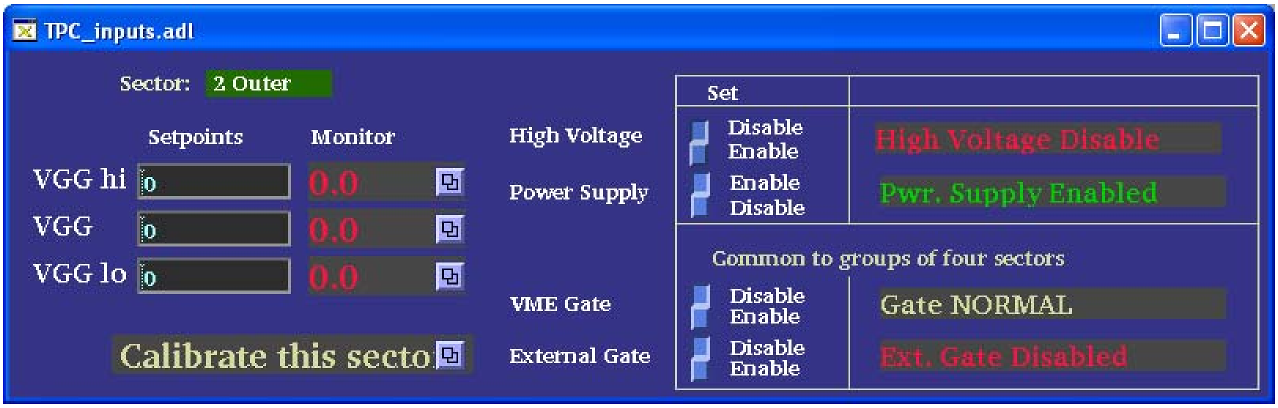


When starting up the voltage is initially off. The GG processor is connected to port 9002 on the terminal server. To turn the GG voltages on, click on the “Default Sequences” button on the GG GUI:



To turn the gating grid voltage on (all sectors), click on the “Grid On” button. If the processor is alive (see below), the status should change to “Downloading Setpoints” and the slow controls script will set all the driver voltages on in turn and enable the gate. If the Status continues to read “Idle”, then you’ll need to reboot the processor and then try again.

The turn on sequence takes a few minutes – to watch the progress, click on one of the buttons in the TPC sector display on the GG GUI. This brings up the sector control GUI:



TPC_inputs.adl

Sector: 2 Outer

	Setpoints	Monitor
VGG hi	0	0.0
VGG	0	0.0
VGG lo	0	0.0

	Set	
High Voltage	Disable Enable	High Voltage Disable
Power Supply	Enable Disable	Pwr. Supply Enabled

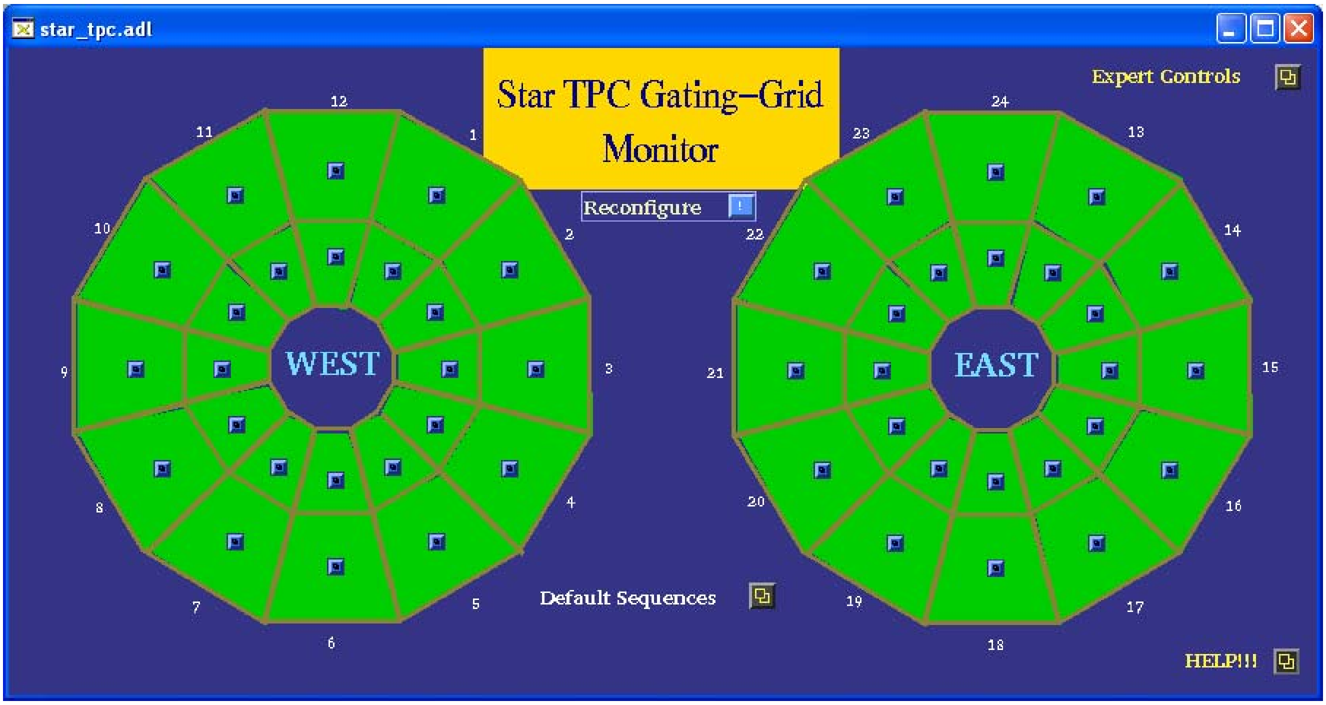
Common to groups of four sectors

VME Gate	Disable Enable	Gate NORMAL
External Gate	Disable Enable	Ext. Gate Disabled

You should see the script input the voltage setpoints (VGG hi & VGG lo = 75, VGG = 115

and see the voltage ramp up in the monitor window. The High Voltage should change to enabled and the Ext. Gate should change to Enabled.

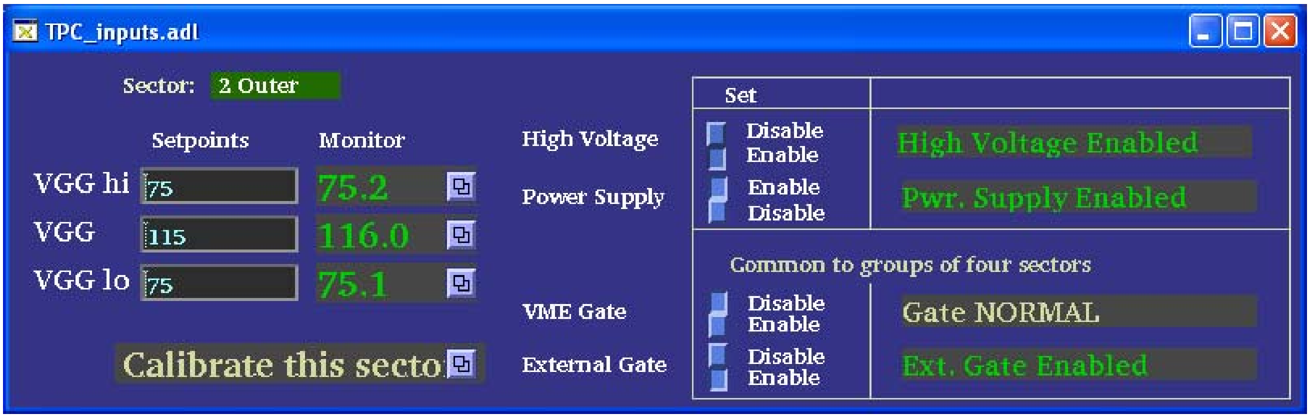
When all the sectors have been set, the main GG GUI should turn green:



star_tpc.adl

The GUIs for a typical sector and for the global control are shown below for normal operation:

Single sector control GUI:



TPC_inputs.adl

Sector: 2 Outer

	Setpoints	Monitor
VGG hi	75	75.2
VGG	115	116.0
VGG lo	75	75.1

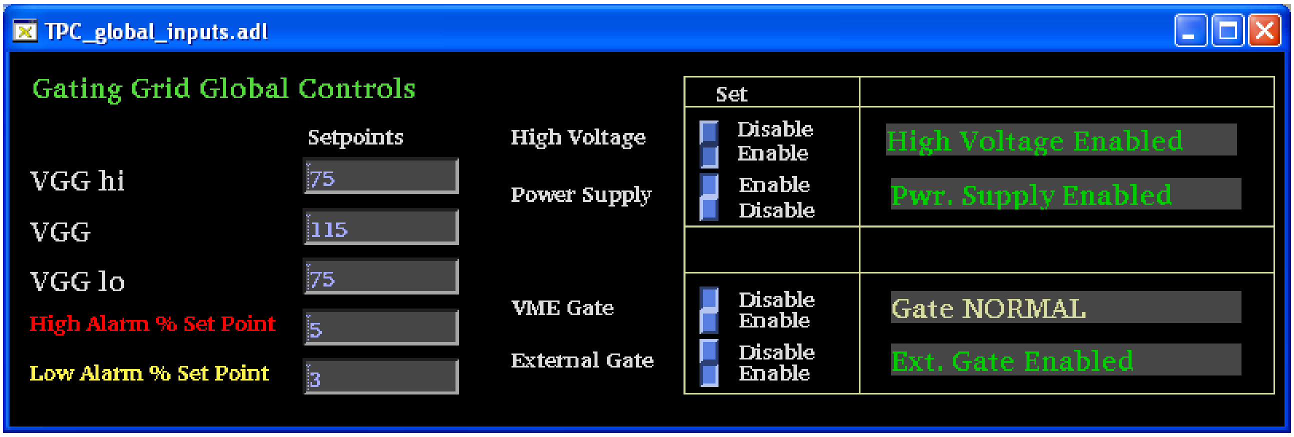
Calibrate this secto

	Set	
High Voltage	Disable Enable	High Voltage Enabled
Power Supply	Enable Disable	Pwr. Supply Enabled

Common to groups of four sectors

VME Gate	Disable Enable	Gate NORMAL
External Gate	Disable Enable	Ext. Gate Enabled

Global control for all sectors:



TPC_global_inputs.adl

Gating Grid Global Controls

	Setpoints
VGG hi	75
VGG	115
VGG lo	75
High Alarm % Set Point	5
Low Alarm % Set Point	3

	Set	
High Voltage	Disable Enable	High Voltage Enabled
Power Supply	Enable Disable	Pwr. Supply Enabled
VME Gate	Disable Enable	Gate NORMAL
External Gate	Disable Enable	Ext. Gate Enabled

For normal running, the gated grid voltages are left on all the time. It is not necessary to turn them off between fills. The GG voltages are monitored by slow controls and will alarm if they drift from nominal. The current criteria are a yellow alarm for a 3% excursion and a red alarm for 5%. Studies originally done by Geno Yamamoto determined that a 3% excursion would not cause a distortion that could be seen in the data, so we can keep running with a yellow alarm. A red alarm would cause noticeable problems with the data, so data taking should stop until the problem is fixed.

For normal data taking in Runs 7 and 8 the gated grid was driven at sustained rates of up to 300 Hz, with no problems. Note that rare triggers that issue a level 0 trigger, but then abort at level 2, cause the gate to be opened, even if the event was discarded. This is because the level 2 decision comes after the 40 microsec drift time of the TPC. Hence, the total GG rate is the TPC DAQ rate plus the level 2 abort rate. It’s the total GG rate that determines the charge loading in the TPC and hence the lifetime of the wires.

At the end of Run 8 we did tests of the TPX electronics and the GG was driven at rates up to 2000 Hz. (Note that in a mixed system, with only some sectors having TPX electronics, the gate is opened for ALL sectors even for TPX only events.) For the high rate tests the charge loading scaled linearly with the trigger rate. See page 36 of my notebook #2.

EXPERT OPERATIONS:

Normally, the gated grid system needs no operator changes once it is turned on and the GUI is all green. However, for special calibration runs or to calibrate one of the voltages, there are some expert only controls. To access these controls, click on the “Expert Controls” button on the Gated Grid GUI. This brings up the GUI:

In order to make changes to the voltages (global or individual sector) one must first click on the “Write Disabled” button on the Expert GUI. Then:

One can now use the global control or a single sector control to input a new set of Vgg voltages (e.g. if runs will be taken at a different cathode voltage) or to open and close the gate during the calibration procedure (see below). When the changes have been made don’t forget to click on the “Write Enabled” button to change it back to “Disabled”.

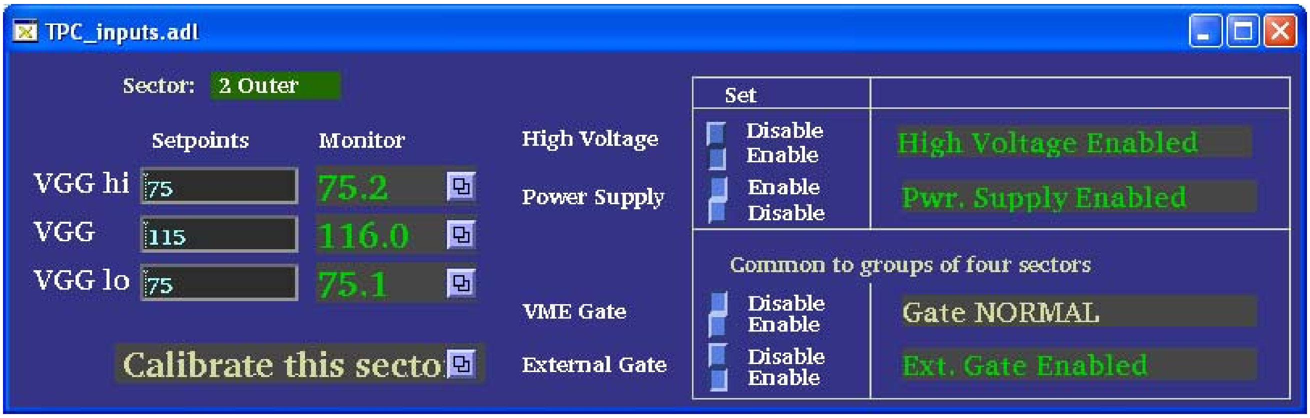
We used to have problems with the stability of some of the GG voltages, especially after long shutdowns. Most of these problems were eventually traced to the ribbon cables that connect the control modules to the drivers. These cables were replaced in 2006 and we have had virtually no problems with wandering voltages since. However, it may be necessary to occasionally recalibrate a drifting voltage.

As stated above a voltage that drifts 3% from nominal will cause a yellow alarm, but data taking can continue in this case. A 5% drift probably causes enough of a distortion in the data that it needs to be fixed as soon as possible.

To recalibrate a voltage that has drifted, follow this procedure:

1. Gain access to the platform.

2. Bring up the GUI for the sector that is drifting:



TPC_inputs.adl

Sector: 2 Outer

	Setpoints	Monitor
VGG hi	75	75.2
VGG	115	116.0
VGG lo	75	75.1

Calibrate this secto

	Set	
High Voltage	Disable Enable	High Voltage Enabled
Power Supply	Enable Disable	Pwr. Supply Enabled

Common to groups of four sectors

VME Gate	Disable Enable	Gate NORMAL
External Gate	Disable Enable	Ext. Gate Enabled

(For purposes of illustration we'll assume the readback (monitor) voltage for VGG hi reads 70 V and has turned red.

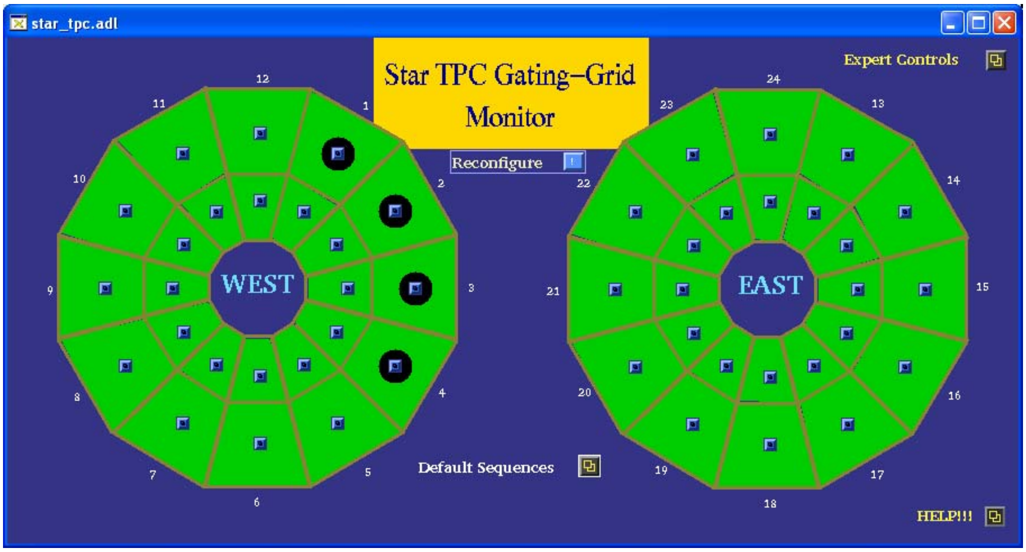
3. Make sure that the button in the Experts GUI says "Write Enable"

4. Record the readings of the three voltages shown in the Monitor window: i.e. VGG hi, VGG, and VGG lo).

5. In back of Rack 2A6 find the breakout box and the cable for the bad sector (here 2 Outer). Disconnect the driver pigtail from the 100' cable and plug the two ends into the breakout box.

6. Using a DVM measure the voltage between VGG hi and ground, and between VGG lo and ground – record these values.

7. Using the GUI for the bad sector click on the enable button for the VME Gate. It should change from "Gate Normal" to "Gate Open" – this opens the gate for all four sectors of that driver module. (Because of the modulo 4 nature of the controls, you can't open the gate for only one channel.) The GG GUI should now look like:



This shows Sectors 1-4 Outer have their gate in the open state.

8. Using the breakout box, again measure from VGG hi to ground and VGG lo to ground – since the gate is open they should both read the same (canonical = -115 V). Record this value.

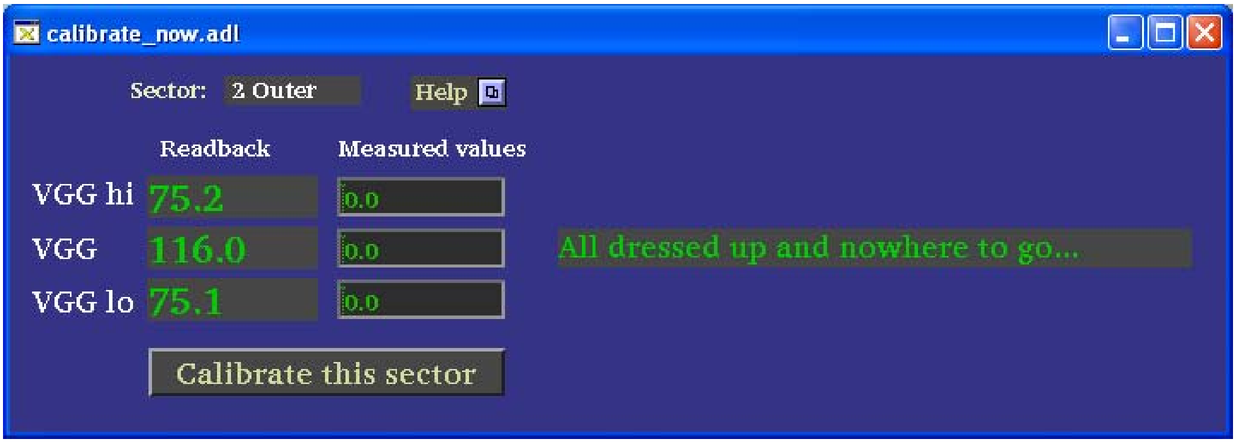
9.Note that there are two possibilities for a drifting voltage:

The DAC which sets the voltage could be wrong, in which case the voltage you measure with the DVM will agree with the voltage measured on the GUI i.e. they both read something other than the nominal value.

The ADC which reads the voltage back could be wrong, in which case you will measure a correct voltage with the DVM (i.e. 75 volts), and the monitor readback on the GUI is wrong.

The only way to distinguish these two cases is to measure using the breakout box.

10.On the sector control GUI, click on the “Calibrate This Sector” button. This brings up the calibrate GUI:



Sector: 2 Outer

	Readback	Measured values
VGG hi	75.2	0.0
VGG	116.0	0.0
VGG lo	75.1	0.0

All dressed up and nowhere to go...

11. Input the absolute value of the three MEASURED voltages that you recorded from the breakout box (make sure to hit enter after each entry) and then click on “Calibrate this sector”. The program should then recalibrate the drifting channel and save the new scale factors in the data base.

12. Check the sector control GUI again to confirm that all voltages now read nominal. If the calibration didn’t work, remeasure all voltages and try again.

13. When finished, make sure the gate is set back to “Normal” and the Expert GUI has been set back to “Write Disabled”.

It sometimes happens that a voltage has drifted far from nominal and the automatic calibration program is unable to bring it back. In such cases you can try replacing either the control or driver module or revert to the old calibration method which requires inserting new constants into the GG database by hand (see below for Geno’s original writeup.)

STARTUP PROCEDURE

As part of the startup check list for each new run we have developed a method to check if the GG cables are still attached to the TPC sectors. It is especially important to perform this check if cables have been installed or removed for other detectors. Note that this procedure was developed after we discovered that one sector was not cabled for a data run, necessitating a pole tip removal to fix it.

The method consists of measuring the capacitance between each twinex pin and ground and between the two pins, for all sectors. The check is done on the platform by breaking the connection between the pigtail and the long cable in the back of the driver crate. The blue TPC portable Fluke meter will measure capacitance to the needed accuracy. The canonical values are listed below. The measurement is made at the connector of the long cable – if the other end is not attached the reading will be different from that listed for wach sector.

Once this check is finished, it is usually sufficient to turn both crates on and turn on the voltages to check for uncalibrated channels.

TWO KNOWN PROBLEMS

1. It was discovered before run 7 that Sector 8 outer had an additional grid leak besides the known one between pad rows 13 and 14. It appeared that, in two places, some GG wires were possibly not connected to the buss. Experimentally we found that reversing the polarity for this sector helped to close this leak. We therefore installed a short polarity reversing cable for that sector between the driver pigtail and the long cable. This extra cable has an identifying tag. No other sectors were found that had this problem.

2. For some unknown reason, the VME processor for the GG seems to “go to sleep” after ~ some hours after a reboot. Various slow controls experts have looked at this but found no solution – we have even upgraded the processor once. It could be a slow controls problem or a memory leak or ? Fortunately, the processor continues to monitor the voltages, so alarms will still be generated for a drifting value. However the processor does NOT respond to any commands from the GUI, so one can’t change values, calibrate, or even turn the system off. The only way to recover control is to reboot the processor (which by definition turns the voltage off.) Since the GG system has been stable for the last 2 runs this “feature” has not caused too much grief.

SPARES & REPAIR

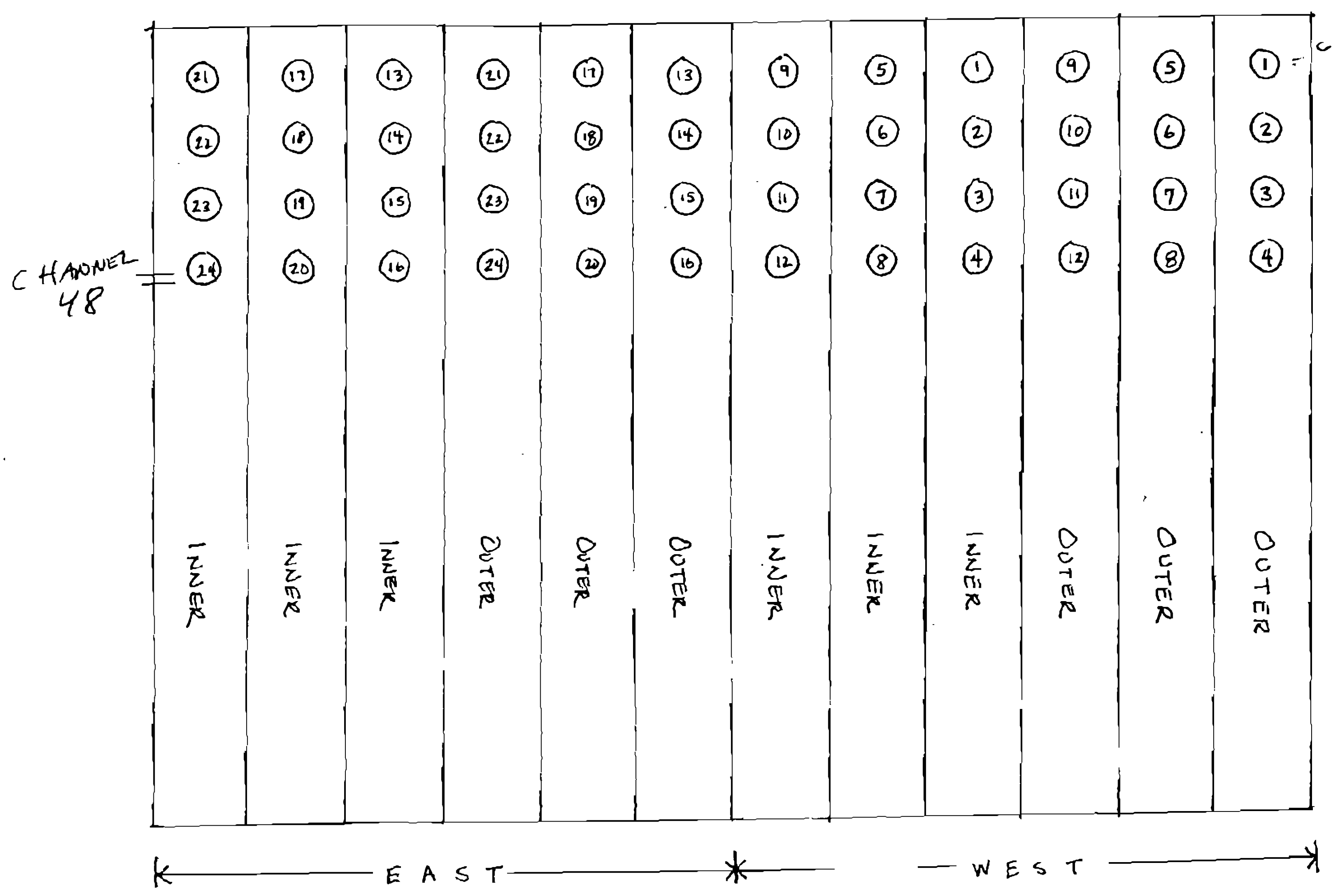
The GG system was originally built by Vahe Ghazikhanian from UCLA, and he also did repairs. He has now left UCLA, but the tech who did the repairs is still there, so there is some hope. Spare drivers and control modules (2 flavors) are in the TPC spares cabinet.

I have not replaced a module for 2 years, but the GG rate will increase for the DAQ1000 era.

HISTORICAL DOCUMENTS

Below are some documents for the GG, including the capacitance measurements, Geno’s original write-ups, Dennis Reichhold’s calibration code etc.

GATING GRID DRIVER: HV OUTPUT MAPPING (REAR VIEW)



LEGEND:

Ⓝ ← HIGH-VOLTAGE CABLE FOR SECTOR N.

"OUTER" ← OUTER SECTOR

"INNER" ← INNER SECTOR

"WEST" ← WEST END OF TPC

"EAST" ← EAST END OF TPC

E. YAMAMOTO

Gating Grid Capacitance To Ground

Measured 11 July, 2000

Eugene T. Yamamoto
geno@physics.ucla.edu

Capacitance Measured between each pin and the ground sleeve. Pin 1 is pin closest to connector key.

	Capacitance (nF)				
Sector Number	**Outer**		**Inner**		
	Pin 1	Pin 2	Pin1	Pin 2	
1	5.85	5.94	5.4	5.43	
2	5.87	5.87	5.32	5.42	
3	5.88	5.95	5.29 5.34	5.39 5.29	- 3/20/01?
4	5.89	5.9	5.34	5.48	
5	5.93	6.01	5.39	5.41	
6	5.89	5.97	5.4	5.46	
7	5.89	5.83	5.36	5.42	
8	5.89	5.97	5.4	5.46	
9	5.86	5.96	5.37	5.44	
10	5.9	6	5.32	5.48	
11	5.9	6	5.35	5.42	
12	5.9	6	5.4	5.45	
13	5.89	6	5.37	5.44	
14	5.84	5.95	5.29	5.47	
15	5.92	6.02	5.33	5.41	
16	5.87	5.98	5.27	5.44	
17	5.89	5.99	5.28	5.44	
18	6.14	6.26	5.3	5.46	Outer Sector. Long Ca
19	5.88	5.98	5.31	5.47	CABLE
20	5.84	5.96	5.33	5.42	
21	5.81	5.91	5.33	5.41	
22	5.83	5.94	5.12	5.2	Inner Sector. Short Ca
23	5.79	5.88	5.28	5.45	CABLE
24	5.8	5.93	5.33	5.42	
Mean	5.88125	5.966667	5.328333	5.42875	
sDev	0.065959	0.078777	0.06084	0.054479	

easured 11 July, 200
Eugene T. Yamamoto
geno@physics.ucla.edu
Capacitance Measured between two pins of twinX cable
at the driver modules.

	Capacitance (nF)		
Sector Number	Outer	Inner	
1	5.47	4.24	
2	5.5	4.21	
3	5.52	4.2	
4	5.46	4.24	
5	5.54	4.23	
6	5.53	4.26	
7	5.45	4.23	
8	5.52	4.26	
9	5.52	4.27	
10	5.53	4.25	
11	5.5	4.25	
12	5.53	4.26	
13	5.53	4.24	
14	5.52	4.23	
15	5.53	4.22	
16	5.53	4.23	
17	5.49	4.24	
18	5.66	4.24	Outer Sector. Long Cable
19	5.52	4.25	
20	5.48	4.23	
21	5.48	4.23	
22	5.53	4.11	Inner Sector. Short Cable
23	5.46	4.22	
24	5.48	4.24	
Mean	5.511667	4.2325	
sDev	0.041772	0.030822	

Replacing a Gating Grid (GG) module:

1) Make sure gating grid is off and the crates are unplugged from the wall socket. The crates are in rack 2A6.

2)Take cables off the front of the offending module and the module to the left and right of it. This is a necessary precaution to prevent pinching/cutting the cables when installing the replacement module.

3) Go to the back of the rack and unhook the HV cables from the TPC. Do the following: Slide the black insulation DOWN. Slide the connector sleeve as you are pulling the cable. This should disconnect the cable.

4) There are two screws holding the module in the crate. They reside on the top and bottom of the module. Unscrew these.

5) Slide module out.

6) To slide the replacement module in, grab the four HV cables in the back and place them as far back in the now open slot as possible. After doing that, slide the module partially in (1/3 of the way).

7) Go to the back of the crate, and grab the HV cables and pull them out. You can now pull the module GENTLY into place. Make sure the cables in front are out of the way and not getting pinched. This is a common problem. Often times there will not be quite enough space to get the module in place all the way. DO NOT FORCE the module into place by pulling the HV wires. Instead, unscrew all the modules on one side of the replacement module. Pull these out part way. Since there is extra space at the ends of the crate, this will allow you to put in the replacement module, assuming it is somewhere in the middle. After you have slide in the replacement module, slide modules in starting with the module that is farthest from the end of the crate.

7) Reattach cables and make sure that the black insulation covers the ground sleeve on the high voltage cables.

What to do if the Gating Grid Driver acts up:

This file lists some of the symptoms that I have encountered in the gating grid and what they have meant in the past. If a channel ever begins to act up:

please note the problem in the TPC run log.

Send e-mail to Vahe Ghazikhanian (vahe@physics.ucla.edu) and Eugene Yamamoto (geno@physics.ucla.edu), and include a copy of the log entry. Please be as descriptive as possible, including the setpoints for each channel in the offending sector, the status of the high voltage, power supply, gates. Also, information about the sector's behavior when the HV and/or power supply is cycled will help. (e.g. When I enable HV, Vgg shoots up to 297 volts. Vgg does not respond to my voltage requests.)

Some easy to solve problems with the gating grid driver.

I look at the GUI for the gating grid driver and all the sectors are white.

Problem: The gating grid control crate is not turned on.

Solution: Make sure both gating grid crates are on.

I look at the GUI for the gating grid driver and sector 1-outer is white.

Problem: mis-initialization of sector 1 power supply.

Solution: Manually enable power supply for that sector.

I did a startup sequence under global general controls. None of the sectors are on.

Problem: The gating grid driver crate my not be turned on.

Solution: Go to the VME status GUI on the lower right hand part of tpc_top.

Check the gating grid crates and make sure that the crates are on. If it isn't turn it on and repeat the startup procedure.

I try to use the default sequence button/global controls and I input stuff but nothing happens.

YES, both gating grid driver crates are on...

Problem: Some tasks need to be restarted on the VME cpu.

Solution: On sc.star.bnl.gov, and ONLY that machine, type '`telnet scserv 9002`'

When you get the '->' prompt, type '`td "global"`'. You need the quotation marks around global

You should get a message like 'value=0=0x0'.

Next, type '`seq &global`'

You should see something like:

```
@(#)SEQ Version 1.9.1: Thu Nov 18 13:48:10 EST 1999

tShell 05/18/00 15:23:57: Spawning state program "global", task name = "global"

tShell 05/18/00 15:23:57: Task id = 12881028 = 0xc48c84

value = 12881028 = 0xc48c84

-> global 05/18/00 15:23:57: Spawning task 12870628: "global_1"

global 05/18/00 15:23:57: Spawning task 12860228: "global_2"

global 05/18/00 15:23:57: Spawning task 12849828: "global_3"

global 05/18/00 15:23:57: Spawning task 12839428: "global_4"

global 05/18/00 15:23:57: Spawning task 12829028: "global_5"

global 05/18/00 15:23:57: Spawning task 16285744: "global_6"
```

And some messages about setting global power, and setting power on sector X, where X is some number.

If this doesn't work, reboot the cpu. If it still doesn't work, try cycling the power on crate 54.

The power on the driver crate was cycled (interlocks or user power cycle). The gating grid crates are on and I just did a HV set using High voltage control. The GUI says the HV is on but when I input a setpoint, nothing happens.

Problem: The HV for the channel was enabled in the software but is not enabled in the gating grid module.

Solution: The best thing to do would be to execute the startup sequence under the default sequences. This will properly reinitiate the database values and ensure an edge for the gating grid modules to trigger on. If this doesn't work, try rebooting the cpu in the gating grid control crate. you can do this from the VME status screen by doing a system reset.

A group of four contiguous outer/inner sectors is not responding. They correspond to one module. THIS MODULE WAS JUST INSTALLED.

Problem: The pins to the power bus in the back are not making connections.

Solution: Pull the module that you just installed, check to make sure that the 6 pins in the back of the module are not pushed in. ** Please take a look at the next problem.

Symptoms which indicate you are in trouble (i.e. need an access):

A group of four contiguous outer/inner sectors is not responding. When I

look at the GG_Mapping.log file. I see that the four sectors are controlled

by the same gating grid module. THIS MODULE HAS BEEN WORKING UP 'TILL NOW.

Problem: Most likely a fuse is blown.

Solution: Please note this in the log and notify the above mentioned people. Call for access.

With HV enabled, Vgg/Vgghi/Vgglo seem to be set to the maximum allowable voltage (150 for Vgghi/Vgglo and 300 for Vgg). There is no way to control the voltage. When HV is disabled, the setting go to zero but as soon as the HV is enabled, the channel goes to its max.

Problem: It is most likely a shorted transistor that needs to be replaced.

Solution: Please note this in the log and notify the above mentioned people.

Vgglo seems to influence the Vgg setting. When Vgglo is set to 0 volts, Vgg

monitor value matches the requested value. In this case, Vgg goes from 130 to 140.6 when I set Vgglo to 75 volts.

Problem:

Solution: Please note this in the log and notify the above mentioned people.

(F)TPC Gating Grid Driver Calibration

Eugene T. Yamamoto [*]
University of California - Los Angeles
Los Angeles, CA 90095

June 11, 2000

Below are the procedures for calibration of the gating grid driver. There are 3 steps to calibrating the gating grid:

1. Measure the voltage out of the back of the driver modules.
2. Calibrate the ADC.
3. Calibrate the DAC.

You must have electrical training in order to perform the gating grid calibrations.
If you do not know what "driver module" means, STOP! you are not qualified to calibrate the gating grid.
If you do not know what ADC or DAC stands for, STOP! You are not qualified to calibrate the gating grid.
To measure the voltage out of the back of the driver modules you will need:

1. Voltmeter or scope
2. HV probe box
3. pen and paper

If you do not know what a voltmeter or scope is, STOP! You are not qualified to calibrate the gating grid.
If you do not know what the HV probe box is, STOP! You are not qualified to calibrate the gating grid.
If you do not know what pen or paper is, STOP! You are not qualified to calibrate the gating grid.
The procedure is as follows. If ANY of this does not make sense, you are not qualified to calibrate the gating grid.

- Make sure you are not getting any triggers if you are using a voltmeter.

---

[*] e-mail: geno@physics.ucla.edu

- Turn on gating grid driver modules to nominal operating voltage settings
- Use probe box to measure the voltage out of back of gating grid driver module (write these values down). Note that gui reads positive volt but output is negative.
    1. With Gate Normal, measure vgghi. This is vgg - vgghi.
    2. With Gate Normal, measure vgglo. This is vgg + vgglow
    3. With Gate OPEN, measure either vgghi or vgglo output. This is vgg
- at a computer, telnet scserv 9002
- In the sc.star.bnl.gov epics root directory, open

  `TPCggridApp/TPCggridDb/calibrations/analog_in_calibrations.txt.`

  This file contains all the ADC calibrations.
- In the serial connection, type: dbpr "channel",4. Channel is defined as:
    1. `GG_A_In_X_X`
    2. The first X is either A,B,C, where A is vgghi, B is vgglo, and C is vgg
    3. The second X is the channel number, from 1 to 48.
- Look for the field labeled 'EGUF'. This is the ADC calibration constant.
- In the serial connection, type: dbpf "channel.EGUF","(int) $measuredvalue/monitoredvalue \times eguf$", where little eguf is the value of EGUF that printed out when you ran the dbpr command. (int) means find the closest integer to the result of $measuredvalue/monitoredvalue \times eguf$. it should look something like:

  ```
  dbpf ''GG_A_In_A_1.EGUF'',''262''
  ```
- copy the dbpf line and paste it to the bottom of the

  `analog_in_calibrations.txt`

  file and allsectors.cal file.
- Once this is done, in the serial line, type:

  ```
  seq &calibrate,"channel=X,sector=X"
  ```

  where X is the appropriate value. This calibrates the DAC and creates a file in the calibrations directory with a self explanatory name. Replace the appropriate line in allsectors.cal with the new DAC calibration.

Note that you can do the DAC calibration globally using the file:

`TPCggridApp/TPCggridDb/scripts/calibrate.txt`

which is a vxWorks script. If you don't know how to run scripts, you should not do the global DAC calibration.
Of course, once you do the calibration, you don't have to cut and paste 144 values, you can cat or grep or whatever to get the values. If you don't know how to do this, you should not do the global DAC calibration.

```
calibrate.st:
thor: Dennis Reichhold
his is based on calibrate.st
hor: Eugene Yamamoto, UCLA
This sequencer handles the calibration of each channel.
This is to deal with drifting of voltages. This can also
be used in the calibration of replacement components.
*/

program newcalibrate

%%#include <stdio.h>
%%#include <stdlib.h>
%%#include <taskLib.h>
%%#include <time.h>

%%char calib_time[26];
%%time_t caltime;
%%struct tm timer;
%%struct tm *timerptr=&timer;
%%char bogus[2];
%%FILE *f;

int i;
float vOAvg;
float vIAvg;

string message;
float VGG_hi_meas;
float VGG_lo_meas;
float VGG_meas;
int sector;

assign message to "GG_Message";
assign VGG_hi_meas to "GG_Calibrate.A";
assign VGG_lo_meas to "GG_Calibrate.B";
assign VGG_meas to "GG_Calibrate.C";
assign sector to "GG_Calibrate.D";
monitor sector;

float VGG_hi_In;
float VGG_lo_In;
float VGG_In;
float VGG_hi_Out;
float VGG_lo_Out;
float VGG_Out;
int VGG_hi_In_EGUF;
int VGG_lo_In_EGUF;
int VGG_In_EGUF;
float VGG_hi_Out_EGUF;
float VGG_lo_Out_EGUF;
float VGG_Out_EGUF;
int VGG_hi_In_SEVR;
int VGG_lo_In_SEVR;
int VGG_In_SEVR;

assign VGG_hi_In to "";
assign VGG_lo_In to "";
assign VGG_In to "";
```

```
assign VGG_hi_Out to "";
assign VGG_lo_Out to "";
assign VGG_Out to "";
assign VGG_hi_In_EGUF to "";
assign VGG_lo_In_EGUF to "";
assign VGG_In_EGUF to "";
assign VGG_hi_Out_EGUF to "";
assign VGG_lo_Out_EGUF to "";
assign VGG_Out_EGUF to "";
assign VGG_hi_In_SEVR to "";
assign VGG_lo_In_SEVR to "";
assign VGG_In_SEVR to "";

float VGG_hi_comp;
float VGG_lo_comp;
float VGG_comp;
float VGG_hi_diff;
float VGG_lo_diff;
float VGG_diff;
int new_EGUF;

char filename[164];
char *sect;
char *chan;
char str[64];

ss calibrate {

  state wait {

    when(sector<0&&delay(0.1)) {
    } state wait

    when(sector==0&&delay(0.1)) {
      sprintf(message,"All dressed up and nowhere to go...");
      pvPut(message);
    } state wait

    when(sector>0) {
      pvGet(VGG_hi_meas);
      pvGet(VGG_lo_meas);
      pvGet(VGG_meas);
      VGG_hi_meas=abs(VGG_hi_meas);
      VGG_lo_meas=abs(VGG_lo_meas);
      VGG_comp=abs(VGG_meas);
      VGG_hi_comp=VGG_meas-VGG_hi_meas;
      VGG_lo_comp=VGG_lo_meas-VGG_meas;
    } state start_cal
  } /* end state wait */

  state start_cal {

    when(VGG_hi_meas<0.1||VGG_lo_meas<0.1||VGG_meas<0.1) {
      sprintf(message,"You must enter values for ALL channels");
      pvPut(message);
      sector=-1;
      pvPut(sector);
    } state wait

    when(VGG_hi_meas>0.1&&VGG_lo_meas>0.1&&VGG_meas>0.1) {
```

```
      sprintf(message,"Connecting channels for calibration...");
      pvPut(message);
      sprintf(str,"GG_A_Out_A_%d.VAL",sector);
      pvAssign(VGG_hi_Out,str);
      sprintf(str,"GG_A_Out_B_%d.VAL",sector);
      pvAssign(VGG_lo_Out,str);
      sprintf(str,"GG_A_Out_C_%d.VAL",sector);
      pvAssign(VGG_Out,str);
      sprintf(str,"GG_A_Out_A_%d.EGUF",sector);
      pvAssign(VGG_hi_Out_EGUF,str);
      sprintf(str,"GG_A_Out_B_%d.EGUF",sector);
      pvAssign(VGG_lo_Out_EGUF,str);
      sprintf(str,"GG_A_Out_C_%d.EGUF",sector);
      pvAssign(VGG_Out_EGUF,str);
      sprintf(str,"GG_A_In_A_%d.VAL",sector);
      pvAssign(VGG_hi_In,str);
      sprintf(str,"GG_A_In_B_%d.VAL",sector);
      pvAssign(VGG_lo_In,str);
      sprintf(str,"GG_A_In_C_%d.VAL",sector);
      pvAssign(VGG_In,str);
      sprintf(str,"GG_A_In_A_%d.EGUF",sector);
      pvAssign(VGG_hi_In_EGUF,str);
      sprintf(str,"GG_A_In_B_%d.EGUF",sector);
      pvAssign(VGG_lo_In_EGUF,str);
      sprintf(str,"GG_A_In_C_%d.EGUF",sector);
      pvAssign(VGG_In_EGUF,str);
      sprintf(str,"GG_A_In_A_%d.SEVR",sector);
      pvAssign(VGG_hi_In_SEVR,str);
      sprintf(str,"GG_A_In_B_%d.SEVR",sector);
      pvAssign(VGG_lo_In_SEVR,str);
      sprintf(str,"GG_A_In_C_%d.SEVR",sector);
      pvAssign(VGG_In_SEVR,str);

      sprintf(filename,
              "/star/sc/users/sysuser/epics/R3.12.2-LBL.4/TPCggridApp/TPCggridDb
      f = fopen(filename, "a");
%%    caltime = time(NULL);
%%    timerptr = localtime(&caltime);
%%    strcpy(calib_time,asctime(timerptr));
      fprintf(f,"# Auto-calibration on %s",calib_time);
    } state ADC_cal
  } /* end state start_cal */

  state ADC_cal {

    when(delay(1.0)) {
      pvGet(VGG_hi_In);
      pvGet(VGG_lo_In);
      pvGet(VGG_In);
      pvGet(VGG_hi_In_EGUF);
      pvGet(VGG_lo_In_EGUF);
      pvGet(VGG_In_EGUF);
      VGG_hi_diff=abs(VGG_hi_In-VGG_hi_comp);
      VGG_lo_diff=abs(VGG_lo_In-VGG_lo_comp);
      VGG_diff=abs(VGG_In-VGG_comp);
      if (VGG_hi_diff>1.5) {
        VGG_hi_In_EGUF*=VGG_hi_comp/VGG_hi_In;
        pvPut(VGG_hi_In_EGUF);
        fprintf(f,"dbpf \"GG_A_In_A_%i.EGUF\",\"%i\"\n",sector,VGG_hi_In_EGUF);
      }
```

```
    if (VGG_lo_diff>1.5) {
      VGG_lo_In_EGUF*=VGG_lo_comp/VGG_lo_In;
      pvPut(VGG_lo_In_EGUF);
      fprintf(f,"dbpf \"GG_A_In_B_%i.EGUF\",\"%i\"\n",sector,VGG_lo_In_EGUF);
    }
    if (VGG_diff>2.) {
      VGG_In_EGUF*=VGG_comp/VGG_In;
      pvPut(VGG_In_EGUF);
      fprintf(f,"dbpf \"GG_A_In_C_%i.EGUF\",\"%i\"\n",sector,VGG_In_EGUF);
    }
    sprintf(message,"Finished calibrating ADCs");
    pvPut(message);

  } state DAC_cal
} /* end ADC_cal */

state DAC_cal {
  when(delay(3.0)){
    pvGet(VGG_hi_In_SEVR);
    pvGet(VGG_lo_In_SEVR);
    pvGet(VGG_In_SEVR);

    if (VGG_hi_In_SEVR!=0) {
      vOAvg = 0;
      vIAvg = 0;
      for(i=0;i<10;i++) {
        pvGet(VGG_hi_Out);
        pvGet(VGG_hi_In);
        vOAvg += VGG_hi_Out;
        vIAvg += VGG_hi_In;
        %%taskDelay(sysClkRateGet()*2);
        sprintf(message,"Took %d voltage measurements\n", i);
        pvPut(message);
      }
      vOAvg *=.1;
      vIAvg *=.1;

      printf("Voltages: %f   %f\n",vOAvg, vIAvg);
      pvGet(VGG_hi_Out_EGUF);
      printf("EGUF  %f\n",VGG_hi_Out_EGUF);
      VGG_hi_Out_EGUF *= (vIAvg/vOAvg);
      printf("EGUF' %f\n",VGG_hi_Out_EGUF);

      pvPut(VGG_hi_Out_EGUF);
      fprintf(f,"dbpf \"GG_A_Out_A_%i.EGUF\",\"%f\"\n",sector,VGG_hi_Out_EGUF)
    }

    if (VGG_lo_In_SEVR!=0) {
      vOAvg = 0;
      vIAvg = 0;
      for(i=0;i<10;i++) {
        pvGet(VGG_lo_Out);
        pvGet(VGG_lo_In);
        vOAvg += VGG_lo_Out;
        vIAvg += VGG_lo_In;
        %%taskDelay(sysClkRateGet()*2);
        sprintf(message,"Took %d voltage measurements\n", i);
        pvPut(message);
      }
      vOAvg *=.1;
```

```
        vIAvg *=.1;

        printf("Voltages: %f   %f\n",vOAvg, vIAvg);
        pvGet(VGG_lo_Out_EGUF);
        printf("EGUF  %f\n",VGG_lo_Out_EGUF);
        VGG_lo_Out_EGUF *= (vIAvg/vOAvg);
        printf("EGUF' %f\n",VGG_lo_Out_EGUF);

        pvPut(VGG_lo_Out_EGUF);
        fprintf(f,"dbpf \"GG_A_Out_B_%i.EGUF\",\"%f\"\n",sector,VGG_lo_Out_EGUF)
      }

      if (VGG_In_SEVR!=0) {
        vOAvg = 0;
        vIAvg = 0;
        for(i=0;i<10;i++) {
          pvGet(VGG_Out);
          pvGet(VGG_In);
          vOAvg += VGG_Out;
          vIAvg += VGG_In;
          %%taskDelay(sysClkRateGet()*2);
          sprintf(message,"Took %d voltage measurements\n", i);
          pvPut(message);
        }
        vOAvg *=.1;
        vIAvg *=.1;

        printf("Voltages: %f   %f\n",vOAvg, vIAvg);
        pvGet(VGG_Out_EGUF);
        printf("EGUF  %f\n",VGG_Out_EGUF);
        VGG_Out_EGUF *= (vIAvg/vOAvg);
        printf("EGUF' %f\n",VGG_Out_EGUF);

        pvPut(VGG_Out_EGUF);
        fprintf(f,"dbpf \"GG_A_Out_C_%i.EGUF\",\"%f\"\n",sector,VGG_Out_EGUF);
      }

    } state clean_up
  } /* ends state DAC_cal */

  state clean_up {
    when(delay(3.0)) {
      fclose(f);
      VGG_hi_meas=0.0;
      VGG_lo_meas=0.0;
      VGG_meas=0.0;
      sector=0;
      pvPut(VGG_hi_meas);
      pvPut(VGG_lo_meas);
      pvPut(VGG_meas);
      pvPut(sector);
      sprintf(str,"");
      pvAssign(VGG_hi_Out,str);
      pvAssign(VGG_lo_Out,str);
      pvAssign(VGG_Out,str);
      pvAssign(VGG_hi_Out_EGUF,str);
      pvAssign(VGG_lo_Out_EGUF,str);
      pvAssign(VGG_Out_EGUF,str);
      pvAssign(VGG_hi_In,str);
      pvAssign(VGG_lo_In,str);
```

```
    pvAssign(VGG_In,str);
    pvAssign(VGG_hi_In_EGUF,str);
    pvAssign(VGG_lo_In_EGUF,str);
    pvAssign(VGG_In_EGUF,str);
    pvAssign(VGG_hi_In_SEVR,str);
    pvAssign(VGG_lo_In_SEVR,str);
    pvAssign(VGG_In_SEVR,str);
  } state wait
}
```

GP Pulser

Ground Plane Pulser

1. Introduction

The TPC uses a pulser system to calibrate the FEE electronics, check for bad channels, and correct for slight variations in the start time for each channel (t0).

The system consists of a Wavetek model 395 Arbitrary Waveform Generator, a rate limiter, fanout/amplifier modules in a VME crate and a patch panel. The system is in Rack 2A5. Fig. 1 shows the VME crate holding the fanout modules, with the patch panel below. The pulser is on a shelf directly below the patch panel. The rate limiter is located inside Rack 2A5 and has its own power (AC to DC converter).

The system, under DAQ control, sends a known constant pulse to the ground plane of each TPC sector. This pulse is detected on the pads through capacitive coupling and is read out by DAQ.

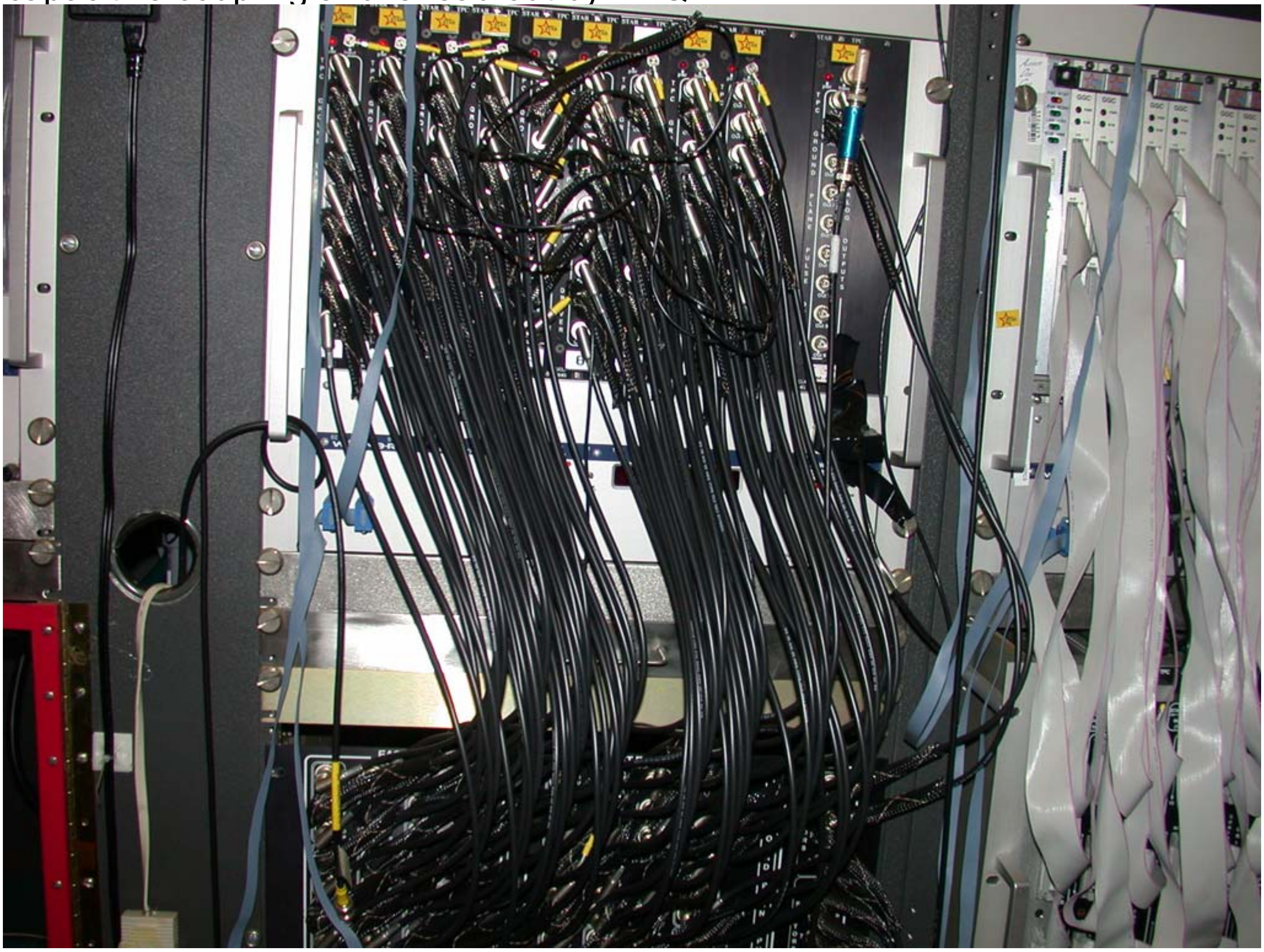
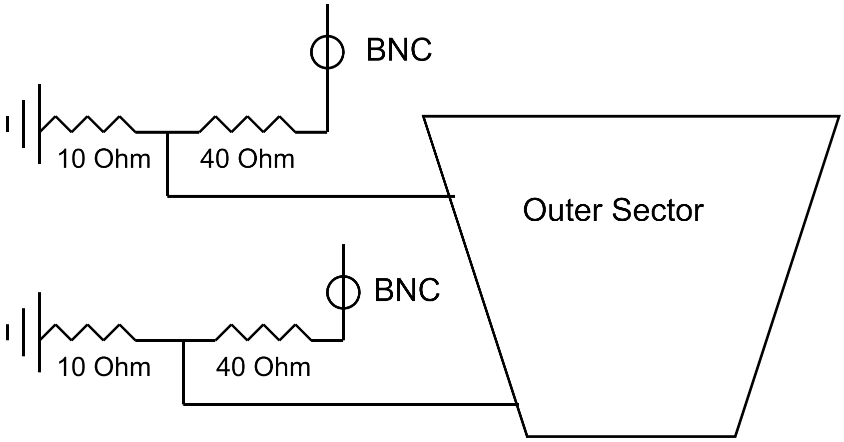


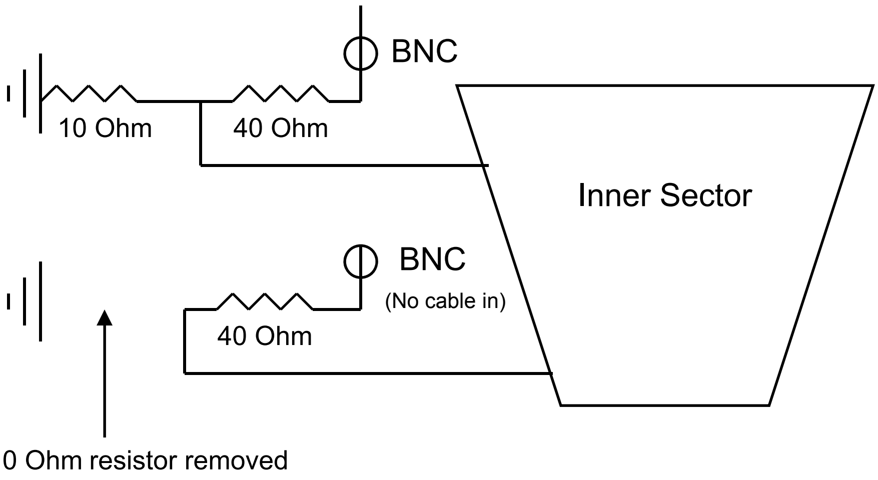
Figure 1

2. Schematic

The pulse from the Wavetek (main out) first goes to a rate limiter module located inside Rack 2A5. This module limits the output frequency to be less than ~800 Hz. A higher frequency would cause the fanout modules to overload. The pulse is then input to one of the amp/fanout units. Each of the 9 outputs from this module is used as an input to the other nine fanout units. (8 for the TPC and 1 for the FTPC). For an outer sector two outputs are used to drive the ground plane, while only one is used for each inner sector. Thus one amp/fanout unit (9 outputs) drives three supersectors. The output cables from the fanouts go to a feedthrough patch panel located below the VME crate. The cables (~ 100 ft RG58 BNC) from the patch panel go to the sectors and are terminated internally with 50 ohms each. The BNC connectors are located on the side of each sector.

The sector terminations look like: (See STAR TPC TESTS LOGBOOK II, pg 58)





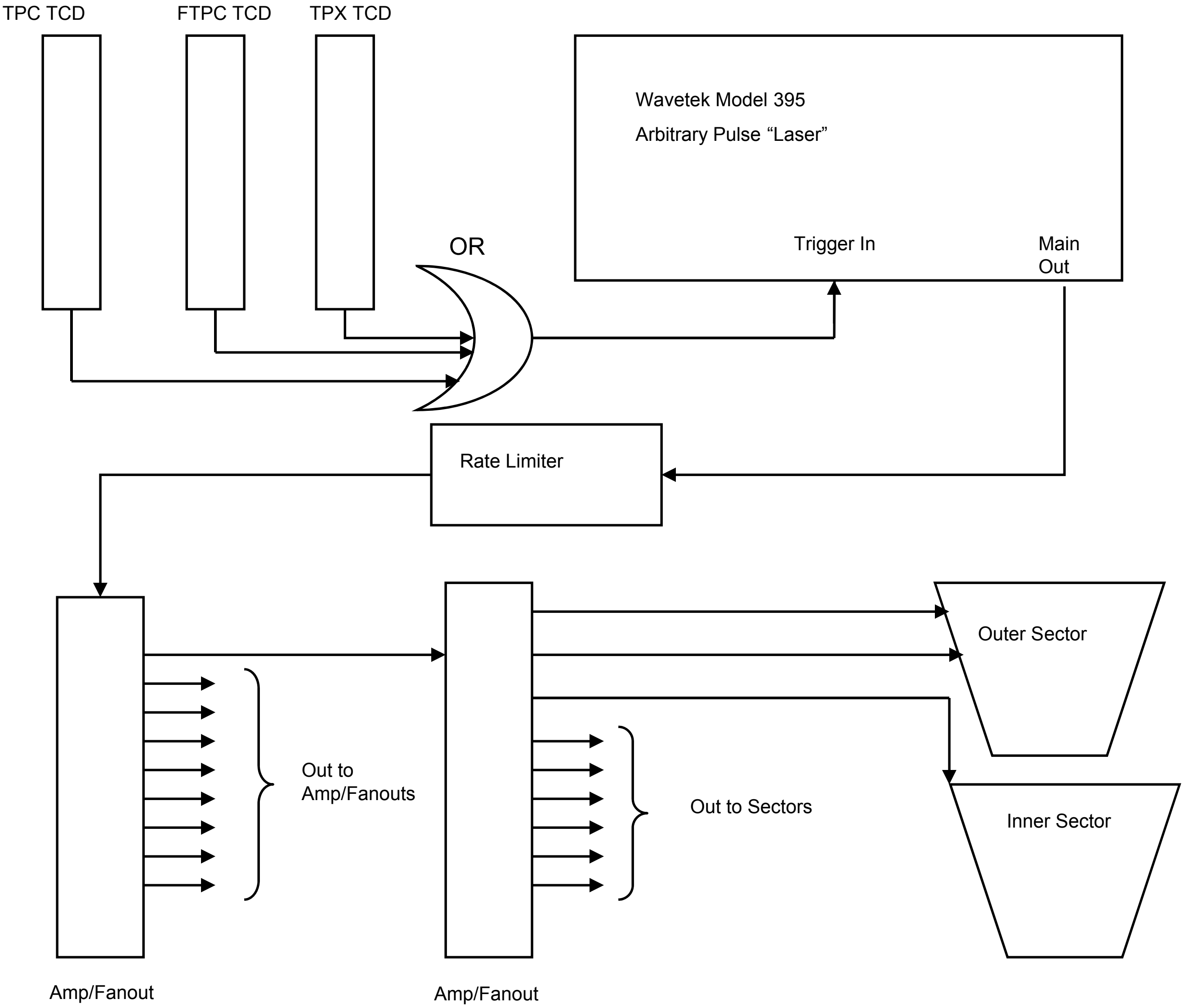


Figure 2

The trigger for the pulser comes from the TPC TCD located in rack row 1A2. This signal is OR'ed with the same output from the TPX (DAQ 1000) and FTPC TCDs. This allows any one of the three systems to make an independent pulser run. The trigger pulse is TTL and comes from the TCD output labeled "pul out". The TCD is controlled by DAQ and run control for making pulser runs.
See Figure 2 for a schematic

3. WAVETEK Settings:

Currently (1/15/2007) we are using an arbitrary waveform labeled “LASER” which has been downloaded to the Wavetek and is stored in memory. This pulse was downloaded in 1999 by Fabrice Retiere and it is a convolution of a TPC signal. It is essentially a square wave with a slightly rounded corner on the rising edge. (See picture in BCS Logbook 1, pages 87-88). Unfortunately we are no longer able to download pulses to the Wavetek – the original method used a Labview program and PC which no longer exist. We also had plans to develop a download ability using a VME processor, but this was never completed. The downloaded pulse has stayed in memory for 7 years. Theoretically the pulse could be restored by entering the datafile by hand, but I have never done this. If this is unsuccessful a standard square wave pulse would probably be sufficient. The data file for the pulse “LASER” is as follows: (see also BCS Logbook 1, page 84.)

1-169	0
170	417
171	1151
172	1501
173	1686
174	1775
175	1818
176	1855
177	1887
178	1914
179	1936
180	1955
181	1969
182	1981
183	1991
184	1997
185	2001
186	2002
187-269	2002
270 – 380	0

Each data point is the relative amplitude for a 100 nanosec time bin. Thus the whole waveform is 38 microsec long, with a rising edge at 17 microsec and a width of 10 microsec.

If the stored pulse is ever lost the Wavetek manual has examples of how to re-enter and store this data file.

After a power outage on the platform it is necessary to make an access and restore some settings for the Wavetek that aren't saved. The settings are input using the front panel pushbuttons and knob, and the built-in LCD screen. Specifically:

1. Push the Waveform Select button "Arbitrary"

2. Push the button which selects the pulse labeled "Laser"

3. Push the Amplitude button then use the knob to change the amplitude to 200 mVp. The two buttons to the left and right of the knob can be used to select the digit that you are changing. Thus, if the amplitude is 1.3 Vp, select the ones digit using the arrow buttons, then use the knob to dial in 0. Then select the tenths digit and dial in 2 for 200 mVp.

4. Select the "Offset" button and make sure the offset is 0.00. If not, set it.

5. Push the "Trig In" button and push the "Source" button until "External" is displayed. Once the trigger is set to External the green LED next to the trigger input BNC should light. Push the "Slope" button until "Positive" is displayed. Then push the "Trigger Level" button and use the knob to set the level to 1.0 V.

6. Push the "Mode" button and select "Trig'd, Cnt" to be 0000001

7. Push the "Arbitrary" button again and make sure the pulse "Laser" is still selected. Then push the "Frequency" button. On the Frequency menu, select "Sample" and set the sample frequency to 10.0 Mhz (Alternatively, set the sample period to 100 ns.) Then select "Waveform" and set the Frequency to 26.32 kHz (or period = 38 microsec.)

8. Push the "Arbitrary" button again.

9. Check the green LED next to the "Main Out" BNC. If the LED is not on, push the "Main Out" button above the connector.

The Wavetek should now be ready for pulser runs.

4. Fanout/Amplifier Modules

The Fanout/Amplifier modules have one input and 9 outputs. The gain for all modules have been adjusted to be equal, since the output pulse is used to calibrate the FEE gain for all sectors. The outputs for all modules were initially checked by me in 1999. (See pages 24-25 of BCS Logbook 1.) For a 200 mV pulse out of the Wavetek the output from each fanout is ~3.68 V. The sigma for all outputs was ~ .037 (1%). I usually check these outputs once each year as part of the startup procedure.

Each module also has a red LED on the front panel to indicate that the power is on. If the LED is not on it usually means that the internal fuses are blown. The fuses are accessible by removing the side panels of the module. One spare module and spare fuses are in the TPC cabinet.

Note also that, for historical reasons, the VME crate that holds the fanouts is interlocked by the TPC interlock system – the interlock is the same as the one for the gated grid. The interlock signal is on a DB15 cable that plugs into the front of the VME crate.

NOTE: During STAR data taking the pulser fanouts are left on continuously, even during physics runs. This means that any excessive noise on the outputs of the fanouts couples directly into the FEE amplifiers. We have had 2 instances where this was seen in the past:

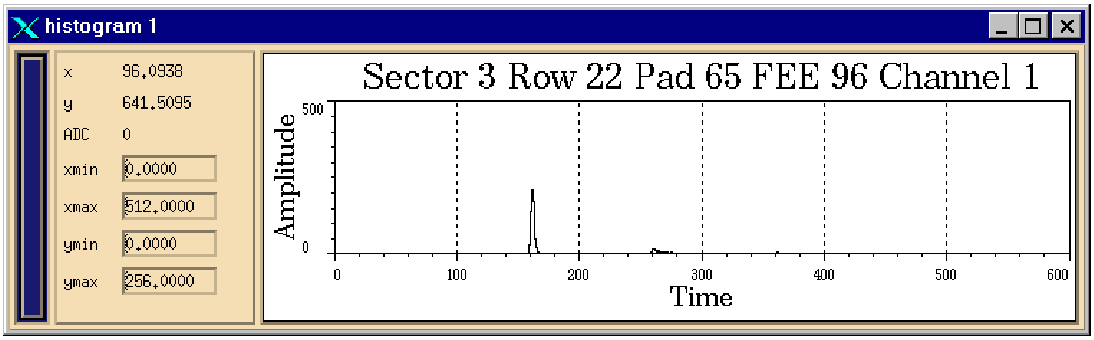
1. The fanout for the FTPC was not screwed into the crate and the output was noisy – this was seen in the FTPC pad monitor. Securing the module fixed the problem.

2. The rms baseline noise for three TPC supersectors went up by a factor of ~ 2. This was noticed during FEE testing in 2006. The effect was found by looking at pedestal runs using the TPC pad monitor, which can measure pedestal means and rms. The problem was eventually traced to a bad input cable to the module.

5. Pulser Runs

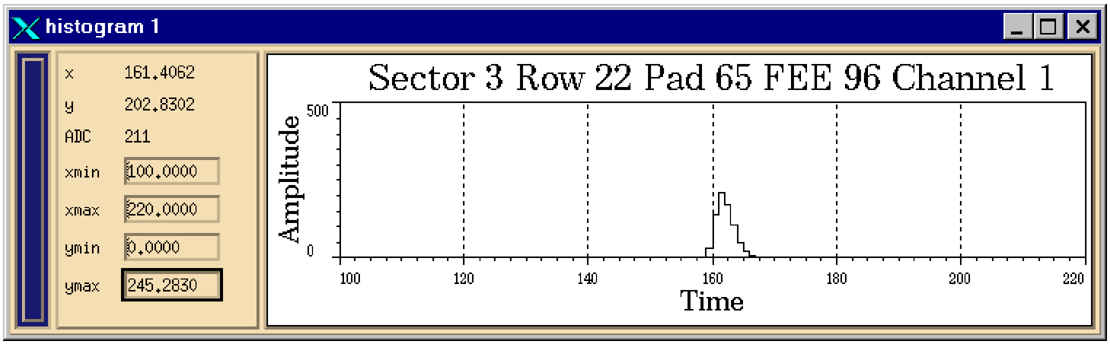
Pulser runs are used to calibrate the gain of each channel of the TPC, correct for jitter in the start time (t0) and to identify dead channels. Pulser runs are initiated using DAQ. Typically a pulser run is 500 events, and is run using the local STAR clock. This means that a pulser run should be immediately preceded by a pedestal run also using the local clock.

The pulse should look like the following pad monitor picture:



x 96.0938
y 641.5095
ADC 0
xmin 0.0000
xmax 512.0000
ymin 0.0000
ymax 256.0000

The pulse is essentially the response of the FEE to the rising edge of the Wavetek pulse. The small pulse ~ 10 microsec later (time bin 260) is the overshoot caused by the trailing edge of the Wavetek pulse. Expanding the time scale shows the pulse shape:



x 161.4062
y 202.8302
ADC 211
xmin 100.0000
xmax 220.0000
ymin 0.0000
ymax 245.2830

6. Known Problems

1. The pulse height for sector 8 inner is smaller than that of the other sectors. Speculation is that, during construction, the 10 ohm resistors was not removed from the unused input. Therefore that sector has less than the normal termination and the pulse seen on the pads is smaller. This anomaly is corrected offline in software.

7. Pulser Troubleshooting

Possible reasons for not seeing the pulser in the data:

1. The Wavetek is not being triggered – make sure DAQ is configured for a TPC pulser run. If an access is possible, look for trigger pulses (TTL) out of the TCD in conjunction with a DAQ run.

2. The fanout VME crate is off or inhibited – check that the VME crate in Rack 2A5 (Canbus #55) is on and the voltages are correct. If the crate can't be turned on remotely, using the slow controls GUI, it may be inhibited by the TPC interlock system. The pulser crate uses the same inhibit signal as the gated grid crate. (The crate inhibit signal is on a DB15 cable that plugs into the front of the crate.) Make sure this cable is plugged in and the the gated grid permissive is on. (Check the state of the TPC interlocks using the slow controls GUI or look at the light panel in the gas mixing room.)

3. The rate limiter may be dead or unplugged. Check if the pulse from the Wavetek comes out of the rate limiter. (We currently have no spare for the rate limiter – the system could be run without it if the rate is kept below < 800 Hz. Typically, DAQ takes pulser events at a 10 Hz rate.)

4. The Wavetek is not set-up properly. Check the settings listed in Section 3. Make sure the trigger and main out green LEDs are lit.

5. If some sectors have a pulse, but others don't, look for bad fanout modules. If the front panel red LED is not lit the module probably has blown fuses. One spare module and fuses are in the TPC spares cabinet.

8. Spares and Repairs

There is no spare for the Wavetek. We would use another pulser with a square wave pulse out if the Wavetek is sent out for repair. There is one spare fanout module, but no spare rate limiter. Vahe Ghazikhanian from UCLA made the fanouts and rate limiter and he can repair these modules.

9. References

1. Wavetek manual
2. BCS TPC manual Volume I
3. STAR TPC tests logbook Vol II

	Voltage
13 - 1	3.72
13 - 2	3.70
13 - 3	3.54 *
14 - 1	3.68
14 - 2	3.68
14 - 3	3.68
15 - 1	3.68
15 - 2	3.36 *
15 - 3	

11/17/99 MEASURE AMPL OUT OF ALL GND PLANE PULSER MODULE

CONDITIONS: TRIGGER ~ 93 HZ RATE LIMITER IS IN

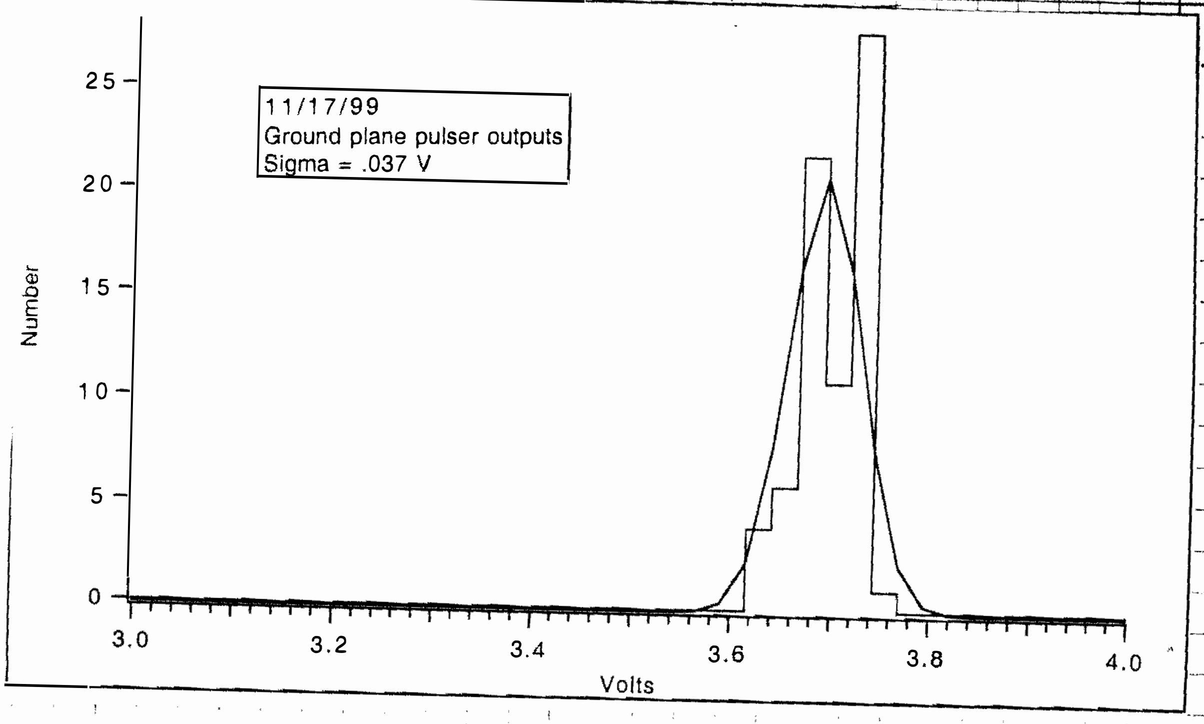
- CHECKED THAT LIMITS @ 800 HZ.

USE DIGITAL SCOPE
INTO 50 Ω

AVERAGE OVER 30 PULSES W
AMPLITUDE MEASUREMENT

MEASUREMENT ERR ~ ± .02V
USING FABRICES STANDARD PULSE LABELED "LASER"

MODULE S/N	SECTOR	V	S/N	SECTOR	V	S/N	SECTOR	V	S/N	SECTOR
1 OUT	13-1	3.72	3	19-1	3.72	6	1-1	3.72	8	7-1
OUT	13-2	3.68		19-2	3.68		1-2	3.72		7-2
INNER	13-3	3.70		19-3	3.68		1-3	3.72		7-3
OUTER	14-1	3.68		20-1	3.68		2-1	3.72		8-1
OUTER	14-2	3.68		20-2	3.68		2-2	3.74		8-2
INNER	14-3	3.68		20-3	3.72		2-3	3.76		8-3
OUTER	15-1	3.68		21-1	3.72		3-1	3.68		9-1
OUTER	15-2	3.70		21-2	3.72		3-2	3.74		9-2
INNER	15-3	3.68		21-3	3.72		3-3	3.72		9-3
2	16-1	3.72	4	22-1	3.68	7	4-1	3.68	9	10-1
	16-2	3.74		22-2	3.74		4-2	3.68		10-2
	16-3	3.74		22-3	3.72		4-3	3.63		10-3
	17-1	3.68		23-1	3.70		5-1	3.64		11-1
	17-2	3.72		23-2	3.74		5-2	3.66		11-2
	17-3	3.72		23-3	3.68		5-3	3.65		11-3
	18-1	3.72		24-1	3.68		6-1	3.66		12-1
	18-2	3.72		24-2	3.72		6-2	3.64		12-2
	18-3	3.72		24-3	3.74		6-3	3.62		12-3



[illegible]

[illegible]

0E

Date: Mon, 24 Apr 2000 13:51:02 -0500 (EST)
From: "Blair C. Stringfellow" <string@physics.purdue.edu>
To: vahe <vahe@physics.ucla.edu>, Geno Yamamoto <geno@physics.ucla.edu>
Subject: pulser modules

Hi Vahe -

The FTPC showed up and Volker did indeed have a ground plane pulser module. I have not tested it yet. So, by my count we have:

HALT

9 in the crate on the platform (TPC)
1 spare in the crate on the platform - NOW FTPC
1 spare (Volker) S/N 01
1 spare back at UCLA (Broken?) - ?

9/17/2001

If you know of any others, let me know.

VENEB SESSION

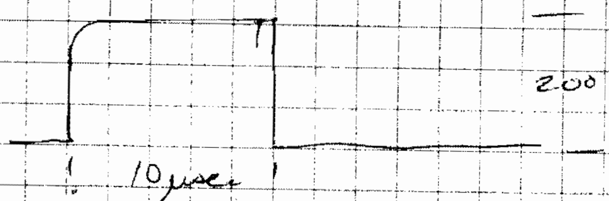
```
S TARONL
SYS/ TEST
> XHOST +
> TELNET SC
      LOGIN

S TPC_TOP
```

002 TPC Anode trip - 9:00 am
Inner Sector #4, #2

3/02 1000 INNER LECROY CRATE
NEITHER EPICS OR SERI
(BOTH HAD BEEN WORKING FI
GET AN ACCESS + CYCLE POWE
(1ST TIME SERIAL SESSION AC

/02 LOOK AT "LASER" PULSE
OUT OF WAVETEK:

DC INTO 50 Ω



1-169	0
170	417
171	1151
172	1501
173	1686
174	1775
175	1818
176	1855
177	1887
178	1914
179	1936
180	1955
181	1969
182	1981
183	1991
184	1997
185	2001
186	2002
187-269	2002
270-380	0

Period = 38 microsec
380 points => 100 nsec per point
Sample Freq = 10.0 MHz
Wave Form Freq = 26.32 kHz
Amplitude 200 mVp
Arbitrary Waveform "Laser"

Trigger In: External, Positive, Level = 1.0 V

WAVETEK SAYS: AMPL = 200 mVp

TRIGGER IN: SOURCE EXTERNAL, POSITIVE — DEFAULT = 0.00V

I CHANGE THIS TO +1.00V AFTER POWER OUT

ARBITRARY FREQUENCY
SAMPLE FREQ = 10.0 MHZ
WAVEFORM PERIOD = 38 μsec
FREQ = 26.32 kHZ

OFFSET = 0
MODE TRIG'D CNT: 000001
PUSH ARBITRARY
PUSH MAIN OUT BUTTON - GREEN LIGHT

Pad Monitor

PAD MONITOR

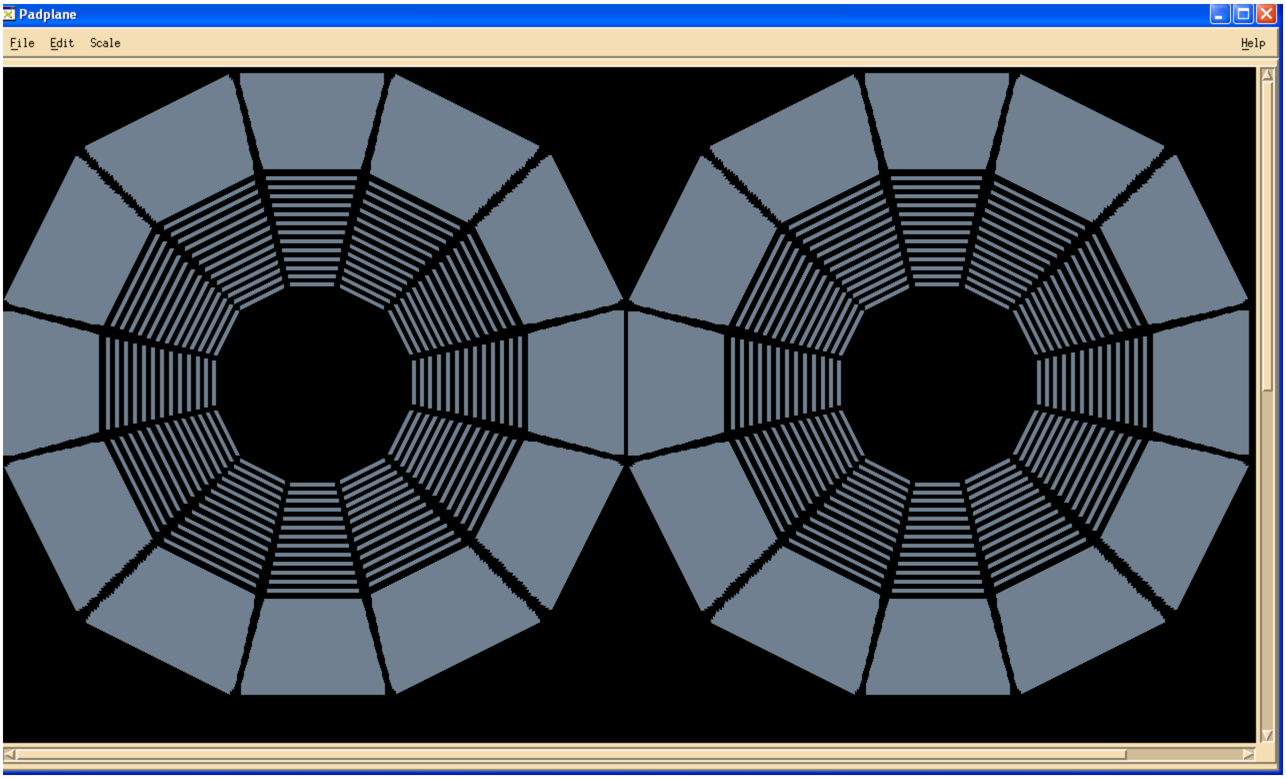
The TPC pad monitor is used to check the performance of the TPC electronics. It can display the amplitude vs time bucket histogram for all TPC pads for both pulser and physics events. It can also be configured to check the pedestal values as well as the sigma (noise) on each channel. Also, for the old electronics, it could check the so called geometry event, where each FEE read out a value corresponding to its position on the sector (ie FEE 0 through FEE 181.)

The pad monitor program resides on the event pool computer, located in the DAQ room and maintained by Jeff Landgraf. The code itself has been developed over the years, starting with Mark Gilkes then Eric Hjort and most recently Jo Schambach. Jeff Landgraf also has some working knowledge of the program and will help with the transistion to DAQ1000.

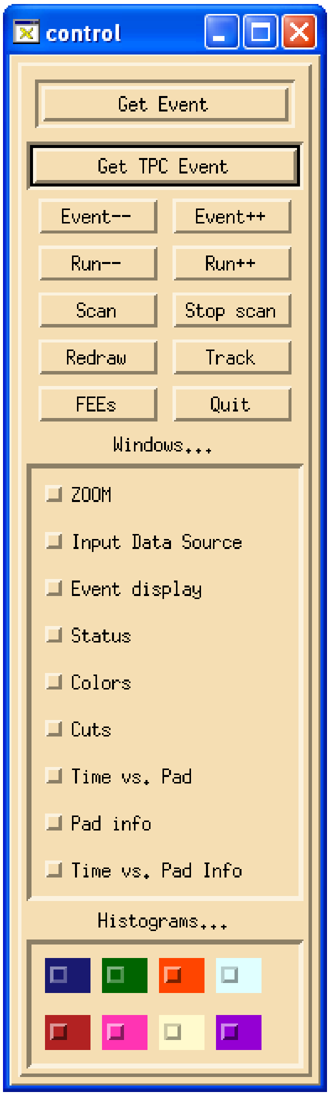
To run the pad monitor log into evp.starp.bnl.gov, username = startpc

(The password is listed elsewhere…) Make sure to have some X Windows program running (eg XManager etc). At the evp prompt type “tpm”, which is the pointer to the program.

This will pop the Padplane display of the west sectors (on the left) and the east sectors (on the right). It will also pop the control GUI.

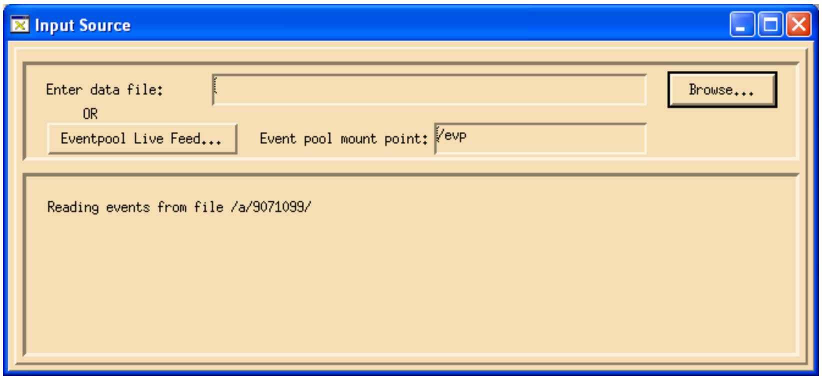


The floating control GUI looks like:



Events are input from the runs that are stored in the event pool. Note that during a data run, any individual run will only stay in the pool for ~ 1 week before it is overwritten. If you need to see an earlier run Jeff can extract it from HPSS and put it some accessible place on evp.

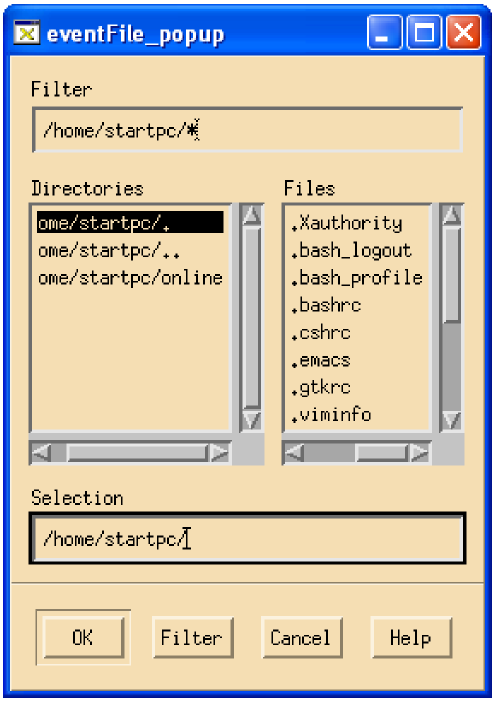
To select a run, click on “Input Data Source” and pop the GUI:



Event pool mount point: /evp

```
Reading events from file /a/9071099/
```

If a run is active you can click on the “Eventpool live feed…” button and then “Get TPC Event” on the contol GUI to get the next event. This ONLY works if the DAQ run is active. Tp select events from previous runs, click on “Browse” on the Input Source GUI. This pops:



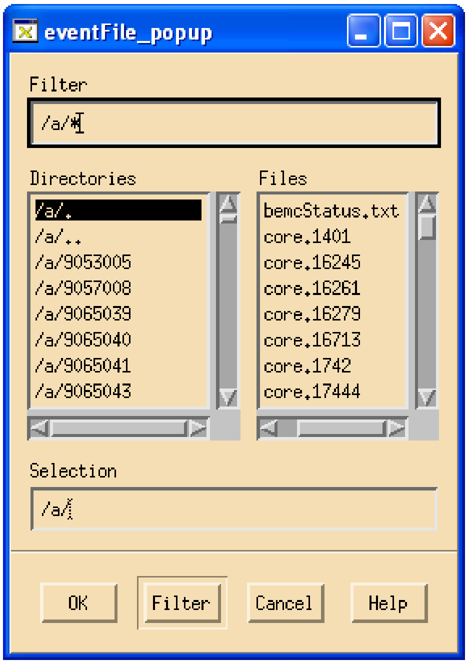
Filter: /home/startpc/*

Directories:
- ome/startpc/.
- ome/startpc/..
- ome/startpc/online

Files:
- .Xauthority
- .bash_logout
- .bash_profile
- .bashrc
- .cshrc
- .emacs
- .gtkrc
- .viminfo

Selection: /home/startpc/

In the “Filter” window, input /a/* enter. This then shows a list of run numbers in the evp/a directory, where each run is in its own sub-directory:



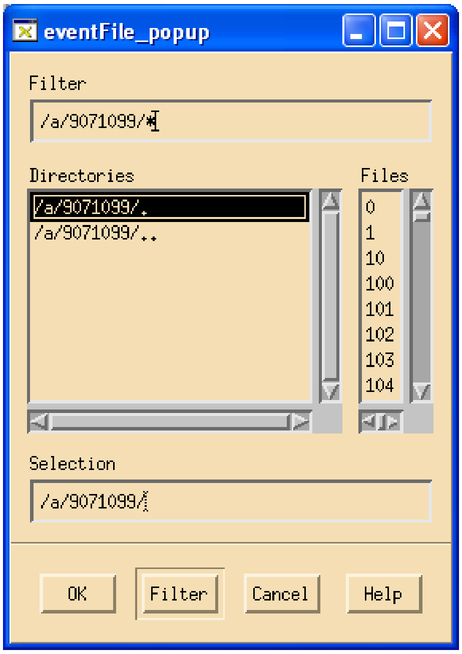
Filter: /a/*

Directories:
- /a/.
- /a/..
- /a/9053005
- /a/9057008
- /a/9065039
- /a/9065040
- /a/9065041
- /a/9065043

Files:
- bemcStatus.txt
- core.1401
- core.16245
- core.16261
- core.16279
- core.16713
- core.1742
- core.17444

Selection: /a/

Scroll down to find the desired run number and double click on that run number. You should then see a list of event numbers in the “Files” box:



Filter: /a/9071099/*

Directories:
- /a/9071099/.
- /a/9071099/..

Files:
- 0
- 1
- 10
- 100
- 101
- 102
- 103
- 104

Selection: /a/9071099/

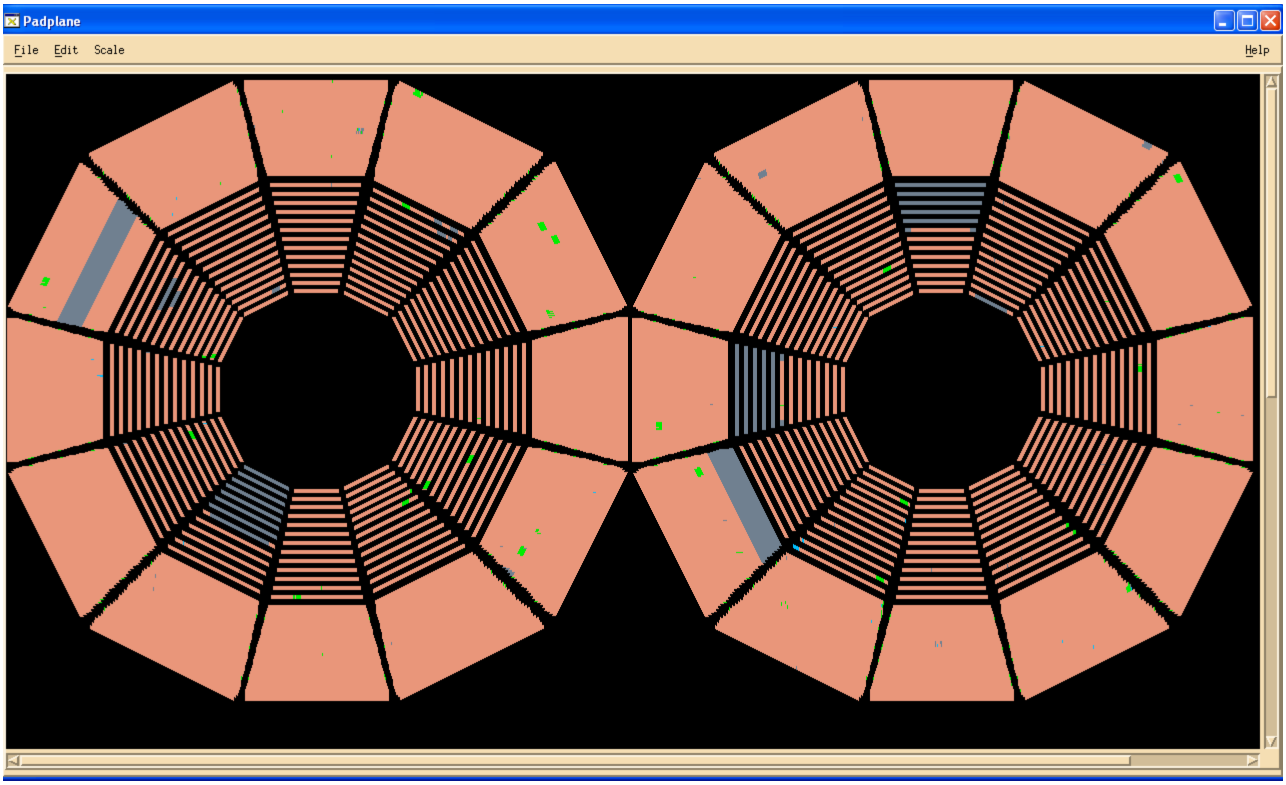
Click the ok button to get back to the Input Source window. It should now say

“Reading events from file /a/Run #/” and

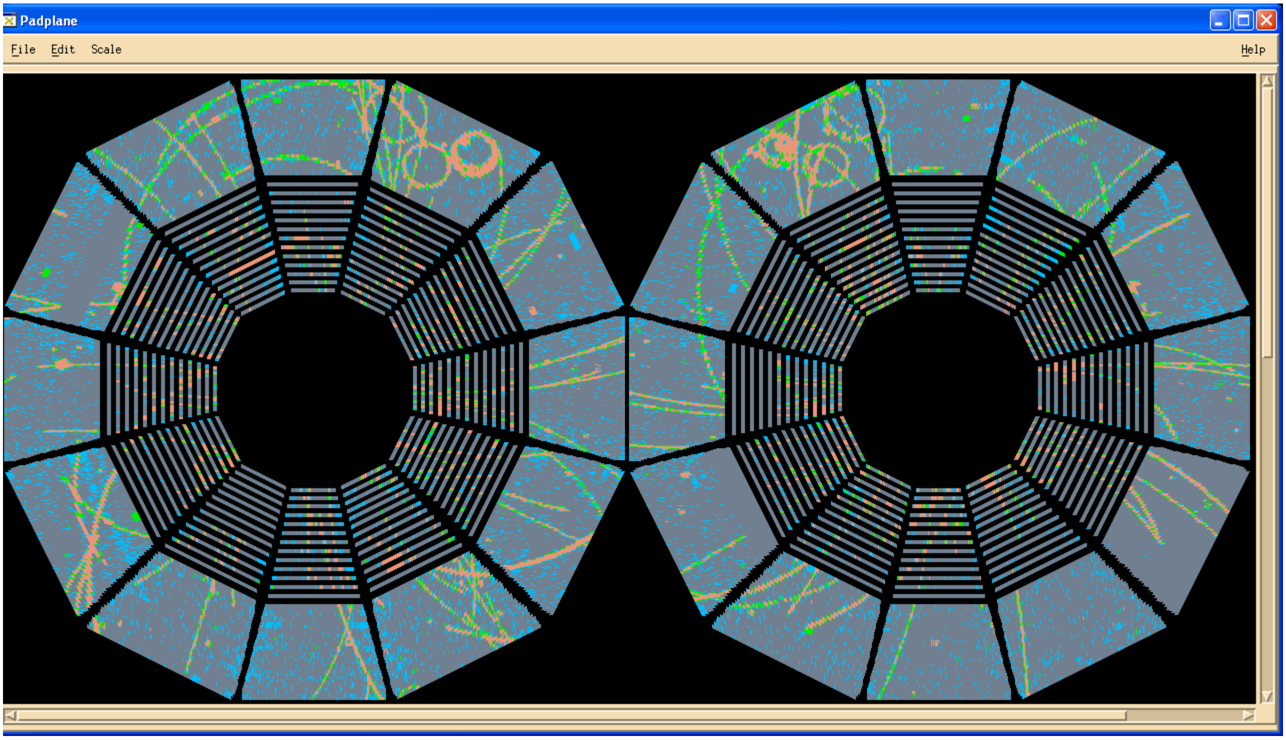
“Found data file /a/Run #/”

Kill the Input Source window. On the control window, click on “Get TPC Event” then click it again – the first event in a run is usually noisy and should be skipped.

You should get a display like:

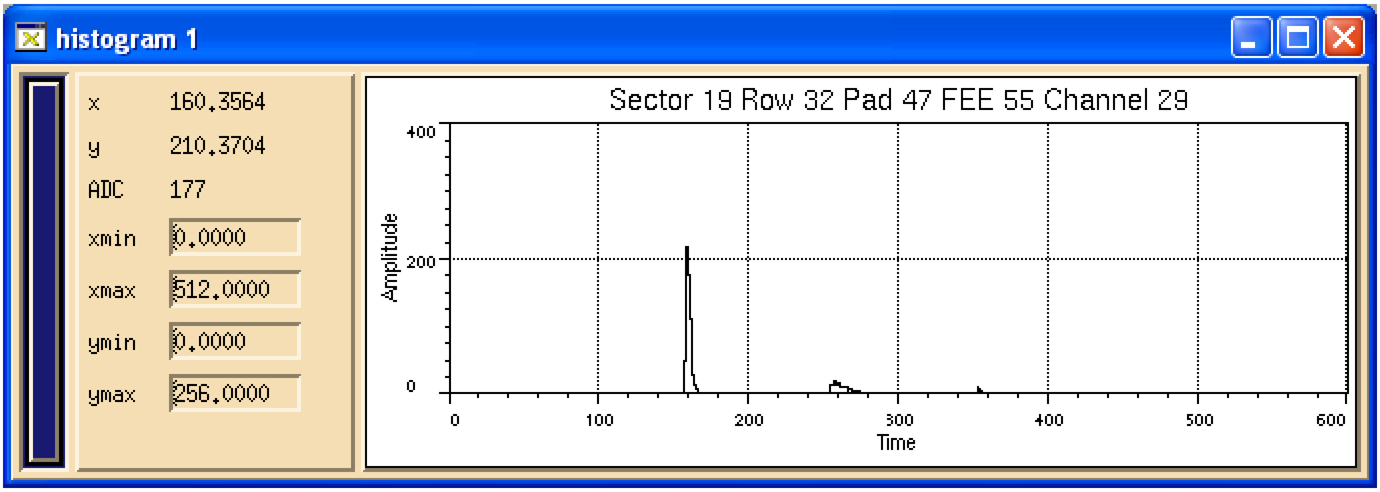


Pulser run – orange pads have normal pulse height, green pads have smaller pulse height and grey pads are dead. Note that the RDOs 7-1, 10-4, 20-3, 21-2 and 24-2 are dead (this run is from the end of run 8)



Low energy physics event. The blue pads have small noise. Note sector 16 is DAQ1000 and has less noise.

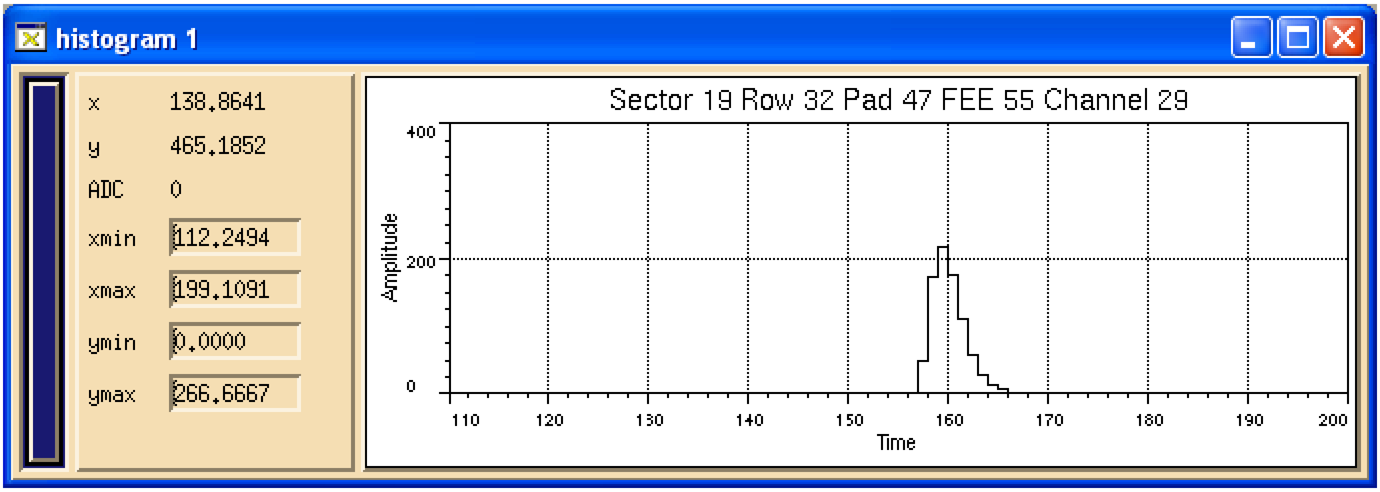
Bring up a histogram display (ADC vs time bin) by clicking on the colored buttons at the bottom of the control GUI. There are 8 histograms available, although one is usually sufficient. After the histogram is up, click on any pad in the pad plane display – the histogram should then look like:



x 160.3564
y 210.3704
ADC 177
xmin 0.0000
xmax 512.0000
ymin 0.0000
ymax 256.0000

The large pulse at time bin 160 is the response of the system to the rising edge of the ground plane pulse. The small bump at time bin 260 is due to the falling edge of that pulse. The large main pulse is the one that is used to calibrate the electronics gain for each channel. Note that for the selected pad the histogram displays the sector number, row, pad number in that row, FEE number (0 to 181) and the channel number in the FEE (0 to 31). This convention and mapping should be preserved after the change to DAQ1000.

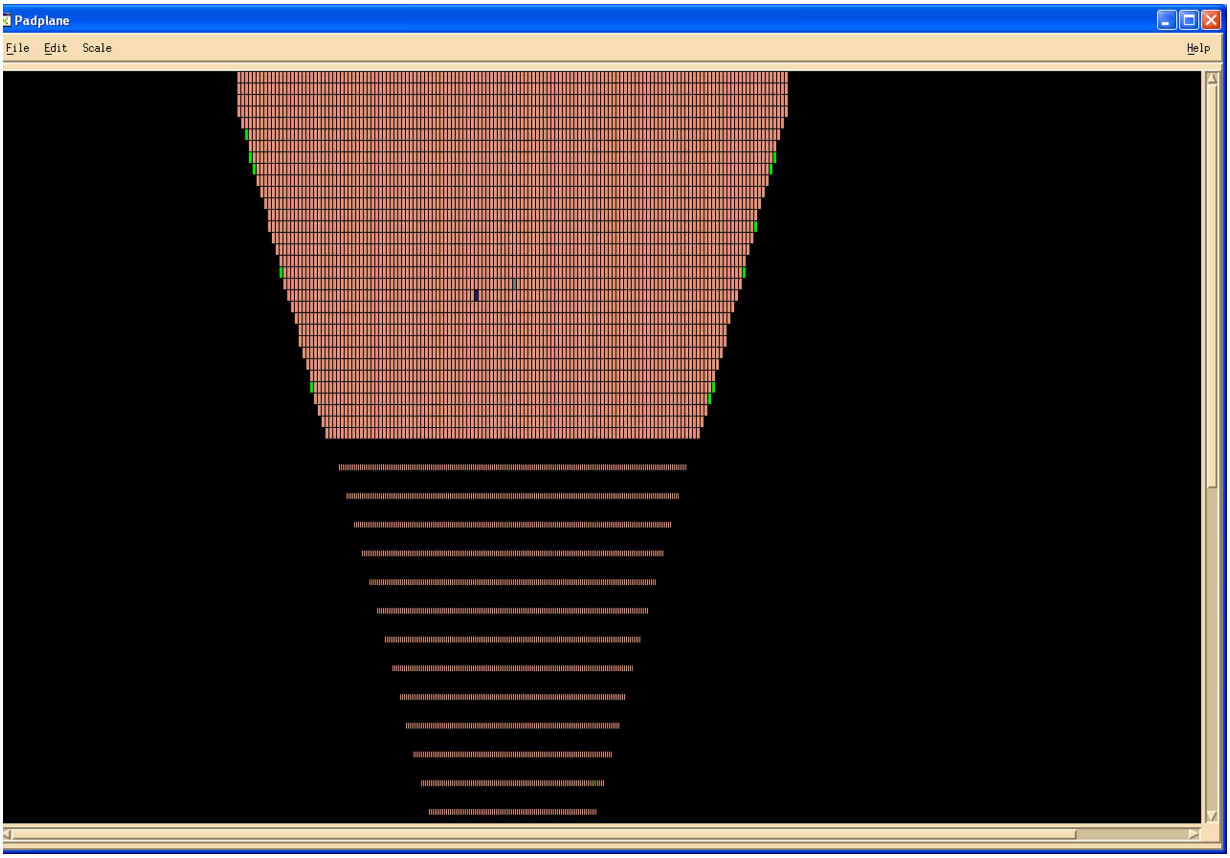
One can expand the time bin scale by clicking and dragging a window around the area of interest:



x 138.8641
y 465.1852
ADC 0
xmin 112.2494
xmax 199.1091
ymin 0.0000
ymax 266.6667

To recover the full scale, right click on the histogram area and select “reset scale”. One can also read out the ADC value for each time bin by moving the pointer over that bin – the ADC value is shown in the display to the left of the display area.

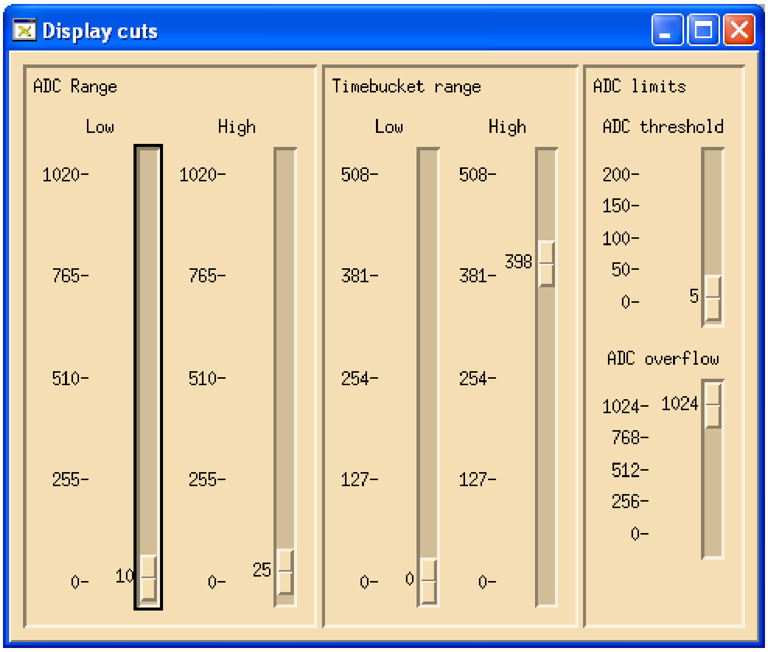
For more detail of each sector, one can zoom the pad plane display: click on the desired supersector and then click on the “zoom” button on the control GUI. This should then change thepad plane display to one supersector:



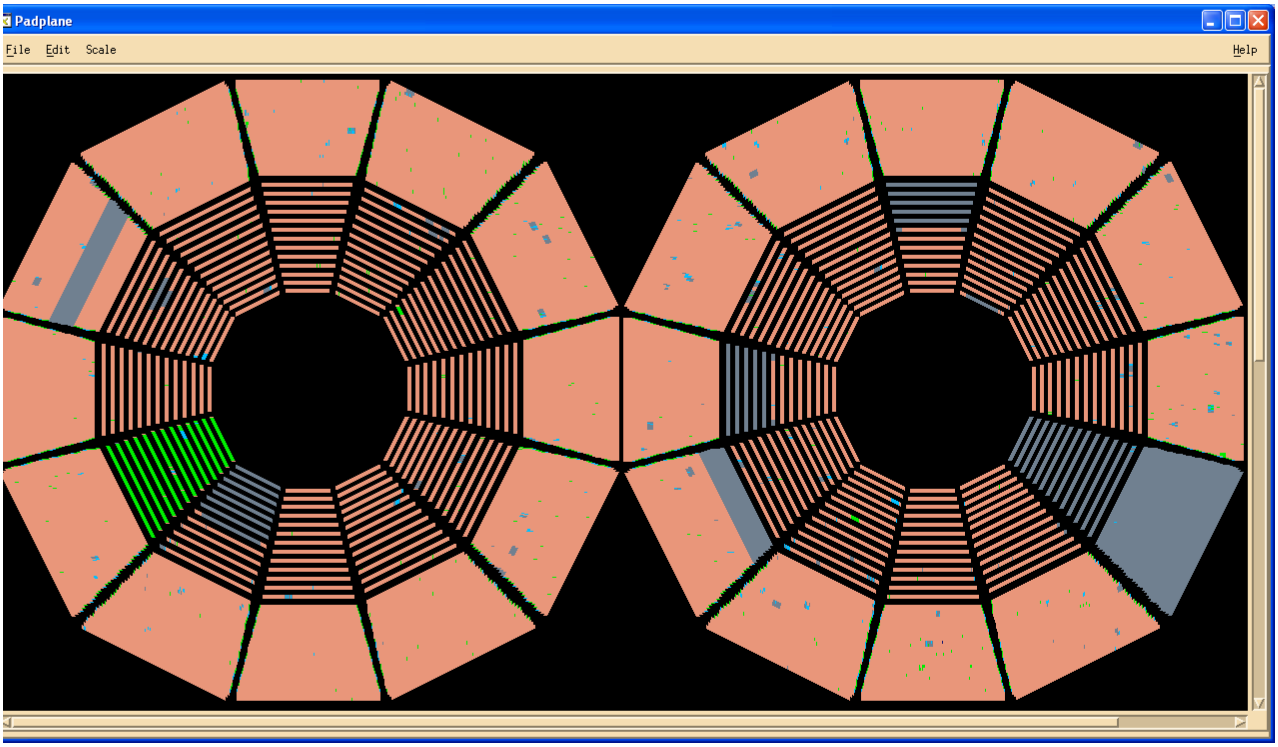
To get back to the full view, click on “zoom” again.

CUTS

One can also apply cuts to the data which can help isolate certain aspects of the data. You can have a lower and upper cut for both the ADC value and the time bin. My standard cuts for looking at pulser runs are 32<ADC<100 and 150<timebin<170. This isolates the main pulse. To apply cuts, click on the “cuts” button on the control GUI. This brings up the page:



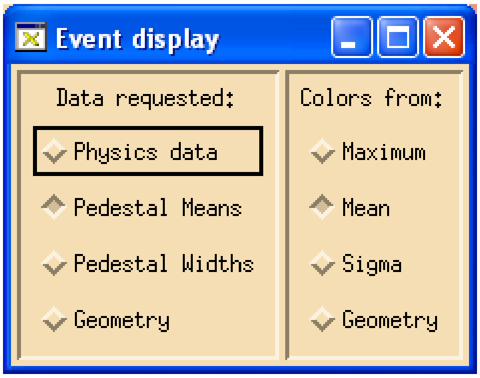
Use the sliders to apply the needed cuts. After applying the pulser cuts the pad plane display looks like:



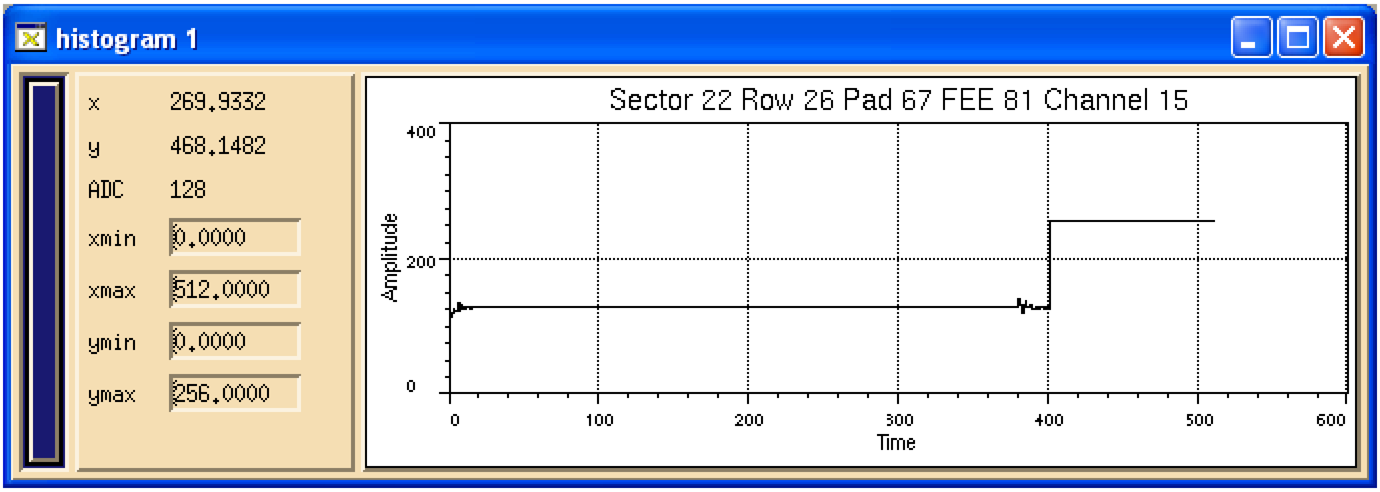
Note that more pads now show grey or green, indicating bad pads. The green for inner sector 8 is because that sector has a smaller pulse height for pulser runs because of an internal wiring mistake – a termination resistor for the pulse was left in by mistake, so the pulse height is a factor of 2 low. This must be taken into account when calibrating the electronics.

PEDESTALS MEANS AND SIGMAS & GEOMETRY

The pad monitor can also be used to look at a display for each pad of the pedestal value and the noise (sigma) of the pedestal for each time bin. To look at the pedestal values, open a new pad monitor session and first select “Event display” on the control GUI. This brings up the window:



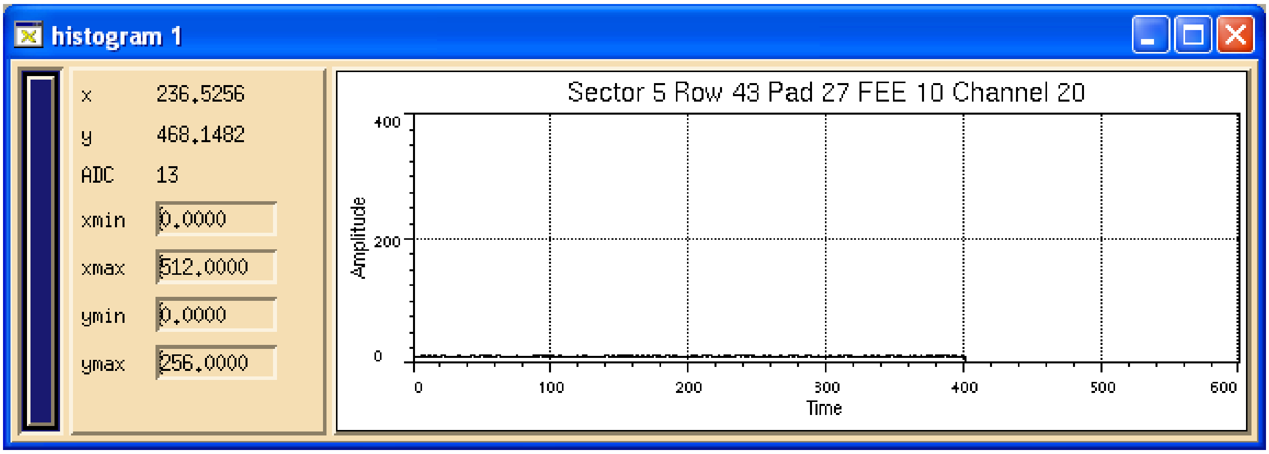
Click on the “Pedestal Means” button. The button “Colors from: Mean” is automatically chosen. Then follow the procedure above for “Input data source” but make sure to select a known TPC pedestal run. Then click on “Get event” in the control GUI (click only once, there is only one “event). Bring up a histogram and then click on a pad – the histogram should look like:



x 269.9332
y 468.1482
ADC 128
xmin 0.0000
xmax 512.0000
ymin 0.0000
ymax 256.0000

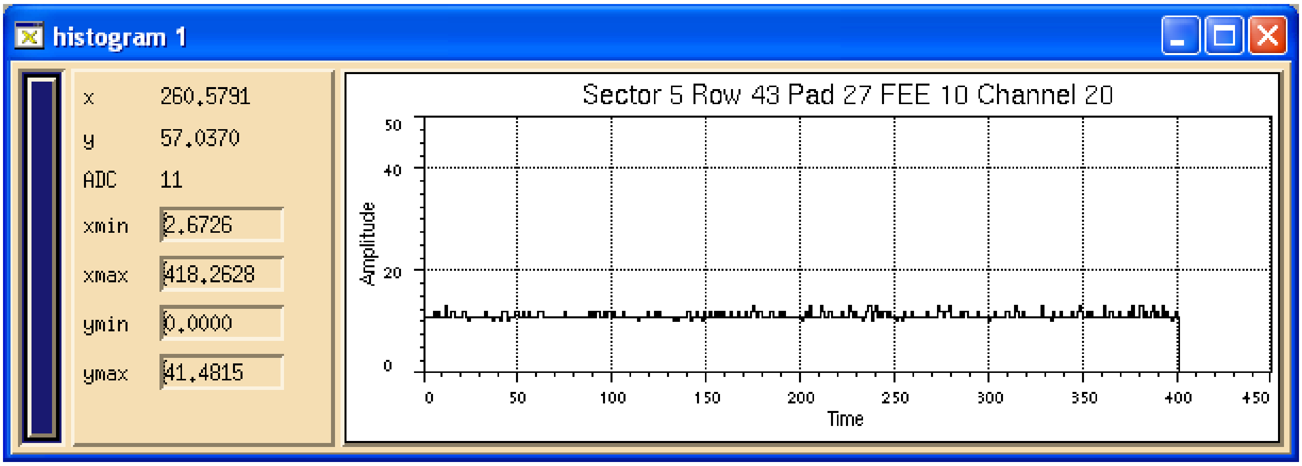
This shows a pedestal value of ~ 129 for all active time bins. The noise in bins 0 – 10 and 390 – 400 is pickup from the gated grid opening and closing. After time bin 400 the pedestal is automatically set to 255 so those pads are ignored in processing. (The central membrane is at time bin ~ 345).

To see the noise (sigma) for each time bin, again open a new pad monitor session. Open the “Event display” GUI and this time select “Pedestal Widths”. Again, “Colors from: mean” is automatically selected. Again select a pedestal run from “Input Data source” and click on “Get Event”. Open a histogram and click on any pad:



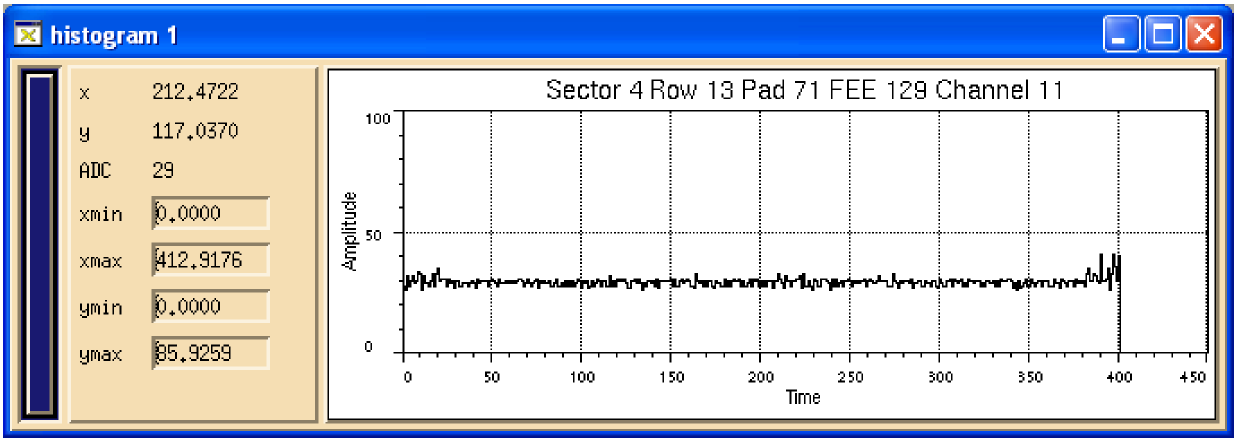
x 236.5256
y 468.1482
ADC 13
xmin 0.0000
xmax 512.0000
ymin 0.0000
ymax 256.0000

Expand the ADC scale by clicking and holding in the histogram and dragging a window from time bin 1 to 400:



x 260.5791
y 57.0370
ADC 11
xmin 2.6726
xmax 418.2628
ymin 0.0000
ymax 41.4815

The histogram displays the average sigma for each time bin times 10. Thus the average sigma for all times bins of this pad is ~ 1.1 ADC counts, which is typical. DAQ1000 is expected to have a better sigma. A noisy pad from row 13 is shown below – the sigma is 2.9.



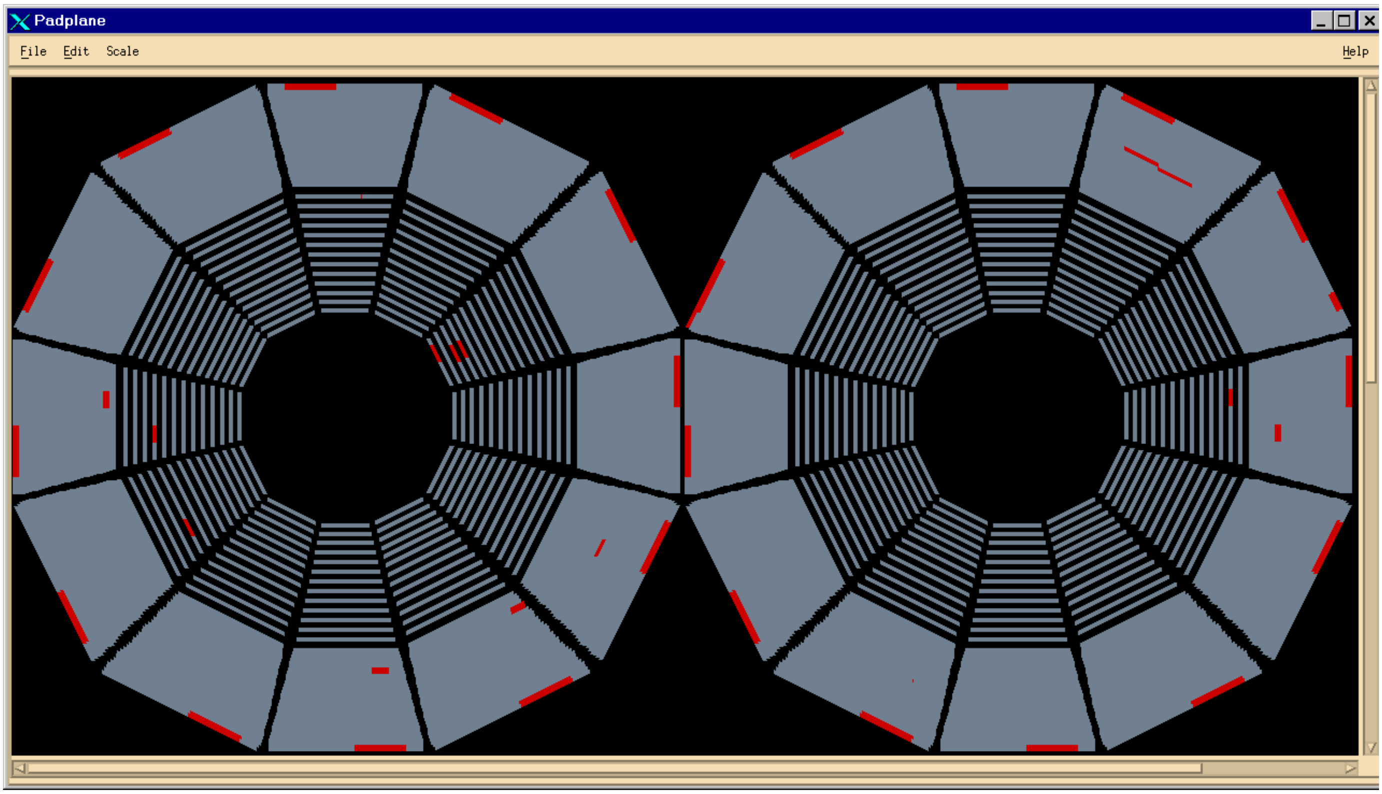
x 212.4722
y 117.0370
ADC 29
xmin 0.0000
xmax 412.9176
ymin 0.0000
ymax 85.9259

GEOMETRY EVENT:

The TPC pad plane connector has a built in feature that used a few of the pins to uniquely identify the FEE slot number on the pad plane. The number goes from 0 to 181 for each supersector. The old FEEs sense this position identifier and respond to a so-called DAQ geometry event by filling the ADC for each time bin with that number. The pad monitor can display this geometry event and shows mismatches in red. This can help identify cabling mistakes etc. I believe Tonko will also use this identifier, but some work may need to be done to upgrade the pad monitor to display the results.

For the old electronics, open a new pad monitor session and open the “Event display” GUI..

This time select “Geometry” – “Colors from :Geometry” is automatically selected. Then got to “Input Data Source” and find a DAQ geometry run. Click on “Get event” The display should look something like:



FEEs shown in red have a discrepancy between the position they sense on the pad plane and their position in the data stream. This can be due to a bad FEE, a miscabling, a problem on the pad plane itself etc. We were never successful in fixing all the problems shown here, but a few were fixed. The repeating problem for the 2 FEEs in row 45 (outer radius) was a software problem.

PADPLANE MAPPING

The mapping from the pad plane to the FEEs and then to the RDOs is documented on the web in the STAR TPC Hardware pages. The pad plane to FEE mapping will stay the same for DAQ 1000 but the FEE to RDO mapping may change, so a new document may be needed. There is also a full size drawing of the inner and outer pad planes showing each connector in detail (pin by pin). These drawings are kept in Dan Padrazo’s lab. For the other maps see:

http://www.star.bnl.gov/public/tpc/tpc.html

And follow the links: Hardware -> Electronics -> Various maps in the Cabling section.

Remote Power

REMOTE POWER SWITCHES

HARDWARE

TPC uses three remote power switches installed on the platform which are used to power cycle various devices. The switches are Western Telematic Model NPS-115. Each switch has 8 individually addressable 110V AC outlets. The switch is accessible via ethernet. Here are the locations of the three switches and the devices that are plugged into them:

Rack	Name	IP address	Switches and plug No
2A4	rps1.starp.bnl.gov	130.199.60.26	Wavetek - 5, TPC TEMP Readout Box – 8 Video PC (Alexei) – Plug 1
2A3	rps2.starp.bnl.gov	130.199.60.205	Glassman Cathode HV - 1
2A6	rps3.starp.bnl.gov	130.199.60.206	Inner Anode Lecroy - 1, Outer Anode – 5, Non Canbus VME Crate in Rack 2A7 (Interlock and TPC Temp) – Plug 4

The switches are set up such that the above plugs are “on” after the switch powers up.

SOFTWARE

The switches can be controlled and configured by logging into each vis telnet. Thus, from SC3 (or SC5):

```
>telnet rps1.starp.bnl.gov
```

The switch has a password, but no username – it will prompt for the password only. All three switches have the same password, listed elsewhere.

After logging in, the following screen is displayed:

```
Network Power Switch v2.04        Site: (undefined)

Plug | Name              | Status  | Boot Delay | Password          | Default |
-----+------------------+---------+------------+------------------+---------+
 1   | videopc          |   ON    |   5  sec   | (undefined)      |   ON    |
 2   | (undefined)      |   OFF   |   5  sec   | (undefined)      |   OFF   |
 3   | (undefined)      |   OFF   |   5  sec   | (undefined)      |   OFF   |
 4   | (undefined)      |   OFF   |   5  sec   | (undefined)      |   OFF   |
 5   | Wavetek          |   ON    |   5  sec   | (undefined)      |   ON    |
 6   | (undefined)      |   OFF   |   5  sec   | (undefined)      |   OFF   |
 7   | (undefined)      |   OFF   |   5  sec   | (undefined)      |   OFF   |
 8   | TPCTEMP          |   ON    |   5  sec   | (undefined)      |   ON    |
-----+------------------+---------+------------+------------------+---------+

Communication Settings:  38400,N,8,1
Modem Init. String:      ATE0M0Q1&C1&D2S0=1
Modem Disc. String:      (undefined)
Disconnect Timeout:      30 Min
Command Echo:            On
Command Confirmation:    On

"/H" for help.

NPS>
```

Typing /h at the NPS prompt brings up the help screen:

```
Network Power Switch v2.04      Site: (undefined)

Commands:

Display
/H        Display this help screen
/S[P]      Display Plug Status, [P] with passwords

Configuration
/G        View/Set General Parameters
/P [n]     View/Set Plug Parameters
/N        View/Set Network Parameters
/DL       Download configuration to file

Control                      +------------------------------------+
/D        Set Plugs to default setting | [n] = optional plug name or number |
/Boot <n>  Boot Plug n               | <n> = required plug name or number |
/On <n>    Turn On Plug n             | n+n = plug n and plug n            |
/Off <n>   Turn Off Plug              | n:n = plug n through plug n        |
/T        Reset Network Interface     | * = all plugs with access          |
/R        Relogin as different user   +------------------------------------+
/X        Exit/Disconnect
```

Using these commands one can turn a plug on or off or change the defaults. One can also set up the unused plugs for any new devices. When finished, type /x at the prompt to exit. After a confirmation, you will be returned to the slow controls prompt.

KNOWN PROBLEMS

In 2005 all three RPS kept dropping off the network. See pages 140-141 in Notebook 1. Wayne investigated, but no obvious problem/solution was found. One possibility was security scans by ITD, but this was not proved. Since that episode the RPS have been stable. Any future problems, contact Wayne!

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SC Strip Charts

STRIP CHARTS

The slow controls EPICS software provides a method to display a scrolling strip chart display for any variable that is measured. As part of the TPC controls I usually pop 6 of these charts and display them on the Linux box nest to the TPC control computer. This provides some feedback for the operators and allowed me to scroll back to look at the previous 24 hours to check on the state of the chamber over night etc.

The six standard charts can be brought up by using an alias on the main slow controls computer. In the past this has been SC3, but since that is being retired, it may be necessary to ask slow controls to install the same pointers on SC5. The current aliases are:

strip2 = PT8, the TPC pressure

strip3 = PTB, the barometric pressure

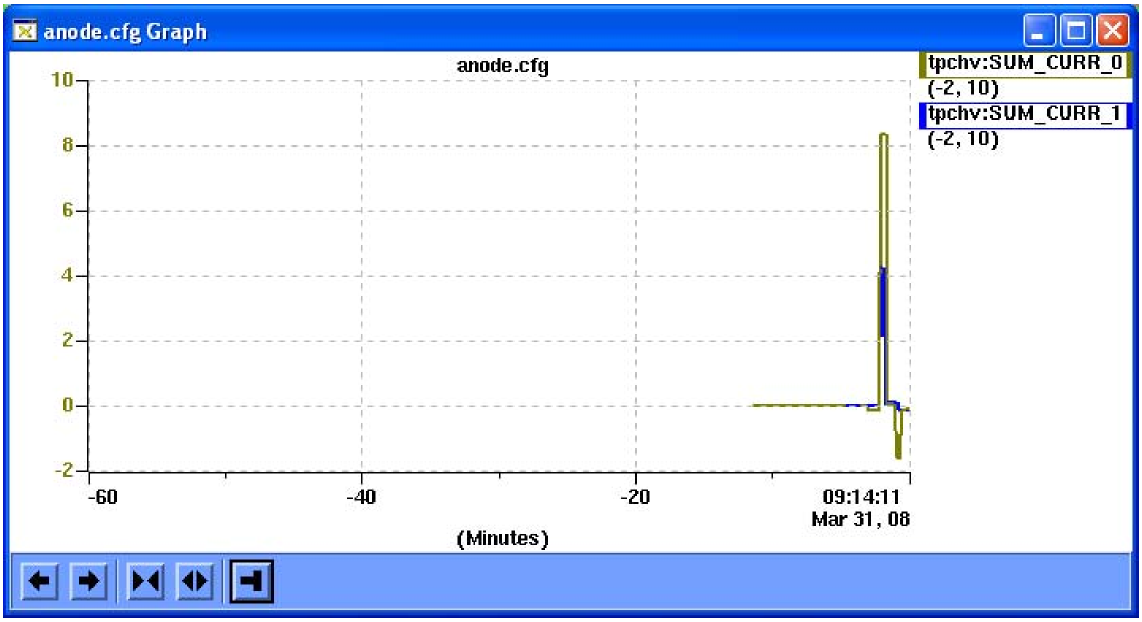
strip4 = the sum of the inner anode currents and the sum of the outer

strip6 = the outer field cages currents, east and west

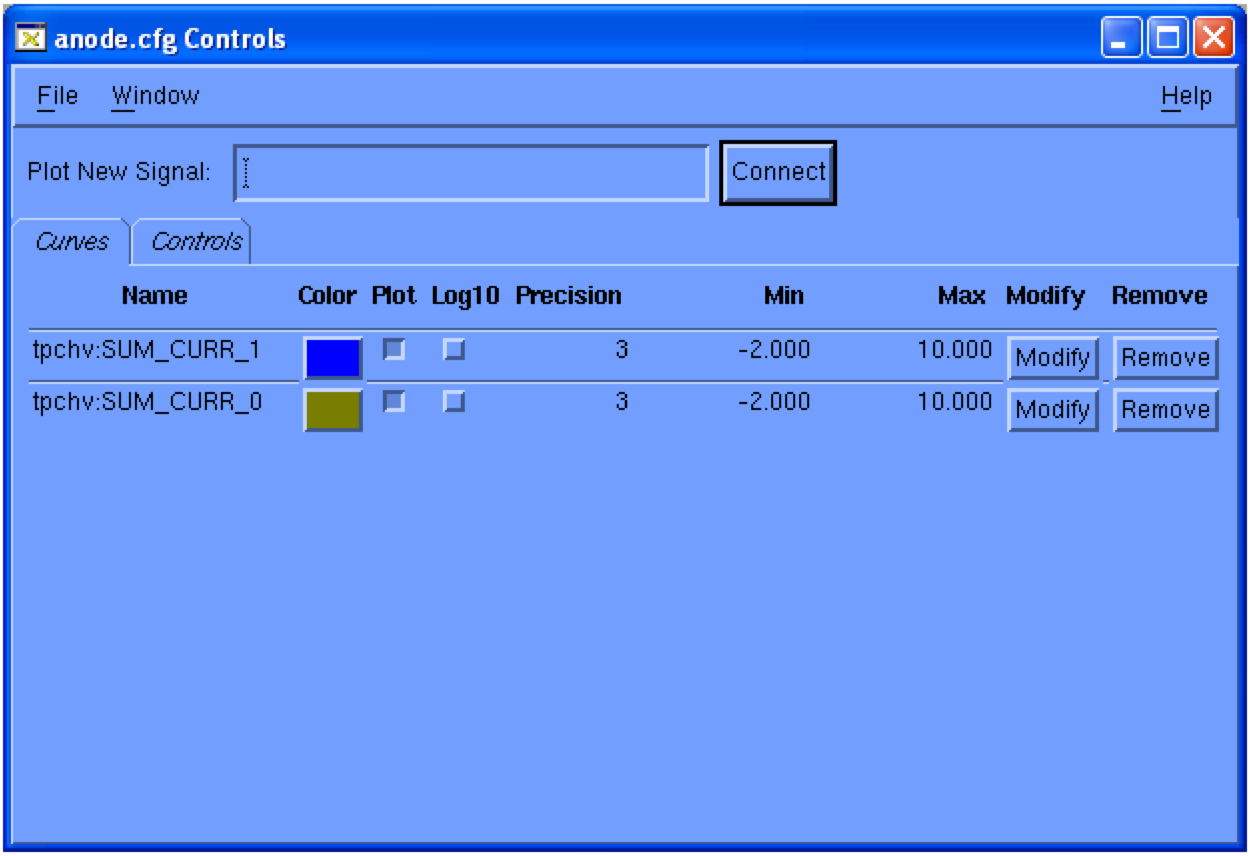
strip7 = inner field cage currents, east and west

To pop these charts, login to SC3 (or SC5) and type the corresponding alias. (You need to have X windowing software running).

A strip chart looks like:



The two arrow buttons on the bottom will scroll the chart forward and backward in time. The next two buttons expand and contract the time axis. The fifth button starts the chart data collection and display. The x and y axes can be changed via the controls dialog for the chart. To access this, right click on the chart and select “Controls Dialog”. This pops the window:

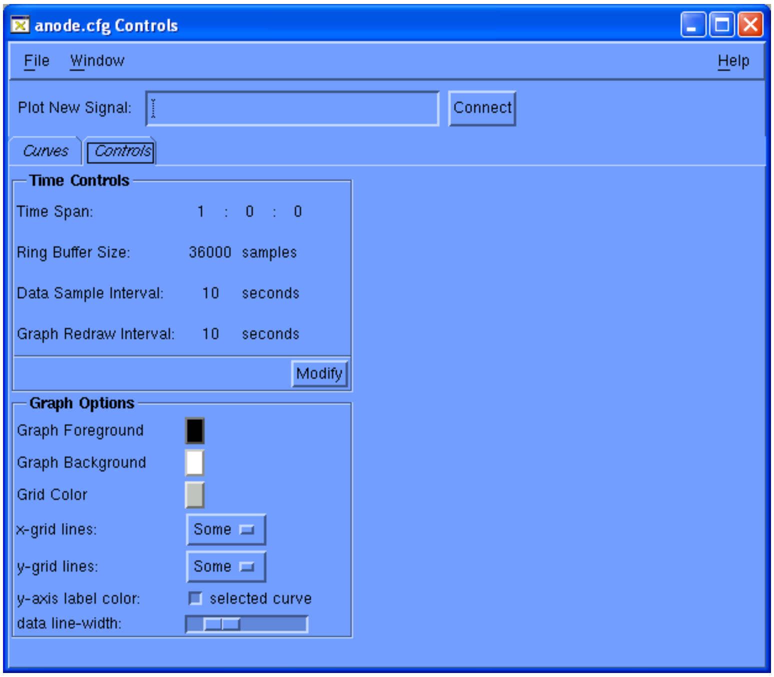


Plot New Signal:

Name	Color	Plot	Log10	Precision	Min	Max	Modify	Remove
tpchv:SUM_CURR_1	🟦	☑	☐	3	-2.000	10.000	Modify	Remove
tpchv:SUM_CURR_0	🟫	☑	☐	3	-2.000	10.000	Modify	Remove

From this window you can change the y axis by clicking on the “Modify” button for each variable and typing in new values. For two variables you have to change both. One can also remove a variable from the plot (“Remove” button) or add a new variable by typing the variable name into the “Plot New Signal” box and clicking on “Connect”

To change the time axis and plotting frequency, click on the “Controls” tab next to the “Curves” tab:



Plot New Signal:

Time Controls

Time Span: 1 : 0 : 0

Ring Buffer Size: 36000 samples

Data Sample Interval: 10 seconds

Graph Redraw Interval: 10 seconds

Graph Options

Graph Foreground ■

Graph Background □

Grid Color ▨

x-grid lines: Some

y-grid lines: Some

y-axis label color: ☐ selected curve

data line-width:

Here one can change can change the time span for the display, the ring buffer size, the data sample interval and the data sample redraw interval. Note that the strip chart only reads the last value stored in that variable name, it does NOT actually go out and measure it at the device. So it makes no sense to plot faster than the variable is getting updated.

If the changes to the plot are meant to be temporary, you can kill the controls dialog box after your changes. The display will keep the temporary changes, but if you kill the plot, the next time it comes up it will revert to the canonical values. To save your changes to the plots you must click on “file” in the controls GUI and drag down to “save”.

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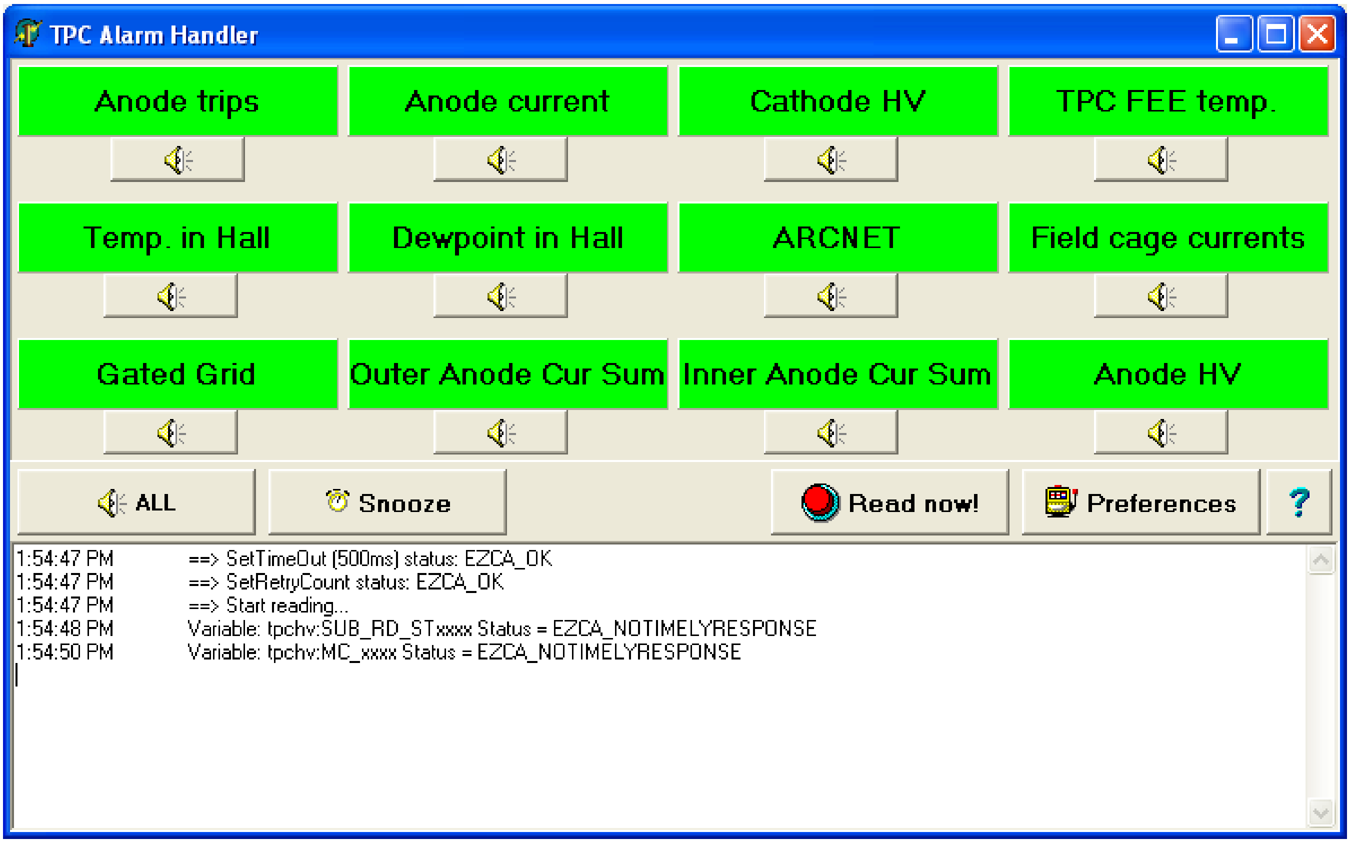
TPC Alarm Handler

TPC ALARM HANDLER

In addition to the big slow controls alarm handler I usually ran a TPC only alarm handler as a separate process. The TPC alarm handler was written by Peter Kravtsov, who also did the TPC gas system programming and controls. The alarm handler uses EPICS commands (CA_GET) to get the needed values of the variables that will be alarmed on. For previous runs the alarm handler ran on a PC next to the TPC controls PC. The alarm computer was sirius.starp.bnl.gov, but Wayne plans to retire that computer. For the new controls setup the alarm handler should be able to run on any windows machine that is on the starp network.

The files needed to run the alarm handler are kept in a folder called “Alarms” on the TPC control computer, chaplin. The current executable is called “Alarms_groups”. The init file and libraries are also in this folder.

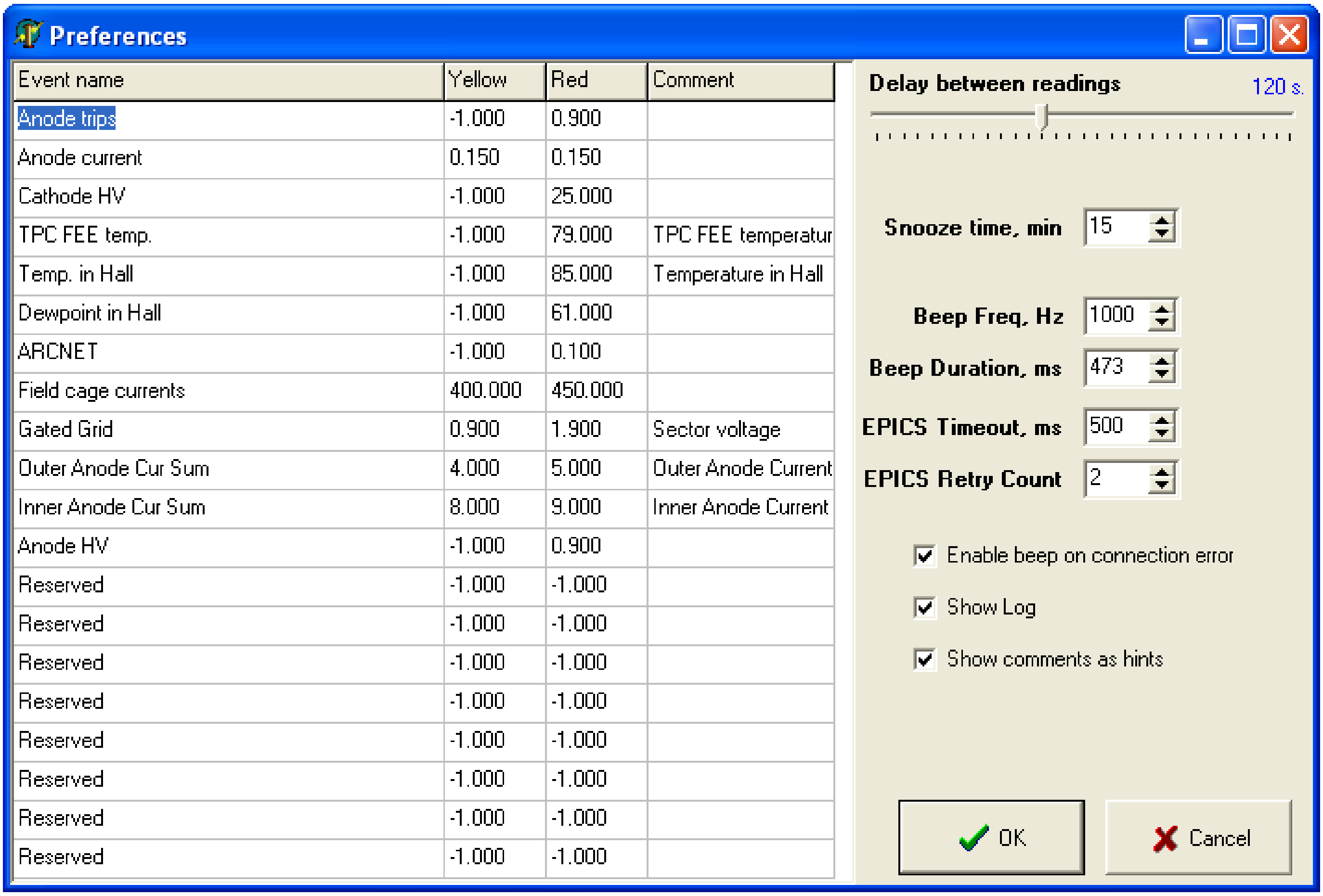
Double clicking on Alarms_groups opens the alarm display and initiates the original scan:



```
1:54:47 PM        ==> SetTimeOut (500ms) status: EZCA_OK
1:54:47 PM        ==> SetRetryCount status: EZCA_OK
1:54:47 PM        ==> Start reading...
1:54:48 PM        Variable: tpchv:SUB_RD_STxxxx Status = EZCA_NOTIMELYRESPONSE
1:54:50 PM        Variable: tpchv:MC_xxxx Status = EZCA_NOTIMELYRESPONSE
```

As shown, the program is monitoring the following: Any anode trip, any single high anode current, cathode HV, TPC FEE temperature, temperature and dewpoint in the WAH, inner and outer arcnet status, field cage currents (deltas), all gated grid voltages, inner and outer anode current sums and all anode HV channels. The philosophy behind the alarm handler is that, if the alarm handler is all green, the TPC is good for physics. Any variable out of range will turn that panel red and set off the alarm beep. Operators acknowledge and silence an alarm by clicking on the button below the panel or the “All” button. The next time the alarm handler reads the variables it will turn a red panel green if the problem has been cleared. If not the panel will stay red but the beep will NOT sound again.

One can change alarms limits and sampling frequency by clicking on the “Preferences” button:



Event name	Yellow	Red	Comment
Anode trips	-1.000	0.900	
Anode current	0.150	0.150	
Cathode HV	-1.000	25.000	
TPC FEE temp.	-1.000	79.000	TPC FEE temperatur
Temp. in Hall	-1.000	85.000	Temperature in Hall
Dewpoint in Hall	-1.000	61.000	
ARCNET	-1.000	0.100	
Field cage currents	400.000	450.000	
Gated Grid	0.900	1.900	Sector voltage
Outer Anode Cur Sum	4.000	5.000	Outer Anode Current
Inner Anode Cur Sum	8.000	9.000	Inner Anode Current
Anode HV	-1.000	0.900	
Reserved	-1.000	-1.000	
Reserved	-1.000	-1.000	
Reserved	-1.000	-1.000	
Reserved	-1.000	-1.000	
Reserved	-1.000	-1.000	
Reserved	-1.000	-1.000	
Reserved	-1.000	-1.000	
Reserved	-1.000	-1.000	

Delay between readings 120 s.

Snooze time, min 15

Beep Freq, Hz 1000

Beep Duration, ms 473

EPICS Timeout, ms 500

EPICS Retry Count 2

☑ Enable beep on connection error

☑ Show Log

☑ Show comments as hints

As shown, the current sampling frequency is 120 sec. There is also a “Snooze” button which puts the program to sleep for the designated time (currently 15 minutes). This is useful to prevent recurrent alarms when the TPC is ramping up to physics voltage. Note also that the program will alarm and show a grey panel if it was unable to get the needed variable – this could happen if a VME processor is rebooting, for instance.

Some important alarm limits to note from the preferences:

A high anode current is set to alarms at .150 microamps

The cathode HV must be above 25 kV

The WAH temperature is set to 85 deg F – this was set this high last June.

The dew point is set to 61 – if modified chilled water is 63 this will give some notice if condensation is possible.

The field cage current deltas are set to 400 nA (yellow) and 450 (red). A shorted stripe is ~ 420 nA. These limits should be lowered since the IFCE problem was fixed.

The inner anode current sum is 8 microamp (yellow) and 9 (red). This may need to be adjusted

Up for DAQ 1000 and AuAu running.

You can change these limits by entering the new values and hitting enter and exiting the preferences GUI by clicking on the “OK” button.

Note that some of these alarms are set up to alarm on a binary flag. Thus if ANY anode channel trips a flag is set to 1 and the alarm handler will alarm, since the threshold is set to 0.9.

Note that the logic for this alarm handler is slightly different from the slow controls alarm handler (which is looking at some of the same variables.) Since the TPC alarm handler is designed to show “GREEN” for physics running, it will normally show two red “alarms” when the TPC is off between fills (Anode HV and Cathode HV) This sometimes confuses the detector operators since the TPC shows alarms in the off state.

Temperature

TPC TEMPERATURE

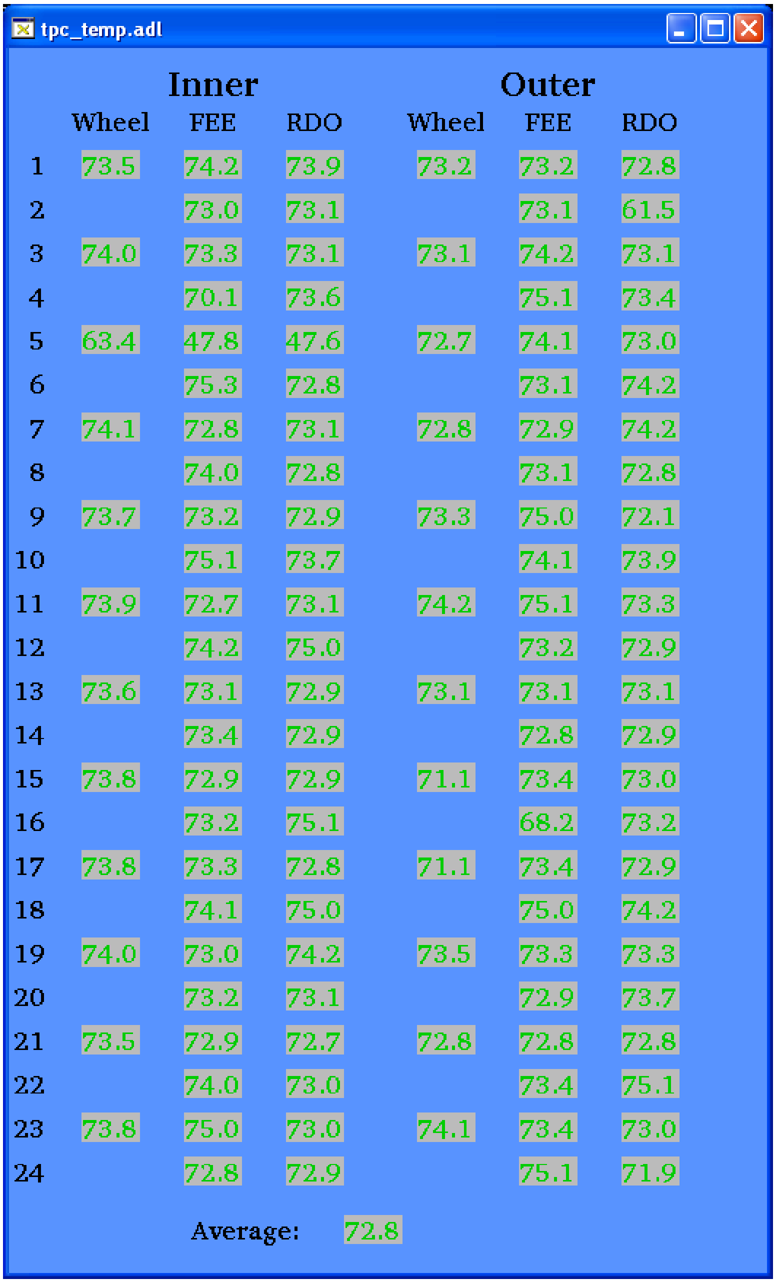
The TPC is equipped with a system of 120 thermocouple devices used to measure the temperature of the end wheels, FEE and RDO cooling manifolds. The system was initially installed by Wayne Betts and Mike Anderson in 1999-2000. The main purpose of the system was to look for temperature gradients across the end wheels, and most important, to look for hot spots on the cooling manifolds. Since the manifolds are Aluminum there is a danger that cooling water with a low pH could cause corrosion and clog the manifolds. So far we have not seen evidence of this.

The original readout of this system was by a PC on the platform, but in 2003 the PC was replaced by a stand alone readout box based on a microprocessor. This new system was designed and installed by Peter Kravtsov, who also did the gas system readout PC.

HARDWARE

The small readout box is kept inside Rack 2A4 at the bottom (this is where the cables from the thermocouples terminate. The box is powered by an AC/DC converter and has a small LCD display which shows the sensor number and temperature. The box is readout via an RS232 serial cable, which goes to the transition module for a VME processor in rack 2A7. The processor is in the non-CANBUS crate that was added last year. The processor is on port 9012 of the terminal server, and also reads out the status of the TPC AB interlock system. Since this crate is not on the CANBUS chain one can only reboot the processor by logging in, or by using the remote power switch to cycle power.

The readout display of the 120 temperatures is accessible from the TPC top level GUI. Click on “TPC TEMPERTURE” and the temperature GUI will come up:



	Inner			Outer		
	Wheel	FEE	RDO	Wheel	FEE	RDO
1	73.5	74.2	73.9	73.2	73.2	72.8
2		73.0	73.1		73.1	61.5
3	74.0	73.3	73.1	73.1	74.2	73.1
4		70.1	73.6		75.1	73.4
5	63.4	47.8	47.6	72.7	74.1	73.0
6		75.3	72.8		73.1	74.2
7	74.1	72.8	73.1	72.8	72.9	74.2
8		74.0	72.8		73.1	72.8
9	73.7	73.2	72.9	73.3	75.0	72.1
10		75.1	73.7		74.1	73.9
11	73.9	72.7	73.1	74.2	75.1	73.3
12		74.2	75.0		73.2	72.9
13	73.6	73.1	72.9	73.1	73.1	73.1
14		73.4	72.9		72.8	72.9
15	73.8	72.9	72.9	71.1	73.4	73.0
16		73.2	75.1		68.2	73.2
17	73.8	73.3	72.8	71.1	73.4	72.9
18		74.1	75.0		75.0	74.2
19	74.0	73.0	74.2	73.5	73.3	73.3
20		73.2	73.1		72.9	73.7
21	73.5	72.9	72.7	72.8	72.8	72.8
22		74.0	73.0		73.4	75.1
23	73.8	75.0	73.0	74.1	73.4	73.0
24		72.8	72.9		75.1	71.9

Average: 72.8

Since the TPC cooling water is regulated at ~ 74 deg F most of the sensors should be near this value. Note the readings for inner 5 are clearly incorrect – they have been this way since the new readout system was installed.

In the early RHIC runs we used to see a ~ 2 degree F rise in the FEE and RDO manifold temperatures when the FEEs were powered on. We then added more plates to the TPC water skid heat exchanger and we no longer see this rise. Note that TPC water exchanges heat with the STAR modified chilled water system, which is usually kept at ~ 62 degrees F. However, for running during hot weather, MCW is sometimes raised to 65 or 66, to avoid condensation in the hall. For those times one should watch the TPC temperature for any rise.

These temperatures are archived by the Slow Controls archiver and are also input into the TPC alarm handler.

There are two manuals which document this system:

1. “STAR TPC Temperature Monitoring System” by Betts, Anderson and Wieman describes the sensors and their placement.
2. “Temperature Monitor Manual” by Kravtsov which describes the readout box.

The thermocouples are glued in place and the cable that attaches to each one is not robust. We usually check these connections before each run, especially if there has been extensive work at the TPC endcaps.

STAR TPC Temperature Monitoring System

Wayne Betts (BNL), Mike Anderson (UC-Davis), Howard Wieman (LBNL)

Introduction

We have installed a temperature measurement system on the TPC in order to diagnose cooling (or heating) problems before any damage is done to the TPC electronics (or in extreme cases, damage to the TPC itself). A total of one hundred twenty temperature sensors are on the East and West sector mounting wheels and on the FEE and RDO cooling manifolds. These sensors are readout using an A/D card in a PC and the results (including periodic historical readings) are available on the WWW. The temperature measurements are also placed on a shared disk accessible by Slow Controls for storage in the data stream and the possibility of setting alarms.

Locations

The sector mounting wheels at the two ends of the TPC each have twelve temperature sensors. Each side has six located near the inner radius (referred to as the 'Inner Wheel') and six more located on the boundary between the inner and the outer sectors (referred to as the 'Outer Wheel'). See the picture below for the locations and numbering.

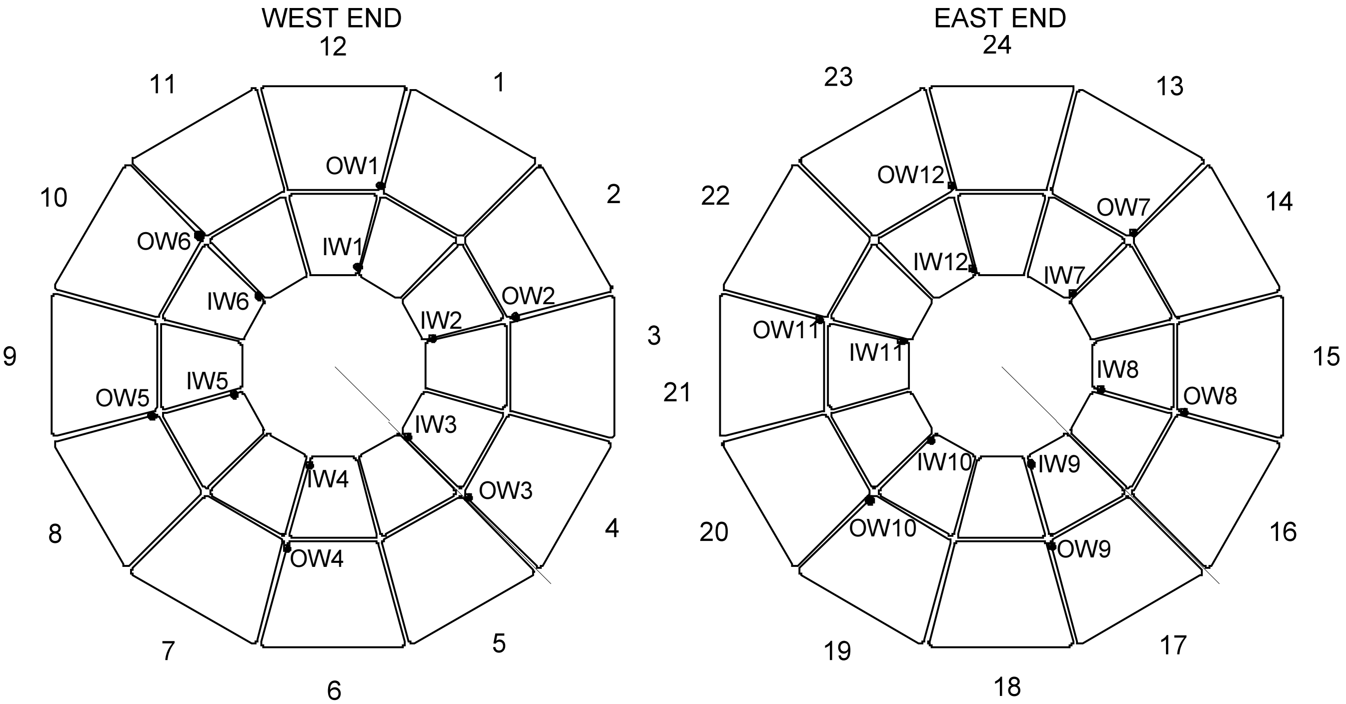


Figure 1. Mounting wheel temperature locations. Each end of the TPC has twelve temperature sensors in the locations shown in the figure.

Each FEE and RDO manifold has one sensor. The sensor locations were chosen to try to diagnose potential cooling (or heating) problems before they become serious. They have been placed in the region most likely to have reduced water flow in the event of particulate buildup in the manifolds (which unfortunately is usually not the same region in which any trapped air is likely to impede flow). The manifolds have water input and output on opposite sides. The sensors are placed on the same side of the manifold as the water exhaust but at the 'dead' end of that side. Figure 2 illustrates a typical layout.

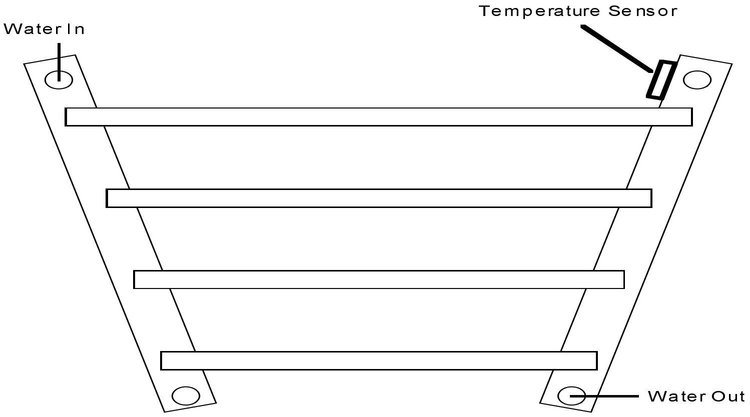


Figure 2. Temperature sensor locations on the TPC electronics manifolds. The sensors are positioned on the same side of the manifold as the water output, but on the far end. The brass mounting base (described later) is epoxied onto the water manifold.

Sensor Description and Readout System

The measurement system uses National Semiconductor LM34CAZ integrated circuit temperature sensors[1] in the circuit shown in Figure 3. The LM34, resistor and capacitor are all captured in an epoxy cast on a ⅛" thick brass 'sled' about 1½"x ⅝". One end of the sled is bent upwards at about 40° to allow for easy removal once it is epoxied to the manifold.

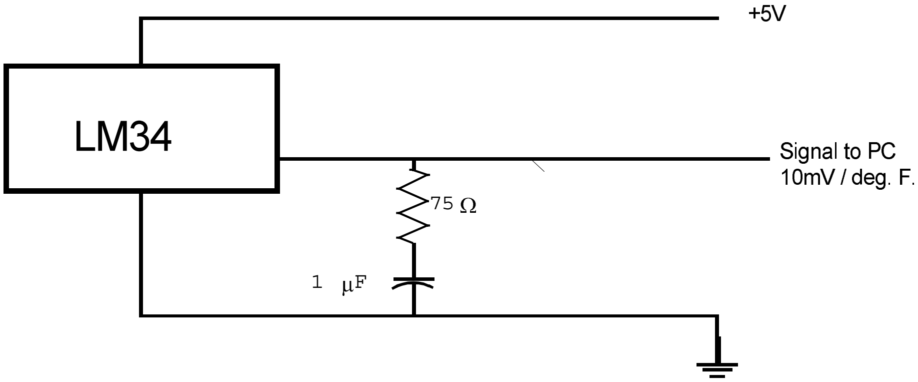


Figure 3. The circuit with an R-C damper used to measure the temperatures.

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[1] More information on this device can be found at http://www.national.com/pf/LM/LM34.html

The low voltage, ground and temperature signal are carried on ribbon cables running between the endcaps and an interface box in Rack 2A4 on the South Platform. Five volts is supplied by a standard wall outlet transformer, which plugs directly into the interface box. The interface box has twenty-four DB-9 connectors, each of which serves five sensors (one pin for each signal plus a common ground and +5V). The 120 signal pins on the DB-9 connectors are connected inside the interface box to four DB-37 connectors, which in turn are cabled to the four computer A/D cards. The exact pin mapping is included in Attachment 1 in case there is need for troubleshooting or upgrades in the future.

The A/D cards are NuDAQ ACL-8113 units[2], each with 32 isolated 12-bit channels. The PC is a Pentium 90 running Microsoft Windows NT 4.0 (w/ Service Pack 5 as of this writing) which also sits on the second floor of the South Platform. Since physical access to this computer is subject to RHIC access controls, a remote desktop can be obtained using a VNC Viewer (requires the password). The readout is done by a C++ program that runs continuously and writes out the results to files. Several files hold information from the most recent measurements, and a history file holds a periodic sample of measurements indefinitely. Additionally, the C++ code invokes a Perl program that generates a new Temperature Homepage (described below) for each new set of temperatures. Routine access to the measurements is performed through the WWW in a manner described later. Several parameters of the readout code can be set at start time, such as the frequency of measurements (typically once per minute), how often to write an event to the history file (every 57 events, which is approximately one hour) and what temperature range should be considered normal (typically 68-78°F). If any temperature is found to be outside of the specified range, a special event is written to the history file and the web page display clearly shows the out-of-bounds condition. At this time however, there are no automatic actions taken when an out-of-bounds temperature is detected other than updating the Web display. In the near term, it is expected that the temperature homepage will be checked sufficiently often to avoid any serious problems. At some point in the future, Slow Controls will include automatic monitoring of the temperatures and generate alerts when necessary.

WWW Display Setup

The TPC Temperature Homepage is accessed at http://tpctemp.star.bnl.gov/. This page displays the most recent measurements, including the highest and lowest temperature, the overall average temperature and the time the measurements were made. Temperature values that fall outside the acceptable range are displayed in bold and color coded (red for high temperatures, blue for cold temperatures). Special events are recorded whenever the temperature service is started, or when a temperature crosses the normal temperature limits. The most recent special event is displayed by clicking on the appropriately labeled button. Additionally, the six most recent special events can be accessed by name as 'AlertX.txt' where X=1,2,3,4,5 or 6 (one being the most recent). Below the textual information, each of the six sensor location types (such as Inner Wheel or Outer FEE Manifold) has a graph with the most recent measurement from each sensor. These graphs display out-of-bound temperatures in different colors as well. This front page updates itself automatically, if the browser is sufficiently modern. It has been shown to work with MS Internet Explorer 4 and 5 and with Netscape Communicator 4.6 on PCs with Windows. Several Unix systems with various versions of Netscape Navigator 4.xx have been shown to have problems updating the graphs. This appears to be a Navigator feature/bug, for which there may be no solution.

The user can click any of the six graphs in the vicinity of a point (or somewhere in a vertical region around a point) to request a generic history graph for that sensor (50 events starting with the most recent). Alternatively, the user can fill out a form near the bottom of the page to request a history graph. (Hopefully the available parameters are self-explanatory on the web page.) When either method is used to select a history graph, another Perl script (with a CGI interaction to pass the parameters) generates the desired GIF image, displays it in a new window and returns the main browser window back to the Temperature Homepage. This makes it possible to have multiple history graphs open at once, while still looking at the main page. Each history graph is also color-coded and marks special events. The individual history graphs attempt to update themselves every ten minutes. Under normal circumstances, the history file is only updated once an hour, but the history can be updated more frequently in the case of a special event (as defined previously). To prevent historical graphs from clogging the server's disk space, a separate Perl script is automatically started that deletes any GIF images that are more than 2 hours old.

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[2] More information on this device can be found at http://www.web-tronics.com/webtronics/32se12bitisa.html

Attachment 1. Cable and Interface Descriptions

Sensor Location	DB-9 Location (Connector Number - Pin Number)	DB-37 Location (Connector Number - Pin Number - ACL9113 Analog Input Number)
Inner Wheel 1 (Sectors 12&1)	1-3	I - 3 - 4
IW2 (S. 2&3)	3-3	I - 13 - 20
IW3 (S. 4&5)	5-3	I - 23 - 7
IW4 (S. 6&7)	7-3	II - 3 - 4
IW5 (S. 8&9)	9-3	II - 13 - 20
IW6 (S. 10&11)	11-3	II - 23 - 7
IW7 (S. 13&14)	13-3	III - 3 - 4
IW8 (S. 15&16)	15-3	III - 13 - 20
IW9 (S. 17&18)	17-3	III - 23 - 7
IW10 (S. 19&20)	19-3	IV - 3 - 4
IW11 (S. 21&22)	21-3	IV - 13 - 20
IW12 (S. 23&24)	23-3	IV - 23 - 7
Outer Wheel 1 (Sectors 12&1)	2-3	I - 8 - 14
OW2 (S. 2&3)	4-3	I - 35 - 27
OW3 (S. 4&5)	6-3	I - 33 - 23
OW4 (S. 6&7)	8-3	II - 8 - 14
OW5 (S. 8&9)	10-3	II - 35 - 27
OW6 (S. 10&11)	12-3	II - 33 - 23
OW7 (S. 13&14)	14-3	III - 8 - 14
OW8 (S. 15&16)	16-3	III - 35 - 27
OW9 (S. 17&18)	18-3	III - 33 - 23
OW10 (S. 19&20)	20-3	IV - 8 - 14
OW11 (S. 21&22)	22-3	IV - 36 - 29
OW12 (S. 23&24)	24-3	IV - 34 - 25
Inner Sector 1 RDO	1-5	I - 5 - 8
IR2	3-1	I - 11 - 16
IR3	3-5	I - 15 - 24
IR4	5-1	I - 21 - 3
IR5	5-5	I - 25 - 11
IR6	7-1	II - 1 - 0
IR7	7-5	II - 5 - 8
IR8	9-1	II - 11 - 16
IR9	9-5	II - 15 - 24
IR10	11-1	II - 21 - 3
IR11	11-5	II - 25 - 11
IR12	1-1	I - 1 - 0
IR13	13-1	III - 1 - 0
IR14	13-5	III - 5 - 8
IR15	15-1	III - 11 - 16
IR16	15-5	III - 15 - 24
IR17	17-1	III - 21 - 3

IR18	17-5	III - 25 - 11
IR19	19-1	IV - 1 - 0
IR20	19-5	IV - 5 - 8
IR21	21-1	IV - 11 - 16
IR22	21-5	IV - 15 - 24
IR23	23-1	IV - 21 - 3
IR24	23-5	IV - 25 - 11

Outer Sector 1 RDO	2-5	I - 32 - 21
OR2	4-1	I - 16 - 26
OR3	4-5	I - 20 - 1
OR4	6-1	I - 26 - 13
OR5	6-5	I - 30 - 17
OR6	8-1	II - 6 - 10
OR7	8-5	II - 32 - 21
OR8	10-1	II - 16 - 26
OR9	10-5	II - 20 - 1
OR10	12-1	II - 26 - 13
OR11	12-5	II - 30 - 17
OR12	2-1	I - 6 - 10
OR13	14-1	III - 6 - 10
OR14	14-5	III - 32 - 21
OR15	16-1	III - 16 - 26
OR16	16-5	III - 20 - 1
OR17	18-1	III - 26 - 13
OR18	18-5	III - 30 - 17
OR19	20-1	IV - 6 - 10
OR20	20-5	IV - 33 - 23
OR21	22-1	IV - 16 - 26
OR22	22-5	IV - 20 - 1
OR23	24-1	IV - 26 - 13
OR24	24-5	IV - 30 - 17

Inner Sector 1 FEE	1-4	I - 4 - 6
IF2	3-2	I - 18 - 30
IF3	3-4	I - 14 - 22
IF4	5-2	I - 22 - 5
IF5	5-4	I - 24 - 9
IF6	7-2	II - 2 - 2
IF7	7-4	II - 4 - 6
IF8	9-2	II - 12 - 18
IF9	9-4	II - 14 - 22
IF10	11-2	II - 22 - 5
IF11	11-4	II - 24 - 9
IF12	1-2	I - 2 - 2
IF13	13-2	III - 2 - 2
IF14	13-4	III - 4 - 6
IF15	15-2	III - 12 - 18
IF16	15-4	III - 14 - 22
IF17	17-2	III - 22 - 5
IF18	17-4	III - 24 - 9
IF19	19-2	IV - 2 - 2
IF20	19-4	IV - 4 - 6
IF21	21-2	IV - 12 - 18

IF22	21-4	IV - 14 - 22
IF23	23-2	IV - 22 - 5
IF24	23-4	IV - 24 - 9

Outer Sector 1 FEE	2-4	I - 31 - 19
OF2	4-2	I - 17 - 28
OF3	4-4	I - 36 - 29
OF4	6-2	I - 27 - 15
OF5	6-4	I - 34 - 25
OF6	8-2	II - 7 - 12
OF7	8-4	II - 31 - 19
OF8	10-2	II - 17 - 28
OF9	10-4	II - 36 - 29
OF10	12-2	II - 27 - 15
OF11	12-4	II - 34 - 25
OF12	2-2	I - 7 - 12
OF13	14-2	III - 7 - 12
OF14	14-4	III - 31 - 19
OF15	16-2	III - 17 - 28
OF16	16-4	III - 36 - 29
OF17	18-2	III - 27 - 15
OF18	18-4	III - 34 - 25
OF19	20-2	IV - 7 - 12
OF20	20-4	IV - 31 - 19
OF21	22-2	IV - 17 - 28
OF22	22-4	IV - 37 - 31
OF23	24-2	IV - 27 - 15
OF24	24-4	IV - 18 - 30

The wire colors connected to the sensors outside of the interface box are described below (some colors are repeated):

Pin/Sensor Number	Signal Color	Ground Color	+5V Color
1	Green	Yellow	Orange
2	Red	Black	Brown
3	Violet	Gray	White
4	Blue	Yellow	Green
5	Orange	Red	Brown

Inside the interface box, the DB-9 pins are connected to the DB-37 in the following colors:

Pin Number	Wire Color
1	Red
2	Orange
3	Yellow
4	Green
5	Blue

For the DB-9 connectors, pin 6 connects to +5V (white wire) and pin 9 is for ground (black wire).

Temperature monitor

Manual

Brookhaven National Laboratory
Version 1.0

By Peter Kravtsov (E-mail: PAKravtsov@lbl.gov)

This document location: http://www-rnc.lbl.gov/~pkravt/pdf/tm_manual.pdf

August 2003

Introduction

STAR TPC detector is equipped by 120 temperature sensors placed on the East and West sector mounting wheels and on the FEE and RDO cooling manifolds. Temperature monitor (Fig. 1) is intended for reading out these sensors and provide temperature information for the slow control. These sensors are grouped by location into six groups: Inner Wheel, Outer Wheel, Inner Sector RDO, Outer Sector RDO, Inner Sector FEE, Outer Sector FEE.

Fig. 1. Temperature monitor.

The device is based on the Atmel AT89S8252 (Fig. 2) microcontroller running at 22.1184 MHz clock frequency. It has 8Kb static RAM to keep the temperature values and all data. There is also internal 2Kb EEPROM in the CPU which is used for keeping sensor names and numbers. Analog signals from the National Semiconductors LM34 sensors go through eight 16-channel multiplexers [MPC506] and instrumentation amplifier [AD711] to 16-bit ADC [ADS7813].

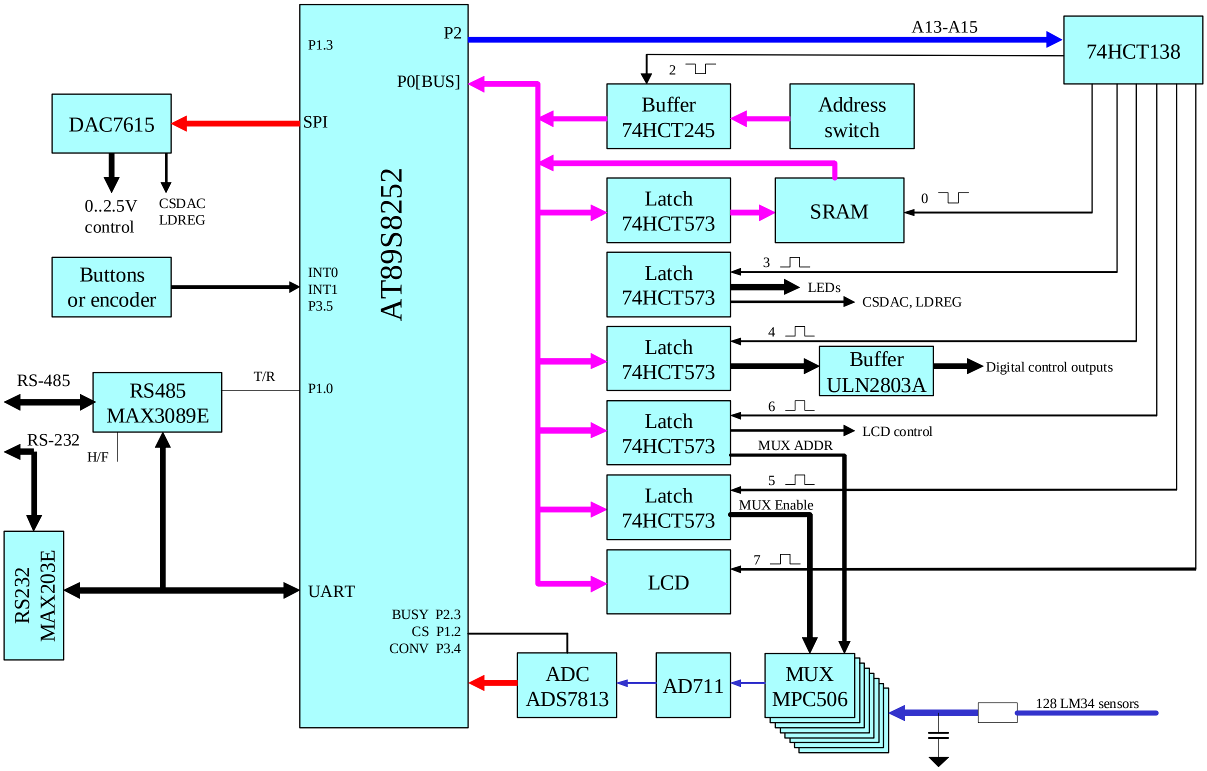


Fig. 2. Temperature monitor function diagram.

All signal lines have RC filters before the multiplexers to avoid long line noise. CPU has internal watch-dog, which attends to controller program faults and resets CPU as fast as in 0.5 s in this case.

Temperature monitor can be connected to PC via standard RS-232 or RS-485 port. Besides, the device is equipped by LCD indicator to display sensors temperature, control buttons, 8+6 open collector digital outputs that can be used in alarms handling procedure. There is a possibility to connect any ±10V sensors to this device. ADC is normally working in 0÷4V range, but this could be changed to 0÷10V or to ±10V range. In spite of single +5V power, multiplexers and amplifiers are powered by ±15V via DC-DC converter [DCP020515D] and can be used for the signals of ±10V range.

Thus input/output features of temperature monitor are the following:

- 128 analog inputs (16-bit, 0÷4V or 0÷10V or ±10V, optional averaging);
- 14 digital outputs (open collector, 500mA maximum current);
- 4 optional analog outputs (12-bit, 0÷2.5V).

There are 26 connectors (9 pin female DSUB marked X1-X26) at the top of temperature monitor to connect all sensors. Each connector has pin 6 connected to +5V for sensors power and pin 9 connected to ground. Pins 1÷5 are used for sensor signals. One additional connector (9 pin male DSUB) connected to 8 digital outputs. Pin 5 of this connector is connected to ground.

Controller software

Controller software is written in C language. It provides reading of 128 sensors with programmed averaging by 1-255 samples, handles communication with the host computer. One of the temperature values is displayed on the LCD. Two buttons are used to scroll the sensors: one selects sensors group (Inner Wheel, Outer Wheel, Inner Sector RDO, Outer Sector RDO, Inner Sector FEE, Outer Sector FEE, Extra 8 sensors) while second one scrolls the sensors of selected group. Sensor names and numbers could be programmed from the host computer and written to the CPU EEPROM.

Optionally controller software also checks all sensors for alarm limits and generates alarm signals.

Serial protocol

Communication protocol consists of two main commands: read memory byte and write memory byte. It could contain also some special commands which are specially described for every device. Protocol is based on 5-byte binary packets exchange. The device sends 5-byte answer for every 5-byte command, if device address field in this command is correct.

Command structure is following:

Byte	Description
1	6-bit device address. Should be equal to device address set on the dip switch inside the device or packet will be ignored otherwise. Two most significant bits are ignored.
2	Bit 7 – read/write bit. Bit 7 = 1 corresponds to write command and bit 7 = 0 – read command. Bit 6 – special command flag. If bit 6 = 1, packet contains special command. Bits 5÷0 – high bits of 14-bits address field.
3	Low byte of 14-bits address field.
4	Data byte.
5	XOR-sum of first 4 bytes. B5=B1^B2^B3^B4. If it is not correct XOR-sum, packet is ignored.

Examples:

1. Host computer wants to read byte at address 0x345 from the device with address 0x02. Device memory contains 0xAA at this address.

```
host request  : 0x02 0x03 0x45 0x00 0x44
device answer : 0x02 0x03 0x45 0xAA 0xEE
```

2. Host computer wants to write byte 0x55 at address 0x1543 to the device with address 0x08 (Note that read/write bit is cleared in the answer).

```
host request  : 0x08 0x95 0x43 0x55 0x8B
device answer : 0x08 0x15 0x43 0x55 0x0B
```

Communication speed could be selected from 9.6, 19.2, 57.6 or 115.2 Kbit/s by dip switch inside the device (see table below). Usually read or write access to the device memory using this protocol takes not more than 2ms for every byte at 115.2 Kbit/s. Memory map is of course different for every device and is specially described as well as additional commands. Byte ordering is little endian, high byte has low address.

Configuration switch description:

Switch position	Description (0=OFF, 1=ON)
1-6	6-bit device address in binary format. Least significant bit is selected by switch position 1. Valid range is 1÷63.
7-8	Communication speed: 00 – 9600 bit/s 01 – 19200 bit/s 10 – 57600 bit/s 11 – 115200 bit/s

Temperature monitor accepts one special command, with byte 2 = 0x41. In response to this command it sends all temperatures as word[128] array and one byte of XOR-sum in the end (257 bytes totally). This command is fastest way to get all temperatures from the device. At 115200 bit/s communication speed it takes about 30ms, while reading by one memory byte takes about 400ms.

Memory map

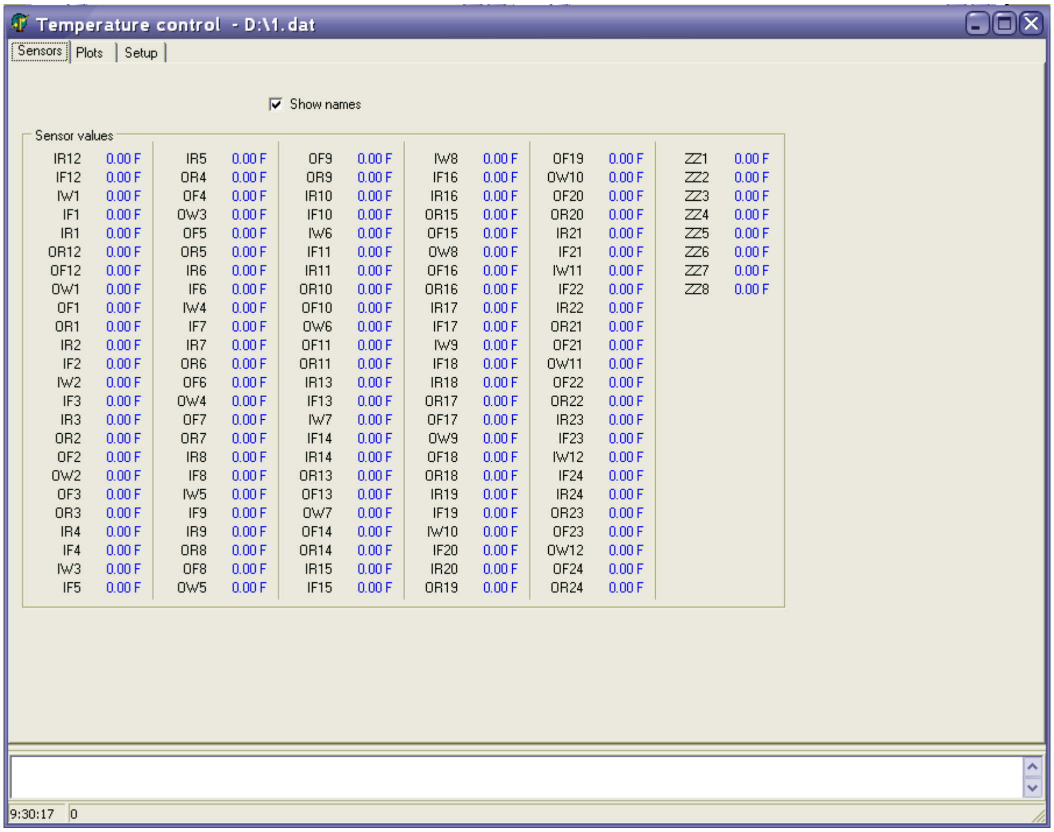
Address	Length	Type	Name	Description
0x0000	2	word	WDCount	Watch-dog resets counter. Should be 0 or small value and not increase. This counter resets to 0 at every “cold” start, i.e. power-on procedure and increases at every watch-dog CPU reset.
0x0007	1	byte	AVGCount	Number of samples to average. No averaging occurs if = 0. Default value is 8.
0x0008	1	byte	ADCchan	ADC channel number. Device will measure only this channel (0÷127) or all 128 channels if ADCchan>127.
0x0009	1	byte	DOUTByte	Digital outputs control byte.
0x000F	1	Byte	ID	Device ID = 0xA1. It is NOT device address.
0x0010	256	Word	ADCval[128]	Sensor values in 2-byte integer form. Temperature should be calculated by the formula: T [F] = ADCval / 0xFFFF * 400
0x04FE	1	Byte	UpdateNums	Control byte for updating sensor numbers in EEPROM. If UpdateNums=1, CPU will write sensor numbers from RAM to internal EEPROM. CPU reads numbers from EEPROM to RAM in startup procedure.

0x04FF	1	Byte	UpdateNames	Control byte for updating sensor names in EEPROM. If UpdateNames=1, CPU will write sensor names from RAM to internal EEPROM, where they will be kept until next power-on procedure. This takes about 1.5 seconds. CPU reads names from EEPROM to RAM in startup procedure.
0x0500	512	Char	Names[128][4]	4-byte sensor names for LCD display.
0x0700	168	Byte	snum[7][24]	Sensor numbers for 7 groups and 24 sensors in each group. Group names are kept in Flash memory and could not be changed.

PC software

Temperature monitor control software for the host PC was developed for Windows platform. Using this software, one could see all 128 temperature values (Fig. 2) either by sensor names or by connector and pin numbers. It also makes it possible to change sensor names and numbers in the device EEPROM (Fig. 3). Number of samples to average also could be changed by user. Note that this number will reset to 8 in device power-up procedure.

The software reads sensor values using byte memory access or buffer command (this can be changed in the setup window). All sensor values could be saved in history file for future analysis.



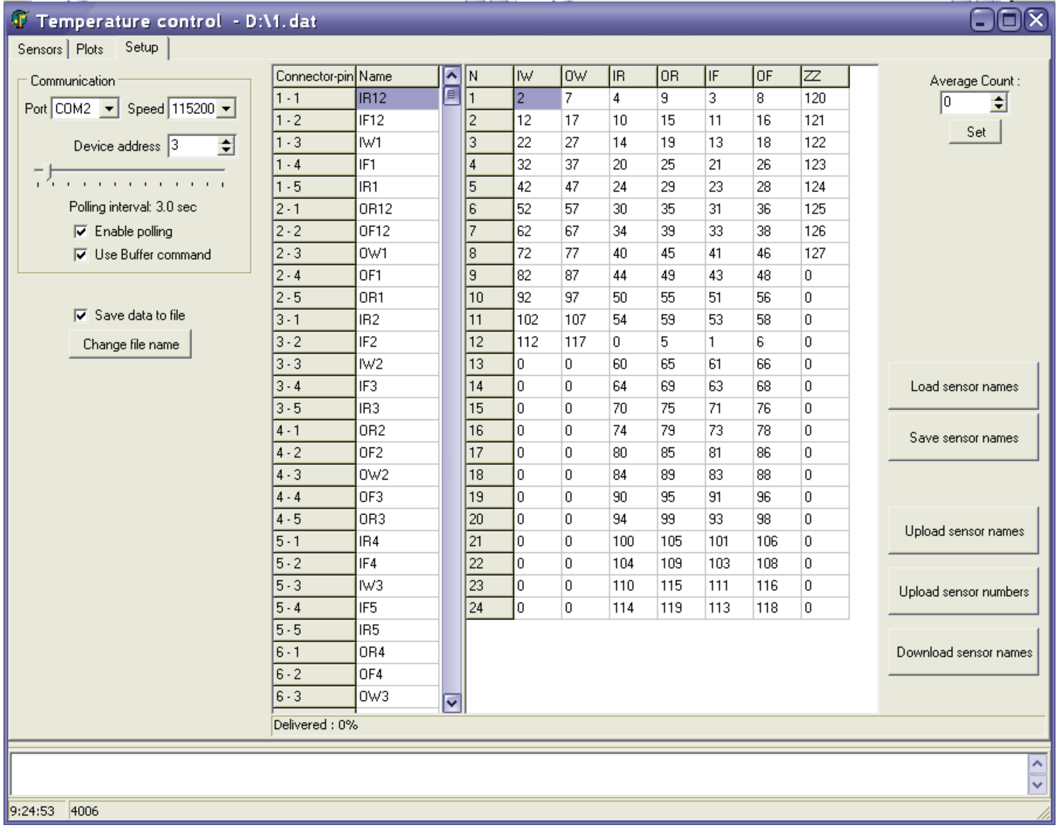
☑ Show names

Sensor values

IR12	0.00 F	IR5	0.00 F	OF9	0.00 F	IW8	0.00 F	OF19	0.00 F	ZZ1	0.00 F
IF12	0.00 F	OR4	0.00 F	OR9	0.00 F	IF16	0.00 F	OW10	0.00 F	ZZ2	0.00 F
IW1	0.00 F	OF4	0.00 F	IR10	0.00 F	IR16	0.00 F	OF20	0.00 F	ZZ3	0.00 F
IF1	0.00 F	OW3	0.00 F	IF10	0.00 F	OR15	0.00 F	OR20	0.00 F	ZZ4	0.00 F
IR1	0.00 F	OF5	0.00 F	IW6	0.00 F	OF15	0.00 F	IR21	0.00 F	ZZ5	0.00 F
OR12	0.00 F	OR5	0.00 F	IF11	0.00 F	OW8	0.00 F	IF21	0.00 F	ZZ6	0.00 F
OF12	0.00 F	IR6	0.00 F	IR11	0.00 F	OF16	0.00 F	IW11	0.00 F	ZZ7	0.00 F
OW1	0.00 F	IF6	0.00 F	OR10	0.00 F	OR16	0.00 F	IF22	0.00 F	ZZ8	0.00 F
OF1	0.00 F	IW4	0.00 F	OF10	0.00 F	IR17	0.00 F	IR22	0.00 F		
OR1	0.00 F	IF7	0.00 F	OW6	0.00 F	IF17	0.00 F	OR21	0.00 F		
IR2	0.00 F	IR7	0.00 F	OF11	0.00 F	IW9	0.00 F	OF21	0.00 F		
IF2	0.00 F	OR6	0.00 F	OR11	0.00 F	IF18	0.00 F	OW11	0.00 F		
IW2	0.00 F	OF6	0.00 F	IR13	0.00 F	IR18	0.00 F	OF22	0.00 F		
IF3	0.00 F	OW4	0.00 F	IF13	0.00 F	OR17	0.00 F	OR22	0.00 F		
IR3	0.00 F	OF7	0.00 F	IW7	0.00 F	OF17	0.00 F	IR23	0.00 F		
OR2	0.00 F	OR7	0.00 F	IF14	0.00 F	OW9	0.00 F	IF23	0.00 F		
OF2	0.00 F	IR8	0.00 F	IR14	0.00 F	OF18	0.00 F	IW12	0.00 F		
OW2	0.00 F	IF8	0.00 F	OR13	0.00 F	OR18	0.00 F	IF24	0.00 F		
OF3	0.00 F	IW5	0.00 F	OF13	0.00 F	IR19	0.00 F	IR24	0.00 F		
OR3	0.00 F	IF9	0.00 F	OW7	0.00 F	IF19	0.00 F	OR23	0.00 F		
IR4	0.00 F	IR9	0.00 F	OF14	0.00 F	IW10	0.00 F	OF23	0.00 F		
IF4	0.00 F	OR8	0.00 F	OR14	0.00 F	IF20	0.00 F	OW12	0.00 F		
IW3	0.00 F	OF8	0.00 F	IR15	0.00 F	IR20	0.00 F	OF24	0.00 F		
IF5	0.00 F	OW5	0.00 F	IF15	0.00 F	OR19	0.00 F	OR24	0.00 F		

9:30:17 | 0

Fig. 2. Sensors display.



Communication

Port COM2 Speed 115200

Device address 3

Polling interval: 3.0 sec

☑ Enable polling

☑ Use Buffer command

☑ Save data to file

Connector-pin	Name
1 - 1	IR12
1 - 2	IF12
1 - 3	IW1
1 - 4	IF1
1 - 5	IR1
2 - 1	OR12
2 - 2	OF12
2 - 3	OW1
2 - 4	OF1
2 - 5	OR1
3 - 1	IR2
3 - 2	IF2
3 - 3	IW2
3 - 4	IF3
3 - 5	IR3
4 - 1	OR2
4 - 2	OF2
4 - 3	OW2
4 - 4	OF3
4 - 5	OR3
5 - 1	IR4
5 - 2	IF4
5 - 3	IW3
5 - 4	IF5
5 - 5	IR5
6 - 1	OR4
6 - 2	OF4
6 - 3	OW3

Delivered : 0%

N	IW	OW	IR	OR	IF	OF	ZZ
1	2	7	4	9	3	8	120
2	12	17	10	15	11	16	121
3	22	27	14	19	13	18	122
4	32	37	20	25	21	26	123
5	42	47	24	29	23	28	124
6	52	57	30	35	31	36	125
7	62	67	34	39	33	38	126
8	72	77	40	45	41	46	127
9	82	87	44	49	43	48	0
10	92	97	50	55	51	56	0
11	102	107	54	59	53	58	0
12	112	117	0	5	1	6	0
13	0	0	60	65	61	66	0
14	0	0	64	69	63	68	0
15	0	0	70	75	71	76	0
16	0	0	74	79	73	78	0
17	0	0	80	85	81	86	0
18	0	0	84	89	83	88	0
19	0	0	90	95	91	96	0
20	0	0	94	99	93	98	0
21	0	0	100	105	101	106	0
22	0	0	104	109	103	108	0
23	0	0	110	115	111	116	0
24	0	0	114	119	113	118	0

Average Count : 0

9:24:53 | 4006

Fig. 3. Configuration window.

National Semiconductor

November 2000

LM34
Precision Fahrenheit Temperature Sensors

General Description

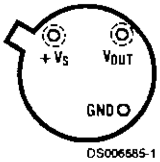
The LM34 series are precision integrated-circuit temperature sensors, whose output voltage is linearly proportional to the Fahrenheit temperature. The LM34 thus has an advantage over linear temperature sensors calibrated in degrees Kelvin, as the user is not required to subtract a large constant voltage from its output to obtain convenient Fahrenheit scaling. The LM34 does not require any external calibration or trimming to provide typical accuracies of ±½˚F at room temperature and ±1½˚F over a full −50 to +300˚F temperature range. Low cost is assured by trimming and calibration at the wafer level. The LM34's low output impedance, linear output, and precise inherent calibration make interfacing to readout or control circuitry especially easy. It can be used with single power supplies or with plus and minus supplies. As it draws only 75 µA from its supply, it has very low self-heating, less than 0.2˚F in still air. The LM34 is rated to operate over a −50˚ to +300˚F temperature range, while the LM34C is rated for a −40˚ to +230˚F range (0˚F with improved accuracy). The LM34 series is available packaged in hermetic TO-46 transistor packages, while the LM34C, LM34CA and LM34D are also available in the plastic TO-92 transistor package. The LM34D is also available in an 8-lead surface mount small outline package. The LM34 is a complement to the LM35 (Centigrade) temperature sensor.

Features

- Calibrated directly in degrees Fahrenheit
- Linear +10.0 mV/˚F scale factor
- 1.0˚F accuracy guaranteed (at +77˚F)
- Rated for full −50˚ to +300˚F range
- Suitable for remote applications
- Low cost due to wafer-level trimming
- Operates from 5 to 30 volts
- Less than 90 µA current drain
- Low self-heating, 0.18˚F in still air
- Nonlinearity only ±0.5˚F typical
- Low-impedance output, 0.4Ω for 1 mA load

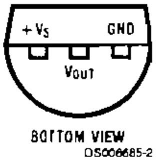
Connection Diagrams

TO-46
Metal Can Package
(Note 1)



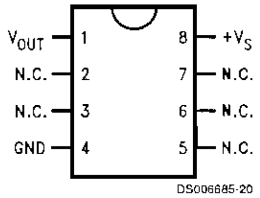
Order Numbers LM34H,
LM34AH, LM34CH,
LM34CAH or LM34DH
See NS Package
Number H03H

TO-92
Plastic Package



Order Number LM34CZ,
LM34CAZ or LM34DZ
See NS Package
Number Z03A

SO-8
Small Outline
Molded Package

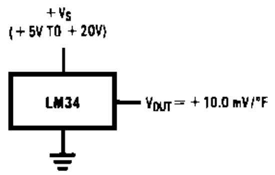


N.C. = No Connection

Top View
Order Number LM34DM
See NS Package Number M08A

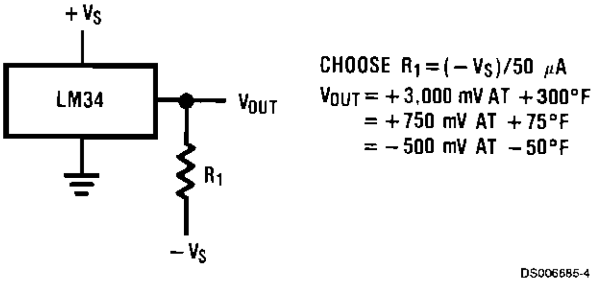
Note 1: Case is connected to negative pin (GND).

Typical Applications



DS006685-3

FIGURE 1. Basic Fahrenheit Temperature Sensor (+5˚ to +300˚F)



DS006685-4

FIGURE 2. Full-Range Fahrenheit Temperature Sensor

Absolute Maximum Ratings (Note 11)

If Military/Aerospace specified devices are required, please contact the National Semiconductor Sales Office/ Distributors for availability and specifications.

Supply Voltage	+35V to −0.2V
Output Voltage	+6V to −1.0V
Output Current	10 mA
Storage Temperature,	
TO-46 Package	−76˚F to +356˚F
TO-92 Package	−76˚F to +300˚F
SO-8 Package	−65˚C to +150˚C
ESD Susceptibility (Note 12)	800V
Lead Temp.	
TO-46 Package	
(Soldering, 10 seconds)	+300˚C
TO-92 Package	
(Soldering, 10 seconds)	+260˚C
SO Package (Note 13)	
Vapor Phase (60 seconds)	215˚C
Infrared (15 seconds)	220˚C
Specified Operating Temp. Range (Note 3)	
	T_{MIN} to T_{MAX}
LM34, LM34A	−50˚F to +300˚F
LM34C, LM34CA	−40˚F to +230˚F
LM34D	+32˚F to +212˚F

DC Electrical Characteristics (Notes 2, 7)

Parameter	Conditions	LM34A			LM34CA			Units (Max)
		Typical	Tested Limit (Note 5)	Design Limit (Note 6)	Typical	Tested Limit (Note 5)	Design Limit (Note 6)	
Accuracy (Note 8)	T_A = +77˚F	±0.4	±1.0		±0.4	±1.0		˚F
	T_A = 0˚F	±0.6			±0.6		±2.0	˚F
	$T_A = T_{MAX}$	±0.8	±2.0		±0.8	±2.0		˚F
	$T_A = T_{MIN}$	±0.8	±2.0		±0.8		±3.0	˚F
Nonlinearity (Note 9)	$T_{MIN} \leq T_A \leq T_{MAX}$	**±0.35**		±0.7	**±0.30**		**±0.6**	˚F
Sensor Gain (Average Slope)	$T_{MIN} \leq T_A \leq T_{MAX}$	**+10.0**	**+9.9,**		**+10.0**		**+9.9,**	mV/˚F, min
			+10.1				**+10.1**	mV/˚F, max
Load Regulation (Note 4)	T_A = +77˚F	±0.4	±1.0		±0.4	±1.0		mV/mA
	$T_{MIN} \leq T_A \leq T_{MAX}$	**±0.5**		**±3.0**	**±0.5**		**±3.0**	mV/mA
	$0 \leq I_L \leq 1$ mA							
Line Regulation (Note 4)	T_A = +77˚F	±0.01	±0.05		±0.01	±0.05		mV/V
	$5V \leq V_S \leq 30V$	**±0.02**		**±0.1**	**±0.02**		**±0.1**	mV/V
Quiescent Current (Note 10)	V_S = +5V, +77˚F	75	90		75	90		μA
	V_S = +5V	**131**		**160**	**116**		**139**	μA
	V_S = +30V, +77˚F	76	92		76	92		μA
	V_S = +30V	**132**		**163**	**117**		**142**	μA
Change of Quiescent Current (Note 4)	$4V \leq V_S \leq 30V$, +77˚F	+0.5	2.0		0.5	2.0		μA
	$5V \leq V_S \leq 30V$	**+1.0**		**3.0**	**1.0**		**3.0**	μA
Temperature Coefficient of Quiescent Current		**+0.30**		**+0.5**	+0.30		**+0.5**	μA/˚F
Minimum Temperature for Rated Accuracy	In circuit of *Figure 1*, $I_L = 0$	+3.0		+5.0	+3.0		+5.0	˚F
Long-Term Stability	$T_j = T_{MAX}$ for 1000 hours	±0.16			±0.16			˚F

Note 2: Unless otherwise noted, these specifications apply: −50˚F ≤ T_j ≤ + 300˚F for the LM34 and LM34A; −40˚F ≤ T_j ≤ +230˚F for the LM34C and LM34CA; and +32˚F ≤ T_j ≤ + 212˚F for the LM34D. V_S = +5 Vdc and I_{LOAD} = 50 μA in the circuit of *Figure 2*; +6 Vdc for LM34 and LM34A for 230˚F ≤ T_j ≤ 300˚F. These specifications also apply from +5˚F to T_{MAX} in the circuit of *Figure 1*.

Note 3: Thermal resistance of the TO-46 package is 720˚F/W junction to ambient and 43˚F/W junction to case. Thermal resistance of the TO-92 package is 324˚F/W junction to ambient. Thermal resistance of the small outline molded package is 400˚F/W junction to ambient. For additional thermal resistance information see table in the Typical Applications section.

Note 4: Regulation is measured at constant junction temperature using pulse testing with a low duty cycle. Changes in output due to heating effects can be computed by multiplying the internal dissipation by the thermal resistance.

Note 5: Tested limits are guaranteed and 100% tested in production.

Note 6: Design limits are guaranteed (but not 100% production tested) over the indicated temperature and supply voltage ranges. These limits are not used to calculate outgoing quality levels.

Note 7: Specification in **BOLDFACE TYPE** apply over the full rated temperature range.

DC Electrical Characteristics (Notes 2, 7) (Continued)

Note 8: Accuracy is defined as the error between the output voltage and 10 mV/°F times the device's case temperature at specified conditions of voltage, current, and temperature (expressed in °F).

Note 9: Nonlinearity is defined as the deviation of the output-voltage-versus-temperature curve from the best-fit straight line over the device's rated temperature range.

Note 10: Quiescent current is defined in the circuit of *Figure 1*.

Note 11: Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. DC and AC electrical specifications do not apply when operating the device beyond its rated operating conditions (Note 2).

Note 12: Human body model, 100 pF discharged through a 1.5 kΩ resistor.

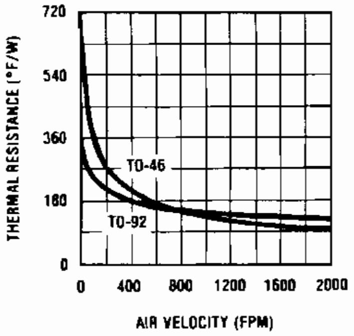
Note 13: See AN-450 "Surface Mounting Methods and Their Effect on Product Reliability" or the section titled "Surface Mount" found in a current National Semicenductor Linear Data Book for other methods of soldering surface mount devices.

DC Electrical Characteristics (Notes 2, 7)

Parameter	**Conditions**	**LM34**			**LM34C, LM34D**			**Units (Max)**
		Typical	**Tested Limit** (Note 5)	**Design Limit** (Note 6)	**Typical**	**Tested Limit** (Note 5)	**Design Limit** (Note 6)	
Accuracy, LM34, LM34C	$T_A = +77°F$	±0.8	±2.0		±0.8	±2.0		°F
(Note 8)	$T_A = 0°F$	±1.0			±1.0		±3.0	°F
	$T_A = T_{MAX}$	±1.6	±3.0		±1.6		±3.0	°F
	$T_A = T_{MIN}$	±1.6		±3.0	±1.6		±4.0	°F
Accuracy, LM34D	$T_A = +77°F$				±1.2	±3.0		°F
(Note 8)	$T_A = T_{MAX}$				±1.8		±4.0	°F
	$T_A = T_{MIN}$				±1.8		±4.0	°F
Nonlinearity (Note 9)	$T_{MIN} \le T_A \le T_{MAX}$	**±0.6**		**±1.0**	**±0.4**		**±1.0**	°F
Sensor Gain	$T_{MIN} \le T_A \le T_{MAX}$	**+10.0**	**+9.8,**		**+10.0**		**+9.8,**	mV/°F, min
(Average Slope)			**+10.2**				**+10.2**	mV/°F, max
Load Regulation	$T_A = +77°F$	±0.4	±2.5		±0.4	±2.5		mV/mA
(Note 4)	$T_{MIN} \le T_A \le +150°F$	**±0.5**		**±6.0**	**±0.5**		**±6.0**	mV/mA
	$0 \le I_L \le 1$ mA							
Line Regulation	$T_A = +77°F$	±0.01	±0.1		±0.01	±0.1		mV/V
(Note 4)	$5V \le V_S \le 30V$	**±0.02**		**±0.2**	**±0.02**		**±0.2**	mV/V
Quiescent Current	$V_S = +5V$, +77°F	75	100		75	100		μA
(Note 10)	$V_S = +5V$	**131**		**176**	**116**		**154**	μA
	$V_S = +30V$, +77°F	76	103		76	103		μA
	$V_S = +30V$	**132**		**181**	**117**		**159**	μA
Change of Quiescent	$4V \le V_S \le 30V$, +77°F	+0.5	3.0		0.5	3.0		μA
Current (Note 4)	$5V \le V_S \le 30V$	**+1.0**		**5.0**	**1.0**		**5.0**	μA
Temperature Coefficient of Quiescent Current		**+0.30**		**+0.7**	**+0.30**		**+0.7**	μA/°F
Minimum Temperature for Rated Accuracy	In circuit of *Figure 1*, $I_L = 0$	+3.0		+5.0	+3.0		+5.0	°F
Long-Term Stability	$T_J = T_{MAX}$ for 1000 hours	±0.16			±0.16			°F

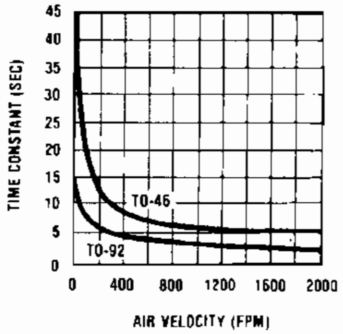
Typical Performance Characteristics

Thermal Resistance Junction to Air



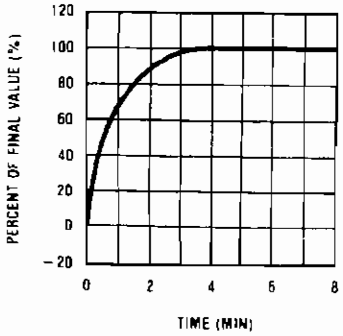
DS006685-22

Thermal Time Constant



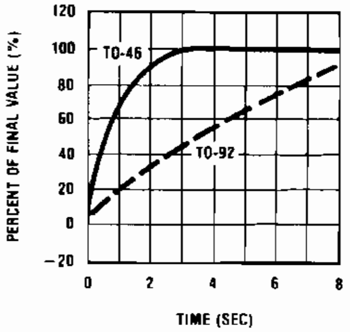
DS006685-23

Thermal Response in Still Air



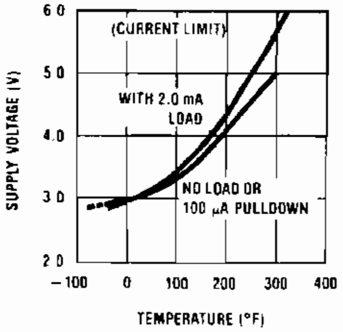
DS006685-24

Thermal Response in Stirred Oil Bath



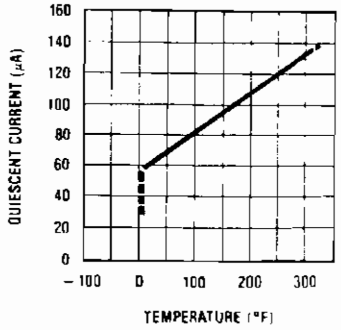
DS006685-25

Minimum Supply Voltage vs. Temperature



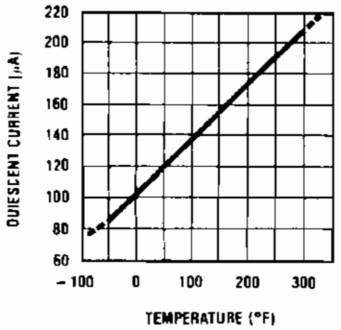
DS006685-26

Quiescent Current vs. Temperature (In Circuit of *Figure 1*)



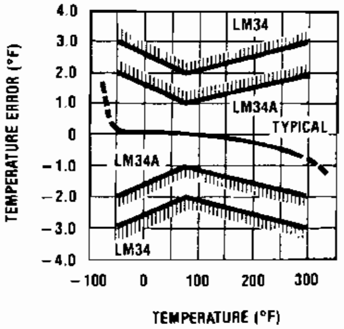
DS006685-27

Quiescent Current vs. Temperature (In Circuit of *Figure 2*; $-V_S = -5V$, R1 = 100k)



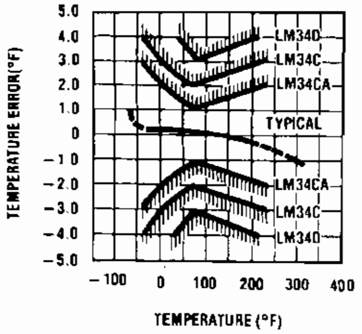
DS006685-28

Accuracy vs. Temperature (Guaranteed)



DS006685-29

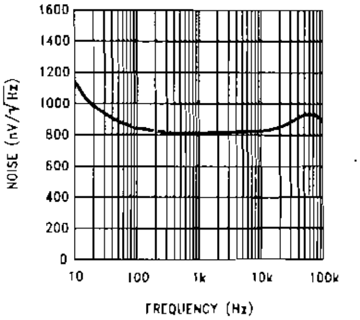
Accuracy vs. Temperature (Guaranteed)



DS006685-30

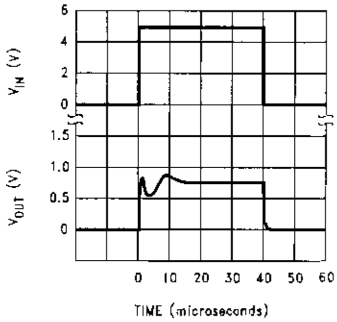
Typical Performance Characteristics (Continued)

Noise Voltage



DS006685-31

Start-Up Response



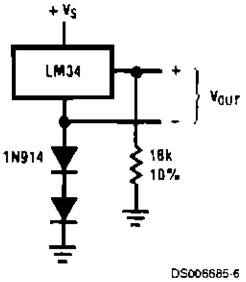
DS006685-32

Typical Applications

The LM34 can be applied easily in the same way as other integrated-circuit temperature sensors. It can be glued or cemented to a surface and its temperature will be within about 0.02°F of the surface temperature. This presumes that the ambient air temperature is almost the same as the surface temperature; if the air temperature were much higher or lower than the surface temperature, the actual temperature of the LM34 die would be at an intermediate temperature between the surface temperature and the air temperature. This is expecially true for the TO-92 plastic package, where the copper leads are the principal thermal path to carry heat into the device, so its temperature might be closer to the air temperature than to the surface temperature.

To minimize this problem, be sure that the wiring to the LM34, as it leaves the device, is held at the same temperature as the surface of interest. The easiest way to do this is to cover up these wires with a bead of epoxy which will insure that the leads and wires are all at the same temperature as the surface, and that the LM34 die's temperature will not be affected by the air temperature.

The TO-46 metal package can also be soldered to a metal surface or pipe without damage. Of course in that case. the V_ terminal of the circuit will be grounded to that metal. Alternatively, the LM34 can be mounted inside a sealed-end metal tube, and can then be dipped into a bath or screwed into a threaded hole in a tank. As with any IC, the LM34 and accompanying wiring and circuits must be kept insulated and dry, to avoid leakage and corrosion. This is especially true if the circuit may operate at cold temperatures where condensation can occur. Printed-circuit coatings and varnishes such as Humiseal and epoxy paints or dips are often used to insure that moisture cannot corrode the LM34 or its connections.



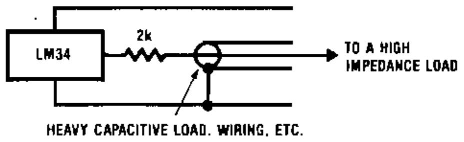
DS006685-6

These devices are sometimes soldered to a small, light-weight heat fin to decrease the thermal time constant and speed up the response in slowly-moving air. On the other hand, a small thermal mass may be added to the sensor to give the steadiest reading despite small deviations in the air temperature.

Capacitive Loads

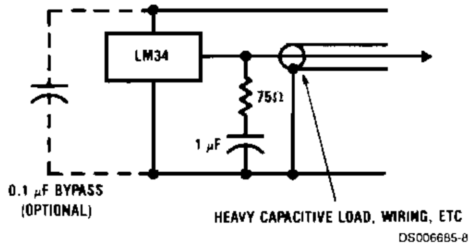
Like most micropower circuits, the LM34 has a limited ability to drive heavy capacitive loads. The LM34 by itself is able to drive 50 pF without special precautions. If heavier loads are anticipated, it is easy to isolate or decouple the load with a resistor; see *Figure 3*. Or you can improve the tolerance of capacitance with a series R-C damper from output to ground; see *Figure 4*. When the LM34 is applied with a 499Ω load resistor (as shown), it is relatively immune to wiring capacitance because the capacitance forms a bypass from ground to input, not on the output. However, as with any linear circuit connected to wires in a hostile environment, its performance can be affected adversely by intense electromagnetic sources such as relays, radio transmitters, motors with arcing brushes, SCR's transients, etc., as its wiring can act as a receiving antenna and its internal junctions can act as rectifiers. For best results in such cases, a bypass capacitor from V_{IN} to ground and a series R-C damper such as 75Ω in series with 0.2 or 1 μF from output to ground are often useful. These are shown in the following circuits.

Typical Applications



DS006685-7

FIGURE 3. LM34 with Decoupling from Capacitive Load



DS006685-8

FIGURE 4. LM34 with R-C Damper

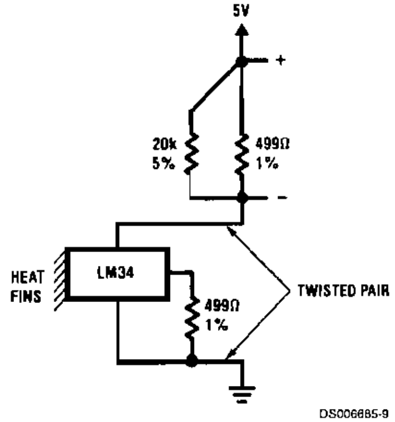
Temperature Rise of LM34 Due to Self-Heating (Thermal Resistance)

Conditions	TO-46, No Heat Sink	TO-46, Small Heat Fin (Note 14)	TO-92, No Heat Sink	TO-92, Small Heat Fin (Note 15)	SO-8 No Heat Sink	SO-8 Small Heat Fin (Note 15)
Still air	720°F/W	180°F/W	324°F/W	252°F/W	400°F/W	200°F/W
Moving air	180°F/W	72°F/W	162°F/W	126°F/W	190°F/W	160°F/W
Still oil	180°F/W	72°F/W	162°F/W	126°F/W		
Stirred oil	90°F/W	54°F/W	81°F/W	72°F/W		
(Clamped to metal, infinite heat sink)	(43°F/W)				(95°F/W)	

Note 14: Wakefield type 201 or 1" disc of 0.020" sheet brass, soldered to case, or similar.

Note 15: TO-92 and SO-8 packages glued and leads soldered to 1" square of 1/16" printed circuit board with 2 oz copper foil, or similar.

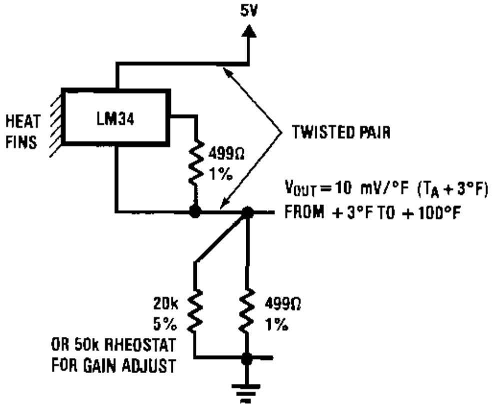
Two-Wire Remote Temperature Sensor (Grounded Sensor)



DS006685-9

V_{OUT} = 10mV/°F (T_A+3°F)
FROM +3°F TO + 100°F

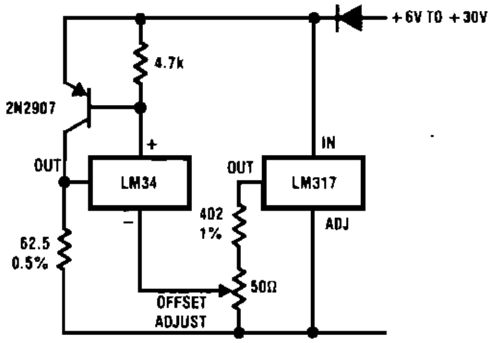
Two-Wire Remote Temperature Sensor (Output Referred to Ground)



DS006685-10

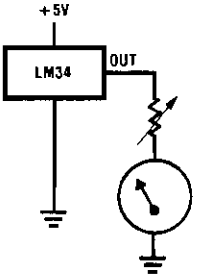
Typical Applications (Continued)

4-to-20 mA Current Source
(0 to +100˚F)



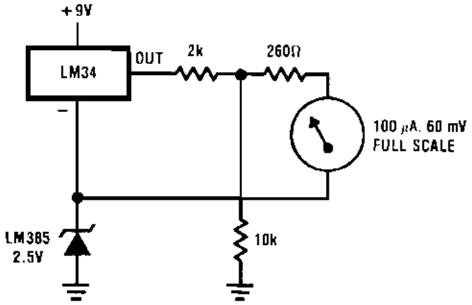
DS006685-11

Fahrenheit Thermometer
(Analog Meter)



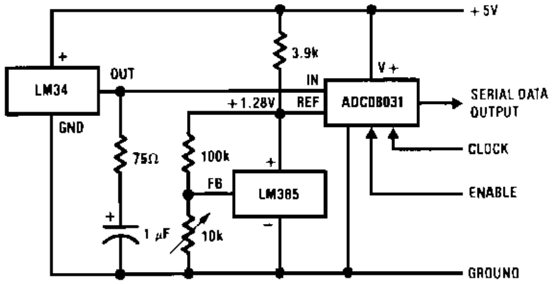
DS006685-12

Expanded Scale Thermometer
(50˚ to 80˚ Fahrenheit, for Example Shown)



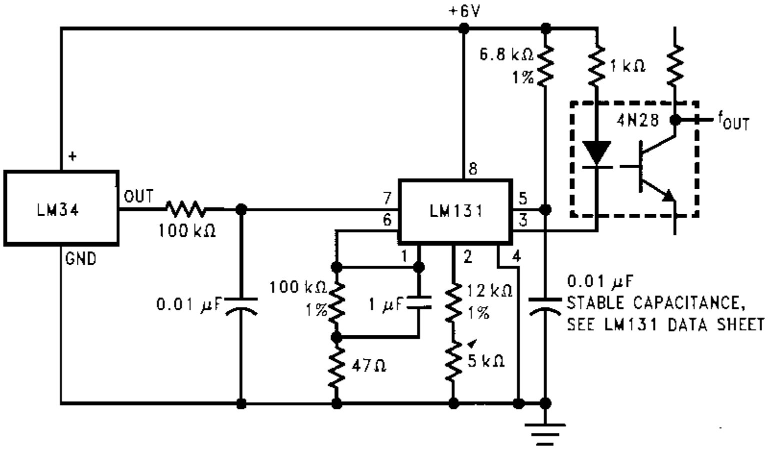
DS006685-13

Temperature-to-Digital Converter
(Serial Output, +128˚F Full Scale)



DS006685-14

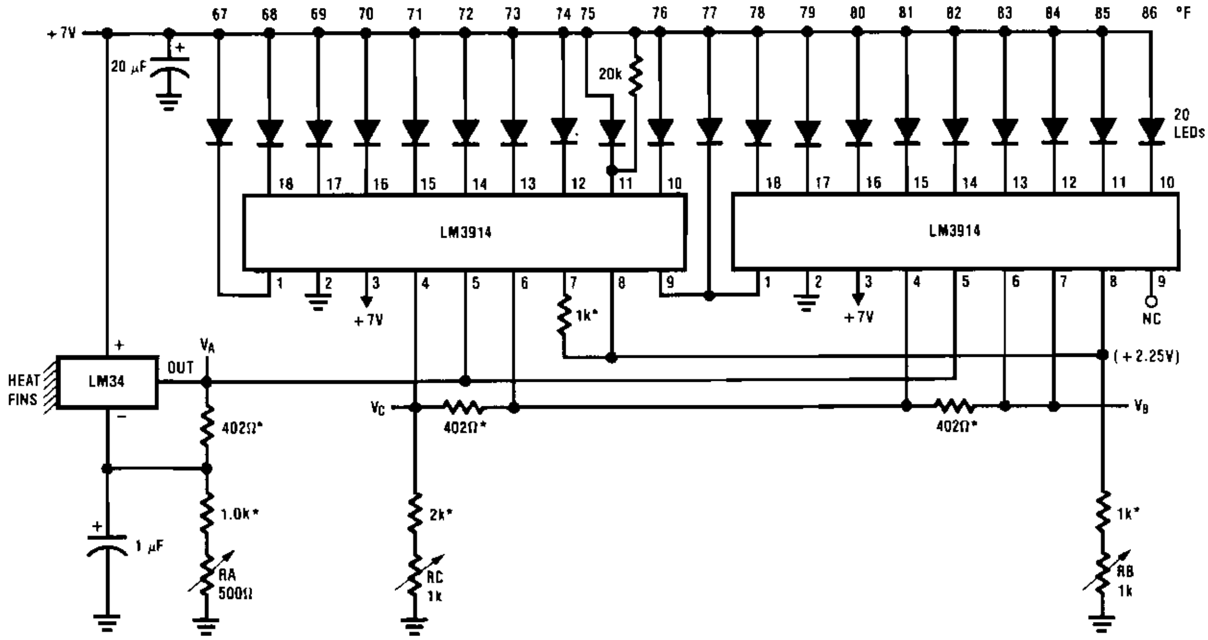
LM34 with Voltage-to-Frequency Converter and Isolated Output
(3˚F to + 300˚F; 30 Hz to 3000 Hz)



DS006685-15

Typical Applications (Continued)

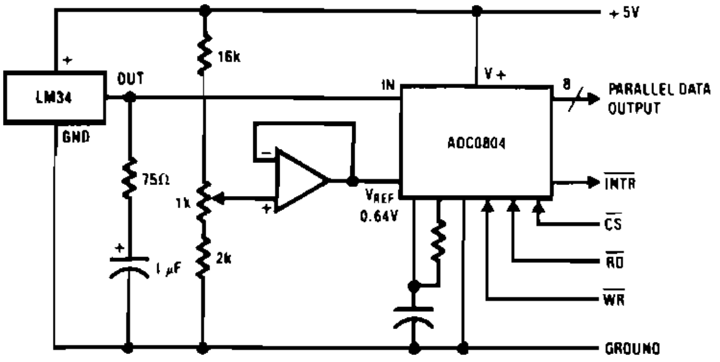
Bar-Graph Temperature Display (Dot Mode)



DS006685-16

* = 1% or 2% film resistor
—Trim R_B for V_B = 3.525V
—Trim R_C for V_C = 2.725V
—Trim R_A for V_A = 0.085V + 40 mV/°F x $T_{AMBIENT}$
—Example, V_A = 3.285V at 80°F

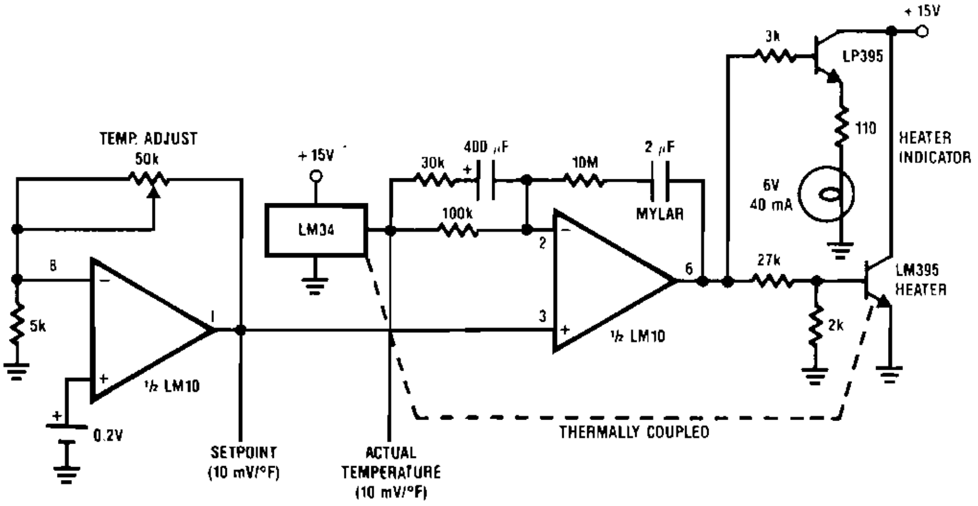
Temperature-to-Digital Converter (Parallel TRI-STATE® Outputs for Standard Data Bus to μP Interface, 128 °F Full Scale)



DS006685-17

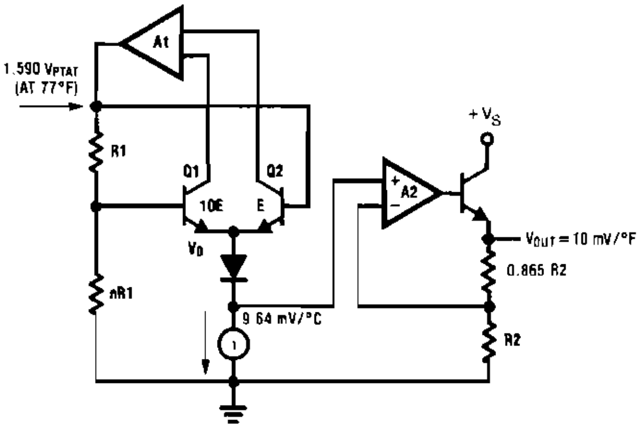
Typical Applications (Continued)

Temperature Controller



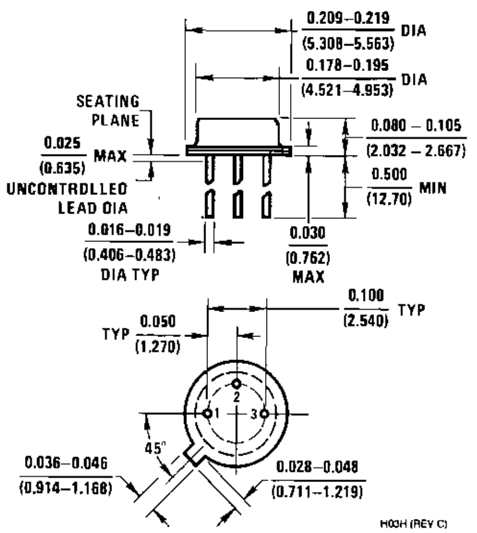
DS006685-18

Block Diagram

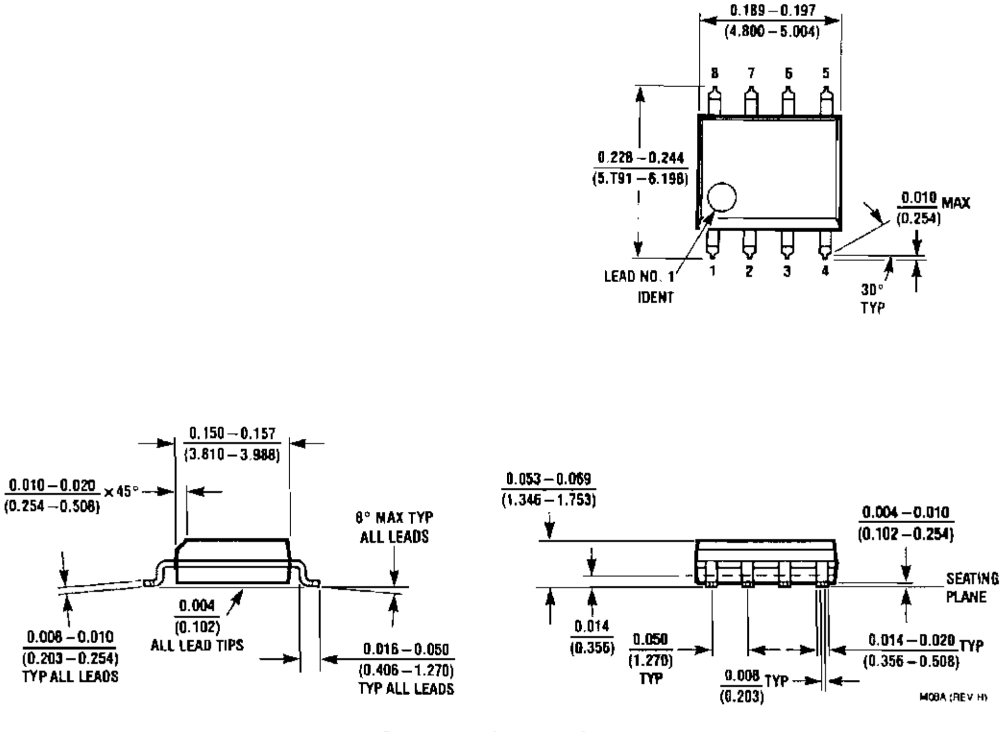


DS006685-19

Physical Dimensions inches (millimeters) unless otherwise noted

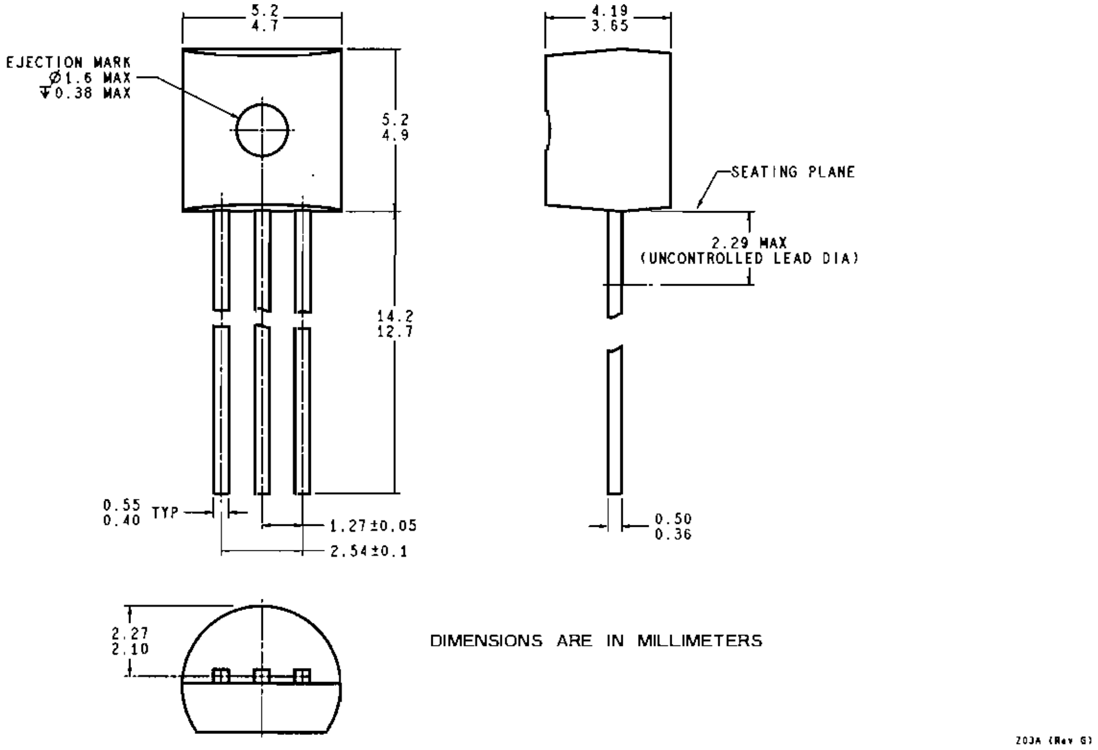


Order Number LM34H, LM34AH, LM34CH, LM34CAH or LM34DH
NS Package H03H



Order Number LM34DM
NS Package Number M08A

Physical Dimensions inches (millimeters) unless otherwise noted (Continued)



Order Number LM34CZ, LM34CAZ or LM34DZ
NS Package Z03A

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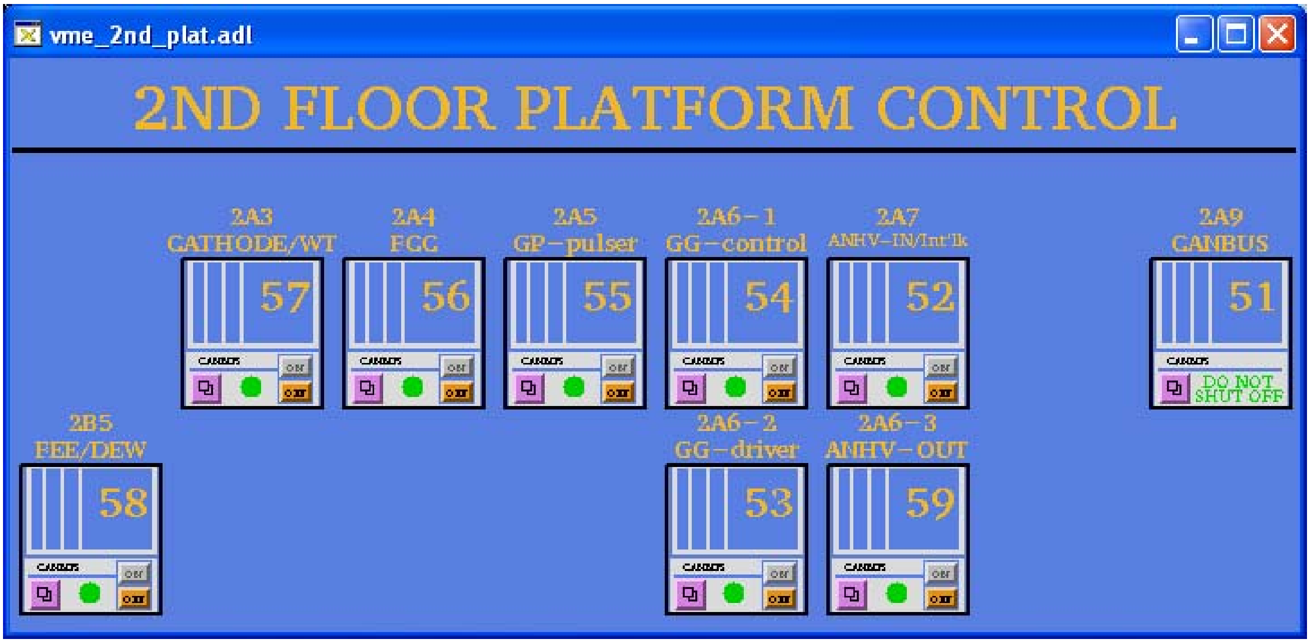
VME Crates

VME CRATES AND PROCESSORS

The TPC uses 9 VME crates for read out and control. These crates are located in rack rows 2A and 2B. Typically, each crate has one VME processor (either Motorola MVME 162 or 167). The crates themselves are controlled via a serial CANBUS chain that daisy chains from crate to crate. The CANBUS chain itself is controlled by yet another VME crate and processor located in Rack 2A9.

VME CRATES

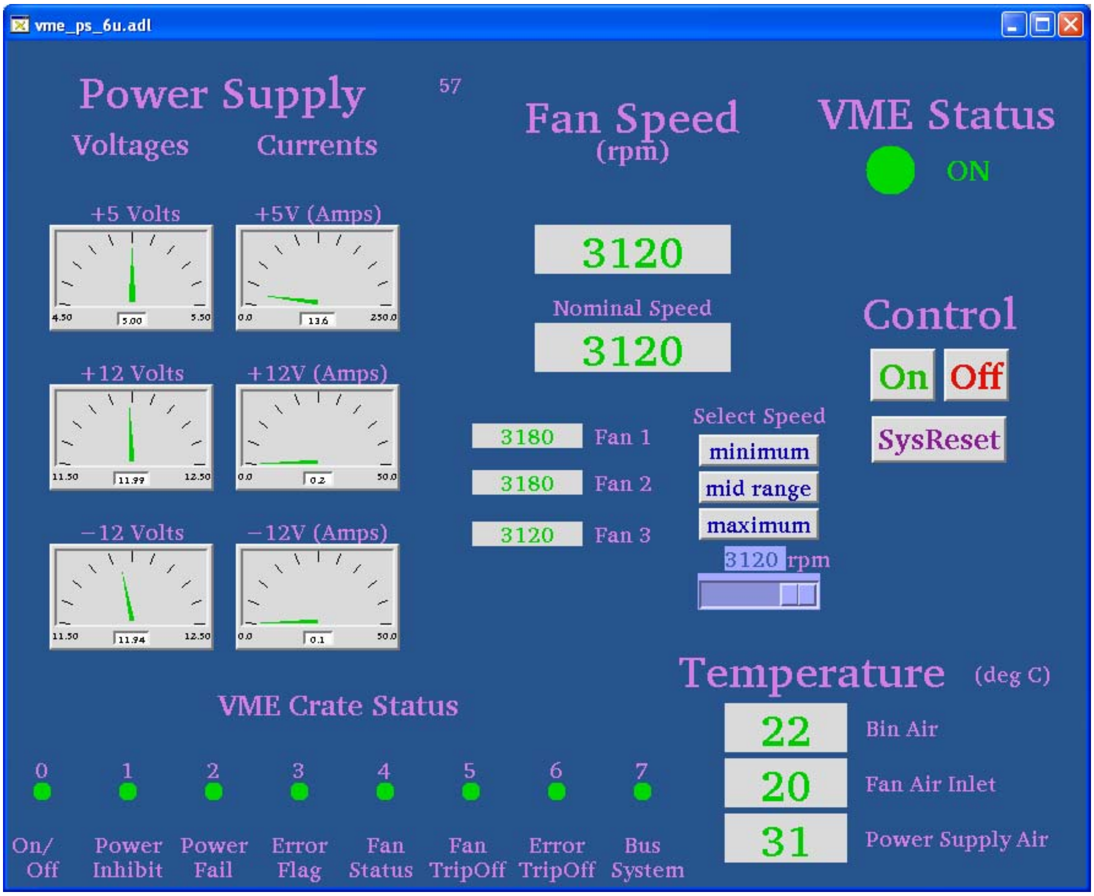
To access the crates via CANBUS, click on the “2nd Floor VME” button on the top level TPC GUI. This brings up the display:



This shows the CANBUS control crate (#51) and the 8 TPC crates that are on CANBUS. One additional crate is located in Rack 2A7, but it is not on CANBUS. That crate was put in to remove a second processor from the inner anode crate which was causing spontaneous reboots of the inner anode processor.(To power cycle this non-CANBUS crate, see the writeup for the remote AC power switches.) Note also that this CANBUS chain continues down to the first floor of the platform and connects to the trigger crates. The CANBUS cable connects to DB9 connectors (in & out) on the fan tray of each crate. Note that a break in the chain causes a loss of control for ALL crates, so if a crate is removed one needs to jumper the cable (connect in to out).

For problems with CANBUS contact a slow controls expert – the CANBUS processor can be rebooted, but usually with an expert present.

To get the parameters for each crate, click and hold on the pink controls button at the lower left of each crate in the GUI. Select “VME-#, where # is the crate address. For a typical crate the GUI looks like:



+5 Volts: 5.00
+5V (Amps): 13.6
+12 Volts: 11.99
+12V (Amps): 0.2
−12 Volts: 11.94
−12V (Amps): 0.1

Fan Speed (rpm): 3120
Nominal Speed: 3120

3180	Fan 1
3180	Fan 2
3120	Fan 3

3120 rpm

22	Bin Air
20	Fan Air Inlet
31	Power Supply Air

This shows the voltages and currents for the crate, the fan speed, the temperatures and some status bits. (Note that most of the these readings for the crates are accurate but there are a few cases where a readout is obviously incorrect.) We always run the fans at the max (typically 3120 rpm). Clicking on the “Sysreset” button on this GUI sends a signal to the backplane telling the processor to reboot. (See below for other reboot methods). You can also turn the crate on/off by using the GUI buttons. These emulate momentary contact buttons, so multiple clicks may be needed to turn on/off. I rarely needed to power cycle a crate – it was sometimes necessary if an interface card in the crate got into a funny state that was not cleared by a reboot.

Each crate consists of a card cage, a fan tray, which also contains the on/off switch, CANBUS input/output and some control switches, and a power supply. Both the power supply and fan tray can be swapped in place for most of these crates – see Dan Padrazo for spares and help.

Note: when swapping a fan tray, it is necessary to set the CANBUS address and communication speed BEFORE plugging in the CANBUS cables. The address and comm speed can be set with the front panel control switches. The comm speed used for this chain is 250 kbaud.

The address and comm speed can be set by using the “mode select” and “addr” toggle switches on the fan tray. You can also see the various voltages, fan speed etc.

VME PROCESSORS

Typically the VME processor for each crate is either a Motorola MVME 162 or 167 and sits in the left most slot. Crate 58 is the only remaining crate with 2 processors installed – one controls the HDLC readout for the RDOs and it may be removed for DAQ1000 – consult the slow controls group. To communicate to the outside world a so-called transition module is mounted in the back of each crate. A cable connects the module to the backplane at the same position in the crate as the processor. The transition module usually has two cable attached – an ethernet cable and a serial RS232 cable. Some modules have an additional RS232 cable that is used to readout some interface box (i.e. TPC temperature).

The ethernet cables go to an ethernet switch located in the bottom of Rack 2A8. The processor needs to attach to the ethernet to boot (they used to boot from SC3, but are being moved over to SC5 (LINUX)) One can also log in to the processor using ethernet, although this is not the preferred method for amateurs.

The RS232 cables also go to Rack 2A8 to a specific port on a terminal server. The standard way to reboot is to log in to the processor via the RS232 line – one can then watch the boot dialog and check for problems.

Specifically, to reboot a processor:

Log in to sc5.starp.bnl.gov

Telnet to the desired processor:

```
>telnet scserv XXXX, where XXXX is the port number (see below)
```

Hit enter once to get a prompt from the processor.

Then type: `reboot` (enter)

The processor should initiate a reboot. The GUI that the processor controls should turn white until the reboot is complete.

After the boot, release the scserv port by doing the following:

Type: ctrl and] simultaneously.

At the telnet prompt type: `quit`

This gets you back to sc5. Only one session can be attached to each port, so be sure to release these ports when the boot is finished.

The slow controls group maintains a list of all the processors in STAR, along with their ethernet address, serial port number, the process that they are running, etc. The list for run 8 is shown below – the list should be updated before each run.

Description Port# Crate Location Processor IP address

1. CANbus (STAR) 1st 2nd Floor 9003 51 2A9 grant.starp 130.199.61.103
2. CANbus (BARREL) Barrel crates 9040 100 2C4-1 bemccan.starp 130.199.60.59
3. CANbus (EEMC) EEMC/QT/West PT 9020 99 2C4-1 vtpc1.starp 130.199.60.189
4. Field Cage 9001 56 2A4 vtpc4.starp 130.199.60.192
5. Gated Grid 9002 54 2A6 vtpc3.starp 130.199.60.191
6. TPC FEE 9004 58 2B5 vtpc2.starp 130.199.60.190
7. Cathode HV 9005 57 2A3 cath.starp 130.199.60.162
8. Inner Anode HV 9006 52 2A7 vtpc7.starp 130.199.61.78
9. BBC HV 9010 77 1A7-1 bdb.starp 130.199.61.218 ZDCsmd, and upVPD
10. Ground 9011 57 2A3 vsc2.starp 130.199.60.217
Plane Pulser
11. Interlock 9012 52 2A7 epics2.starp 130.199.60.149
TPC Temperature
12. Outer Anode HV 9013 59 2A6 vtpc5.starp 130.199.60.193
13. Platform Hygrometer
TPC Gas 9015 58 2B5 hdlc.starp 130.199.60.161
14. Trigger HV 9021 63 1A6 cdb.strarp 130.199.60.40
ZDChv programs
15. SSD 9026 79 1C6 sdvmesc.starp 130.199.60.120
16. SVT not used svtmonitor.starp 130.199.61.50
17. FTPC 9033 71 1B5-1 ftpc.starp 130.199.61.83
18. EMC TDC 9039 80 2C4-2 creighton5.starp 130.199.60.229
& Slow Controls
19. daq temp & humidity
& gain DAQ room DC2 burton.starp 130.199.61.104
20. CDEV DAQ room DC3-2 vsc1.starp 130.199.60.188
Scalars and Magnet
21. Autoramp anode DAQroom DC2-1 stargate.starp 130.199.61.48
& cathode & testbits
22. TOF_Gas program DAQroom DC3-3 taylor.starp 130.199.60.6
23. CANbus iowritest DAQroom DC3-1 tutor.starp 130.199.60.46
Program
(needs to be rebooted daily)
24. Daq Hygrometer DAQroom DC3-1 medm.starp 130.199.60.49
& GID (PC in daq room)

TPC Lecroy serial session for inner sectors Port 9037
TPC Lecroy serial session for outer sectors Port 9038
FTPC Lecroy serial session Port 9023
SVT?? Lecroy serial session Port 9034
SMD?? Lecroy serial session Port 9035

REMOTE POWER SUPPLIES---requires a telnet
rps1.starp.bnl.gov 130.199.60.26 2A4
rps2.starp.bnl.gov 130.199.60.205 2A3
rps3.starp.bnl.gov 130.199.60.206 2A6
bemcpower.starp.bnl.gov 130.199.60.54 2C4

TROUBLESHOOTING and PAST PROBLEMS

We have had a few problems over the years with both the crates and the processors.

1. For run 8 we had a crate (outer anodes) which kept tripping off with an excess voltage error on the 12 volts. After many attempts, the problem was eventually traced to a slow water leak from a heat exchanger that dripped into the power supply. The crate power supply was then replaced, as well as the heat exchanger.

2. For run 7 the inner anode processor kept disconnecting from the ethernet. This was finally traced to a loose connector at the transition module.

3. Rumors have circulated for years that a lot of our spontaneous reboots of VME processors were caused by security scans initiated by ITD. For Run 8 a new policy was negotiated whereby ITD scanned at the beginning of the run and then left us alone. Things were much more stable. If you suspect ITD activity, contact Wayne and Jerome.

4. The VME processors are getting old and we have had to replace a few. Contact slow controls if you suspect a sick processor.

SPARES

Spare crates, fan trays and power supplies are kept by Danny Padrazo. There are various flavors of our 6U crates so it is always advisable to go through Dan.

The gated grid driver crate is a 9U non-standard crate. A spare crate is currently stored on the 2nd floor platform in rack row C. The FTPC also has a similar crate.

Spare transition modules are kept in the slow controls cabinet.

We have slowly rebuilt our supply of spare processors – two refurbished ones were bought this year, and we have found someone to repair an additional 3. Slow controls and Dan know the status of this ongoing work. The replacement of a processor always requires a slow controls expert since they have to set up the proper boot parameters in the replacement processor.

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CD Disks

STAR TPC Operating Procedures - back cover