# VDC Manual

*Version 2.1*

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# Preface

The contents of this document are intended to serve as setup and operations documentation for MIT/Jefferson Laboratory Hall A VDCs.

The following individuals have made valuable contributions to this work.

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# Jefferson Laboratory Operations Manual Document

## 1.1 Overview

The High Resolution Spectrometer Vertical Drift Chambers provide a precise ($\pm 125\mu$m) measurement of the position and angle of incidence of both recoil electrons (in the HRSe) and knockout protons (in the HRSh) at the respective spectrometer focal planes. This information may be combined with the knowledge of the spectrometer optics to determine the position and angle of the particles in the target.

Each Hall A spectrometer boasts its own VDC detector package. These packages are located on permanent rails mounted on the spectrometer decks in the shielding huts above the outrun windows but beneath the space frames. The packages consist of two VDCs, and are identical in all aspects. The VDCs have been constructed without guard wires. Each VDC is composed of two wire planes in a standard UV configuration - the wires of each plane are oriented at 90° to one another, and each plane is oriented at 45° with respect to the nominal particle trajectories (see Figure 1.1).

Operation of the VDCs requires the application of both High Voltage (HV) across the chambers themselves and Low Voltage (LV) across the amp/disc cards, which are mounted on the sides of the VDCs, within the confines of the protective aluminum Faraday cage.

The chamber gas is a flammable combination of argon (Ar) and ethane ($C_2H_6$) which is bubbled through alcohol. Gas is routed from bottles located in the Hall A gas supply shed to gas supply control panels located on the main level of the space frames in the detector huts.

As charged particles pass through the chamber gas in the VDCs, they pro-

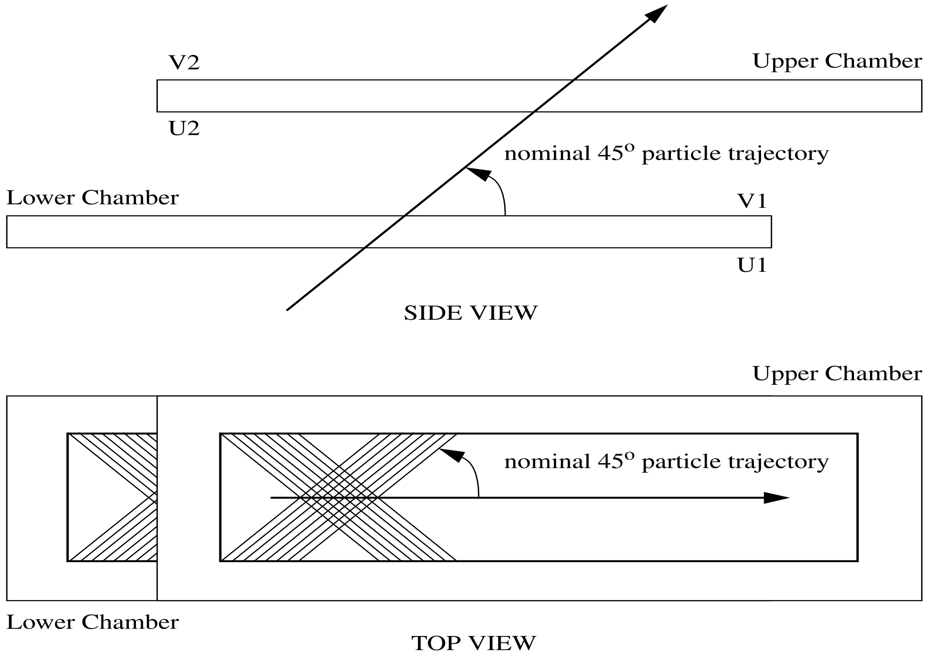



Figure 1.1: Relative VDC geometry.

duce ionization. This ionization drifts along the electric field lines defined by the high voltage planes and the signal wires. Ionization is collected in the form of analog pulses on the signal wires. The pulses are then amplified, discriminated and used to start multihit TDCs, which are subsequently stopped by the overall event trigger. The TDCs are read out by the *CODA* aquisition software. The data are histogramed online by the *DHIST* software. In-depth offline data analysis requires the *ESPACE* software.

## 1.2 Operating Procedure

**Gas Flow Operating Procedures** Chamber gas is delivered to a given VDC detector package via HAWGS, the Hall A Wire-chamber Gas System. Complete details of this system are presented elsewhere in this manual.

Each VDC detector package consists of two VDCs connected in parallel (see Figure 1.2). All gas connections are made using POLYFLO$^{TM}$ tubing and Jefferson Lab specified connectors. Gas enters the chamber assembly through a bubbler containing (edible) mineral oil. Each chamber has a volume of approximately 30 $\ell$ and is operated slightly above atmospheric pressure. Standard flow rate set points are clearly labeled next to the control panel flow meters. The gas flow through the chambers may be independently varied and is typically set to 7 $\ell$/hr. Gas is exhausted from the VDC package through a second bubbler also containing mineral oil. A typical chamber leakage rate measured against this load is $\leq 3\ \ell/\mathrm{hr}$. The flow rate of $7\ \ell/\mathrm{hr}$ when combined with the leak rate of $\leq 3\ \ell/\mathrm{hr}$ results in a complete exchange of gas in the chambers roughly every 10 hours. When a bottle is nearly empty (say 90%), it should be changed since the quality of the gas at the bottom tends to be low. Gas bottles may only be changed by authorized personnel.

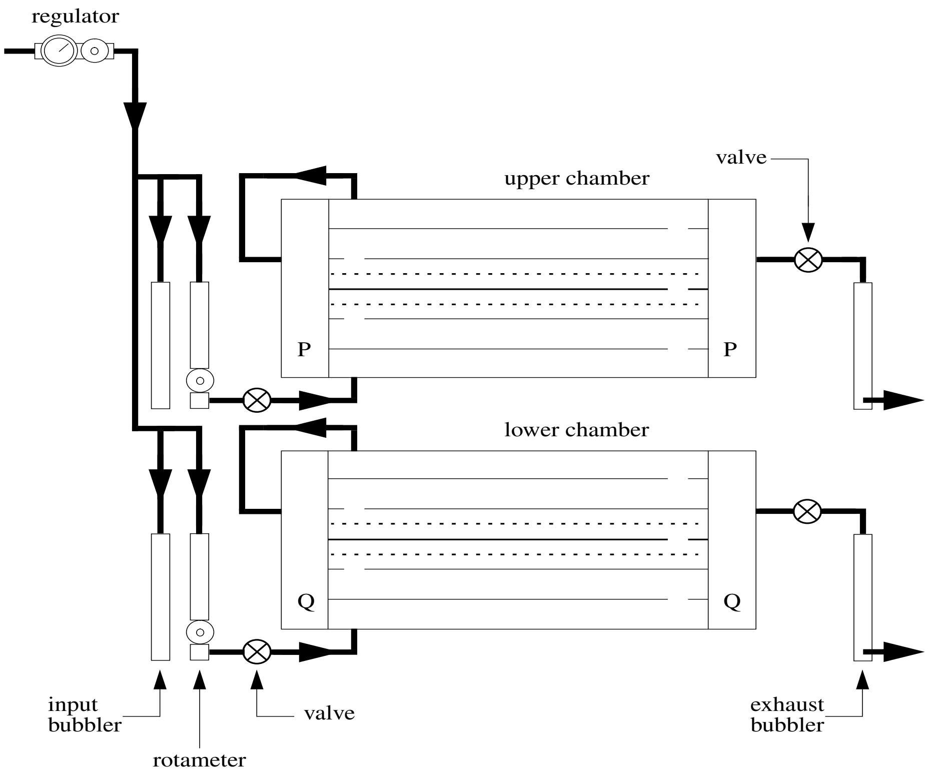



Figure 1.2: Gas flow schematic.

The status of the gas handling system should be monitored carefully as well as logged every shift. Any substantial deviation from the median parameters can result in a change in the operational parameters of the VDCs and should be immediately investigated. If at all possible, gas flow should be continuously maintained, even in no-beam time periods. This avoids time loss to reconditioning and maintains the desirable steady-state operating condition. Further, it is critical that gas flow has been maintained for 24 hours prior to any power up.

**Power Supplies and Electronics Procedures** The power supplies and readout electronics associated with the HRS VDCs are all commercially designed. The reader is directed towards the manuals made available by the manufacturer for the detailed information not provided here.

The Bertan 377N HV power supply provides -4.00 kV nominal to each of three HV planes in a given VDC detector package via a 10 MΩ Hammond splitter box (see Figure 1.3). The power supply is located in the detector hut in a NIM bin on the upper level of the space frame. This unit may be controlled either manually or remotely via the *EPICS* control software, and also provides a monitor of the current drawn (nominally 70 nA) by the VDCs to which it is attached. Connections from the power supply to the Hammond splitter box, as well as from the Hammond splitter box to the VDCs are made using standard SHV connectors mounted on red RG-59/U HV cable good to 5 kV.

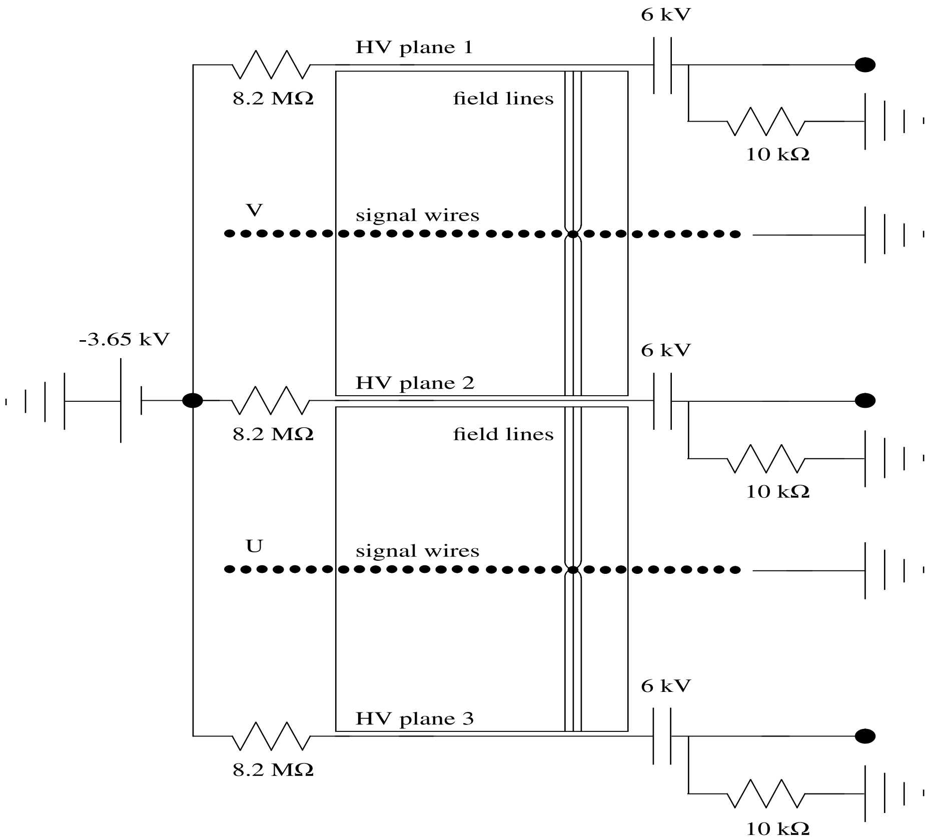



Figure 1.3: Overview.

The Kepco ATE 15-3m discriminator power supply provides +2.5 V (46 cards draw ≤ 2 A) and the Kepco ATE 6-100m pre-amp power supply provides ±5 V nominal to the 26 LeCroy 2735DC pre-amp/discriminator cards used to instrument each chamber via a heavy-duty fuse panel. The precise voltages provided are +5.0 V (46 cards draw 22 A) and -5.2 V (46 cards draw 58 A). These LV supplies are located in the detector hut on the main level of the space frame for the $HRS_e$ and on the upper level of the space frame for the $HRS_h$. Complete connection schematics and instructions for making or breaking the connections are located on the aluminum Faraday cage protective plates covering the respective interface nodes between the power supplies and the VDCs.

Each VDC wire plane consists of 400 20 $\mu$m $\phi$, Au-plated tungsten wires. The first 16 wires on each end of the wire plane are connected to ground for field-shaping purposes. There are 368 wires per wire plane which act as signal wires. Thus, each spectrometer is instrumented with 1472 channels of LeCroy 1877 multihit FASTBUS TDCs. These TDCs are located in a Bira 8000 FASTBUS crate located on the main level of the spectrometer space frame in the detector hut. The connections between the pre-amp/discriminator cards mounted on the VDCs and the TDCs are made with 16-conductor twisted-pair cables. Clip-on ferrites are used to filter noise. A connection schematic is posted on the side of the rack holding the FASTBUS crate on the space frame in the detector hut.

**Power-up Procedure**

1. ensure gas flow has been established in the chambers as previously outlined. If it has not, *STOP RIGHT HERE!* Gas flow must be well-established and steady-state *BEFORE* the HV may be enabled.

2. Ensure that all power supplies as well as the FASTBUS crate are off and then connect the LV, HV, and TDC cables.

3. enable the LV. Set points are clearly labeled on the face of the power supplies. Note that they have overcurrent setpoints, and some fine adjustments over the first 30 minutes after a cold start power-up may be required. Appropriate LEDs should all be active on both the power supplies and the pre-amp/discriminator cards.

4. slowly (steps of no more than -300 V) ramp the HV to its nominal set point of -4.00 kV using either the manual or the remote controls. While the trip current is set to 10 $\mu$A, do not allow the chambers to draw more than 1 $\mu$A during the ramping procedure or serious damage may result. If the power supply trips during the ramping procedure, you are moving too fast. Rezero things and begin the procedure again. *NEVER USE THE AUTO-RESET FUNCTION.* If the power supply trips again, *STOP IMMEDIATELY AND INVESTIGATE.*

5. enable the FASTBUS crate. Appropriate LEDs should all be active.

6. check for poor signal connections evidenced by hot wires (wires counting extremely fast) or dead wires (wires with no counts) using the histogramming software and cosmic rays. Remake any connections as necessary by first powering down the FASTBUS crate.

If at all possible, the HV and LV power supplies should be left on continuously if and only if gas is available to the chamber. This avoids time loss to reconditioning and maintains the desirable steady-state operating condition.

## 1.3 Handling Considerations

The VDCs are very delicate devices which are absolutely essential to the instrumentation of the Hall A spectrometers. Thus, extreme care must be exercized whenever they are moved or used.

- Before moving a VDC detector package, ensure that the protective plates are in position. Plates include tapped aluminum sheets to be bolted over the entrance and exit aperatures, as well as aluminum sheets which slide in between the two chambers.
- Disconnect and reconnect all TDC cables with extreme care. The conductor pins are relatively fragile, and should one be broken off, repair will be *extremely* difficult.
- When initiating gas flow, pay strict attention to the feedback parameters. Overpressure may damage the chambers.
- Never attempt to apply HV to the chambers until gas flow conditions have reached steady-state.
- As the amount of heat generated by the pre-amp/discriminator cards it substantial, always make sure adequate cooling is provided before attempting to run. Currently this cooling takes the form of 4 temporary fans which clamp to the aluminum Faraday cage. Eventually permanent fans will be installed.
- When ramping the HV, never allow the chambers to draw more than 1 $\mu$A instantaneously. If they do, something is wrong!

## 1.4 Safety Assessment

The following potential hazards have been clearly identified.

**The High Voltage System** The Bertan 377N HV low current power supply provides a nominal -4.00 kV. Red HV RG-59/U cable good to 5 kV with standard SHV connectors is used to connect the power supply to a Hammond splitter box, and then to connect the splitter box to each of the three high voltage planes in a given VDC. A given chamber draws a current from 50-100 nA.

**The Low Voltage System** Kepco LV power supplies are used for the the LeCroy 2735DC pre-amp/discriminator cards. Each card (23 per chamber) requires +5.0 V (46 cards draw 22 A), -5.2 V (46 cards draw 58 A) and +2.5 V (46 cards draw $\leq$ 2 A).

**Explosive Gas** The Ar $C_2H_6$ chamber gas is explosive and must be handled accordingly. Further, gas flow should be maintained for at least 24 hours prior to the enabling of HV.

**High Pressure Gas Bottles** The gas used in the chambers is supplied in high pressure ($\geq$ 2000 psi) gas bottles. This confined high pressure gas represents a tremendous (potentially lethal) amount of stored energy.

## 1.5 Responsible Personnel

The following individuals are responsible for chamber problems.

Fissum, Kevin - x7325, pager 680-2036

Gao, Juncai - x7254, pager 680-0078

Liyange, Nilanga - x7254, pager 680-3342

Segal, Jack - x7242, pager 680-7242

Wojtsekhowski, Bogdan - x7191, pager 680-7191

# Chapter 2

# Some notes on construction

## 2.1 Stringing wires

*NOTE: Wire stringing must be performed in a clean-room environment. It is a technically demanding task, and can turn out to be a long and a tedious job. For the inexperienced, it can take up to several hours to string one wire correctly - as an indication, it took a group of one technician, two grad students and six undergraduate students 15 months to string the 4000 wires on the five VDCs! Be forewarned!*

1. gather the following list of required items in the clean-room workspace. Nominally, they can be found in the VDC cabinet, which is located on the Mezzanine of the EEL building.

**wire** A spool of 20 $\mu$m gold-plated tungsten wire.

**sleeves** 2 100 $\mu$m interior diameter stainless steel sleeves for each wire to be mounted.

**tubes** 1 long reusable hollow aluminum guide tube.

**crimper** The high-pressure air driven crimping tool system.

**box** The 25 cm X 25 cm flat cardboard box.

**Tekwipes** Several sheets of *lint-free* wipes.

**pulley** The stand-mounted pulley apparatus.

**tensioner** A 70 g tensioning weight/hanging clamp apparatus.

**workspace** The three-piece black rubber sheet set.

**tape** Scotch$^{TM}$ tape, preferably in a desk-top dispenser.

**scissors** A small pair of precision scissors.

**table** A small table of a comfortable working height.

**weight** A small weight such as a 1/2" stainless steel metal washer.

**washers** 2 small gold-plated washers for each wire to be mounted.

**springs** 2 tensioning springs for each wire to be mounted.

**block** The copper spring-tensioning block.

**guard** The washer crimping tool guard.

2. set up the workspace. To facilitate the procedure, it is important to keep the area clean and free from clutter.

   - clean the large piece of black rubber and put it on the table.
   - set up the stationary air-driven crimping tool on the side of the table, at an air pressure of 120 psi.
   - set up the pulley on the stand such that the top of the pulley is at the same level as the wire plane and on the horizontal plane, and the pulley is on the same straight line as the wire.
   - lay one small piece of black rubber on the chamber frame at what is to become the back end of the wire, and the other piece on the PC board at the opposite end of the wire.

3. prepare the wire. Keep in mind that even the smallest kink in this very expensive wire can ruin it.

   - unwrap about 20 cm of wire from the spool, making sure that it is free from any kinks. Lay this length of wire on the rubber.
   - insert the wire into the 100 $\mu$m sleeve. *This is tricky! Patience!* Pull about 10 cm of wire through the sleeve.
   - place the sleeve on the crimping tool table so that the wire goes through the hole on the crimp stand and the back end of the tube comes to the indicated line (see Figure 2.1).
   - hold the sleeve in position with your finger and attach the small weight (metal washer) at the end of the wire with a piece of tape so that the wire is held by the weight of the washer to the bottom wall of the sleeve.
   - crimp fast and hard at point A without releasing the sleeve. Move the end of the tube to point B and crimp again in the same manner.
   - cut the wire at the end of the tube. *If you can't figure out which end of the tube, you should not be doing this!*
   - carefully pick up the sleeve with the wire in one hand and the wire spool in the other. Gradually raise the spool and let the wire hang on the weight of the tube. With great care, turn the spool so that about 1.1 m of wire comes out very slowly. *Should the wire get stuck in the spool and kink, the work you have done has been wasted. Cut the wire and start again.*

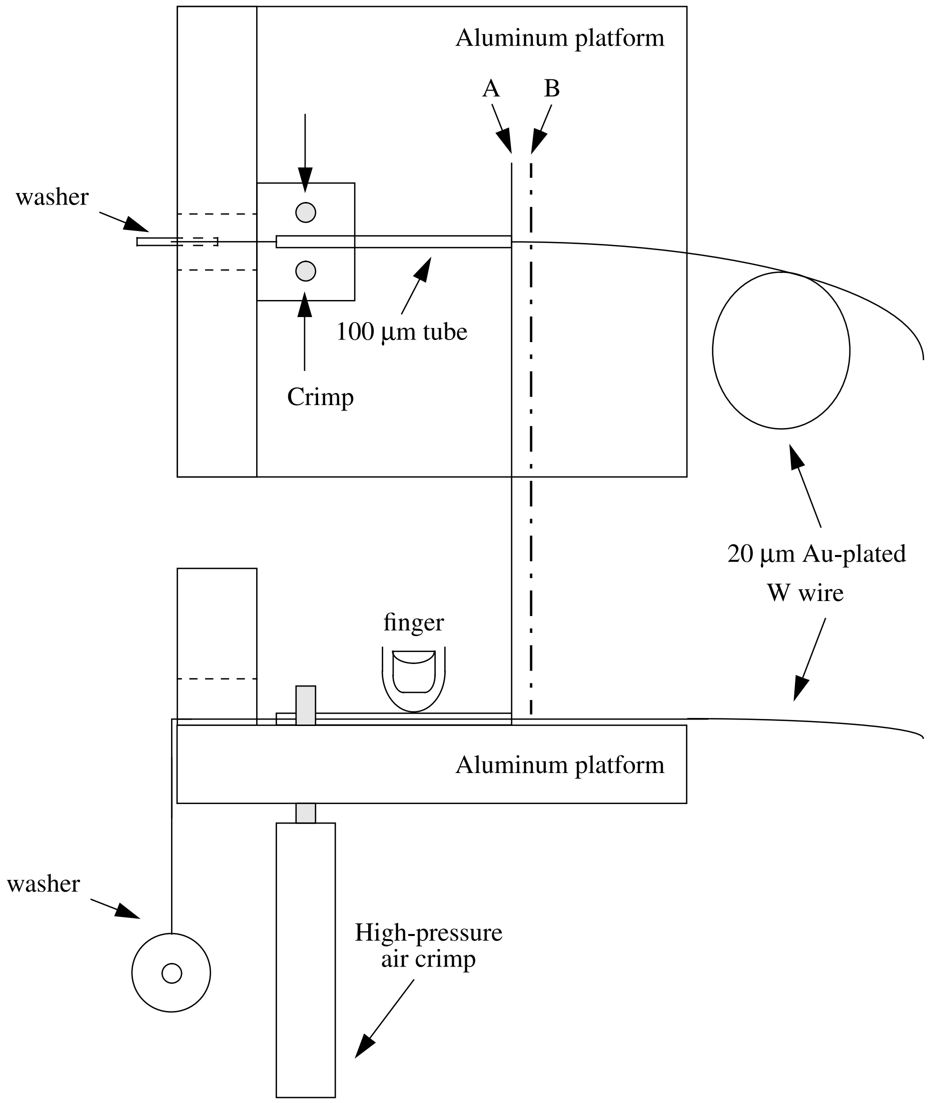



Figure 2.1: Attaching a tube.

- place the sleeve on the table and then carefully lay the wire on the table in a zig-zag pattern. Cut the wire leaving approximately a 5-cm length from the spool.
- thread about 2 cm of wire through the aluminum tube and bend the wire so that it does not slide back through the tube.
- place first a washer and then a spring on the aluminum tube. Hold the tube with the bent wire and raise the tube with the wire slowly, so that the washer and the spring slide along the wire towards the 100 $\mu$m tube. The washer should stop at the crimped point.
- hold the wire at the aluminum tube, and lay it on a Tekwipe on the box in a zig-zag pattern. Make sure that the wire lies completely on the wipe.

4. string the wire. Note that it is best to have two people, one at each side of the frame, to do this job. *Be extremely careful of existing wires!*

   - take the box to the back end of the wire space on the frame.
   - using the aluminum tube as a guide, slide the wire through the (non PC-board side) tube on the wire frame.
   - hold the aluminum tube with the wire in your hand, and carefully pull the wire through the frame slot.
   - when there is enough wire length through, guide the wire through the PC-board side frame tube.
   - while person A pulls the wire through the PC-board side frame tube, person B must ensure that the wire comes out of the box freely. When the 100 $\mu$m tube approaches the frame tube, person B must take it in hand and guide it in to the frame tube.
   - place the copper block at the end of the 100 $\mu$m tube so that the spring is compressed and its contracted length is 1/4". This end of the wire is now finished.
   - lay the end of the wire on the black rubber on the PC-board.
   - take the aluminum tube out and cut off the bent piece of the wire so that a nice end exists. Thread the wire through another 100 $\mu$m tube and put a washer on the tube. Move this tube on the wire, holding the end of the wire until the tube is in the frame tube.
   - run the wire over the pulley, and put a piece of tape at the end of the wire. Hang the 70 g weight on the clamp on the tape, and release the weight gently.
   - adjust the length of the 100 $\mu$m tube inside the frame tube so that the length outside the frame tube is 1.2 cm. Move the washer next to the frame tube, put the washer guard on the 100 $\mu$m tube next to the washer (see Figure 2.2).

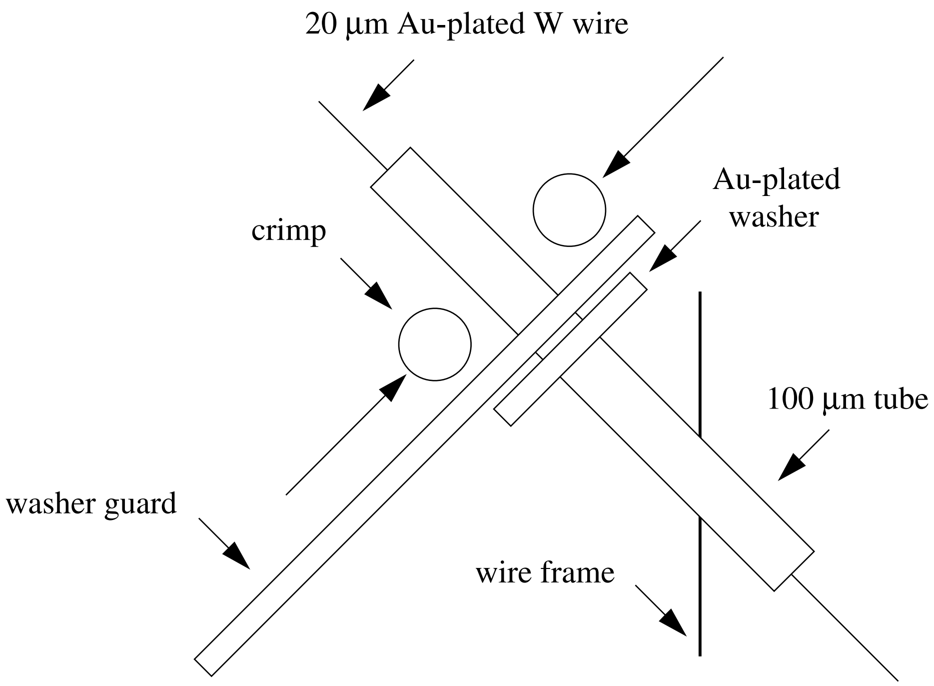



Figure 2.2: Attaching a wire to the frame.

- using the hand-held crimping tool, crimp once next to the washer guard, and a second time 0.5 cm from the washer guard.
- remove the copper block from the back tube, lift the weight, and note how much the spring goes back. The length of the spring should be no more than 3/8". Should it be longer than this, put the block back, let the weight hang and crimp again at a different position on the tube. If it still does not work,
  - reject this wire and start the procedure over again from scratch.
  - check the tightness of the crimping tool as well as the air pressure.
  *It is very important that the wire is rejected if it is still loose. A loose wire can conceivably slide through the tube at any time, with disasterous results should this occur when the chamber is in operation.*
- If the spring is the right length, cut the wire right next to the tube.

## 2.2 Testing wires

Before the VDCs are packaged in a cartridge, it is a good idea to test the wires. This procedure requires the $^{55}$Fe source which is located in the safe in the EEL building, and which must be signed out from Jack Segal (see 1.5). A $\gamma$-source is preferred over a $\beta$-source in this case because it provides uniform (well-defined decay lines) and localized ionization. Also, it is important to ensure that gas has flowed through the chambers for about 72 hours, and that voltage has been on for about 24 hours before proceeding.

1. place the $^{55}$Fe source on the plane to be tested in the region of wires corresponding to the connector in question. Adjust the position of the source to optimize the strength of the signal.

2. using the portable, quasi-linear FENKER amplifier card and a LEMO/ECL cable, check the amplitude of all the signals coming off the chamber wires. This is done one connector at a time. Note that the connector on the FENKER card has only 17 pins, while the connector on the VDC has 18 pins. Thus, there is only one ground pin on the aforementioned.

*The mean signal amplitude should be -135$\pm$5 mV. Make a note in the logbook of the location of any wires whose signals differ dramatically from this value. Also check for shorted wires in the vicinity.*

## 2.3 Copper shielding

Before the VDCs are packaged for mounting, they are encased in a Faraday cage made of thin copper. The general procedure is to mark and cut the copper foil to fit, bend it to shape, drill and tap holes for the ground strap, tape and solder the foil into place, and finally mount the ground straps.

1. gather the following list of required items in the workspace. Nominally, they can be found in the VDC assembly room of the EEL building.

**foil** large rolls of copper foil.

**cutter** a standard paper cutter.

**scissors** a sharp pair of heavy-duty scissors.

**square** a right angle or machining square.

**scribe** a scribing tool.

**tape** Scotch$^{TM}$ tape and copper tape.

**bar** a metal bar.

**knife** an Exacto$^{TM}$ knife.

**sockets** a deep-well socket set.

**bolts** 2 1/4" - 20 bolts.

**straps** 3 chamber length strips of copper and kapton.

**taps** 6-32 tapping set.

**punch** a center punch.

**drill** a power drill.

**soldering iron** a soldering iron.

**solder** 60/40 solder.

2. mark and cut the copper foil to fit as necessary.

   - carry the copper foil to a flat surface. When moving the roll of foil, keep it horizontal and carry it by the core to prevent it from unraveling. This prevents any wrinkling or damaging of the copper.
   - carefully place the foil roll on the flat surface and mark and cut eight 43" pieces and eight 17" pieces of foil to length as follows:
     - unroll and mark the section using the square and scribe.
     - place the blade of the paper cutter along the mark. The blade should bite into the material just enough to hold it in place.
     - ensure the mark runs along the cutting edge, hold the copper in place, and cut along the scribe mark.
     - place the cut section aside carefully, and repeat as required.
   - these pieces must be now be cut to width using the same procedure. There will be:
     - 4 deep corners (17" X 9 12/32" - 9 15/32")
     - 4 shallow corners (17" X 7 12/32" - 7 15/32")
     - 4 deep sides (43" X 9 12/32" - 9 15/32")
     - 4 shallow sides (43" X 7 12/32" - 7 15/32)

     *Note: The above widths vary by as much as 3/32". If there is going to be a "sawtooth" under a given piece, then use the shorter dimension - otherwise, use the longer dimension. A "sawtooth" is a sawtooth-shaped piece of Phenolic$^{TM}$ with one side clad in copper. It serves to protect the traces leading from the VDC to the circuit card plugs mounted on the outer edge of the VDC.*
   - cut a notch in each of the eight corner pieces as shown in Fig. 2.3.

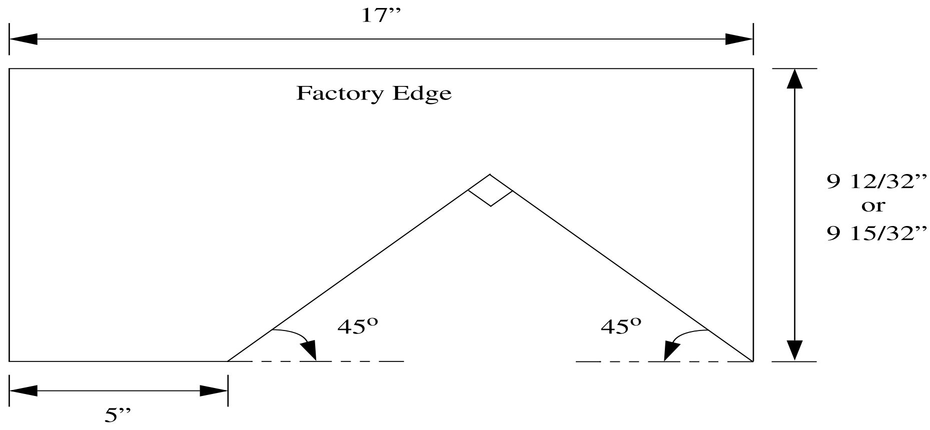



Figure 2.3: A corner sheet.

*Note: All cuts across the copper should be square if possible. Further, it is best to make all cuts with a single stroke; thus, the paper cutter. The long cut made in this manner is free from the burrs and nicks caused by starting and stopping cuts with scissors, tin snips or other instruments.*

3. fashion and attach the corner pieces.

   - place two corner pieces at each end of one side of the VDC, and use Scotch$^{TM}$ tape to hold the corner together and against the chamber for measurements.
   - measure from the inside edge of the copper corner to the midpoint of the VDC. Buttress the 43" side against the corner piece, mark it, and trim it to fit this measurement.
   - cut 1" diameter holes to allow for the threaded rods on each side.
   - mark and trim the foil for the alignment pins and pinholes.
   - tape this section to the VDC.
   - measure from the other corner piece to the edge of the last piece placed, and place this piece on the chamber, cutting the threaded rod holes and trimming for the alignment pins and pinholes.
     *Note: The copper should lie flat without overlapping and without excessive (less than 1/32") gaps between the pieces. The vertical portions (center sections of folded pieces) should not extend beyond the lip of the VDC. If this should occur then the shielding will wrinkle and buckle upon installation. This not only shows poor workmanship, but could also introduce unwanted stresses in the both the nylon retaining screws which secure the ground straps to the sides of the VDC, as well as the planar sections which hold the circuit cards and extend from the VDC. If these planar sections break, the VDC must be dismantled and repaired.*
   - repeat the above steps until all corner pieces are in place.

4. fashion and attach the side pieces. It is assumed that all the pieces start off with a 1/2" fold from the factory edge.

   - place the copper onto the table, and prepare to clamp it using the bolts and the metal bar. From the edge of the table, the copper should overhang the width of the fold to be made.
   - clamp. Using a deep well socket, start in the middle of the work and press down to form a right angle with the edge. It requires about three passes to avoid any buckling, crinkling, and wrinkling.
   - unclamp and remove the work and turn it over. Long pieces will be hard to handle and care should be taken to avoid their tendency to bend.

- measure the depth of the side and subtract 6 1/2". The fold should be made as deep as the excess. Repeat the above procedure for folding. *Note: Be careful to adjust the folds on the corner pieces to allow for the specific positioning of the corner on the VDC. If you fold it first and then mark the holes, the sides should all be the same. All folds on the corner sections should be made toward you, so that the 5" sections are toward the outside. If you've cut the holes first, then the sides will all be different and appropriate adjustments must be made in the folding to reflect these differences.*

5. mark and tap all holes for the ground straps on both sides of the VDC.
   - place the ground strap on top of the copper so that the holes are approximately in the middle of the center layer of the VDC.
   - place the center punch over the ground strap hole and mark the holes onto the copper foil beneath it. Repeat until all holes are marked. Repeat this process for the other side.
   - drill perpendicularly into the marks no deeper than 1/2", or just deep enough for the nylon screws to be used. Drilling too deep will invade the gas volume.
   - tap the newly drilled holes with a 6-32 tap. For each hole, first use the taper tap, then the plug tap, and finally the bottom tap. If the taps seem to be getting dull, they probably are - experience has shown the VDC material dulls taps rapidly. Continued use of a dull tap will result in it breaking off in the VDC, so it must be immediately replaced. If the tap breaks off in the VDC, do not try to remove it.

## 2.4 Making gas lines

*It is often necessary to make a new gas line. This section explains how.*

1. obtain and cut off the required length of POLYFLO$^{TM}$ gas line. Make sure you only use this type of material as other types outgas in a manner that is harmful to the longevity of the chambers. Cap the ends (including that on the spool) with a piece of tape.

2. obtain the necessary fixtures (see Fig. 2.4). One of each illustrated is required per end.

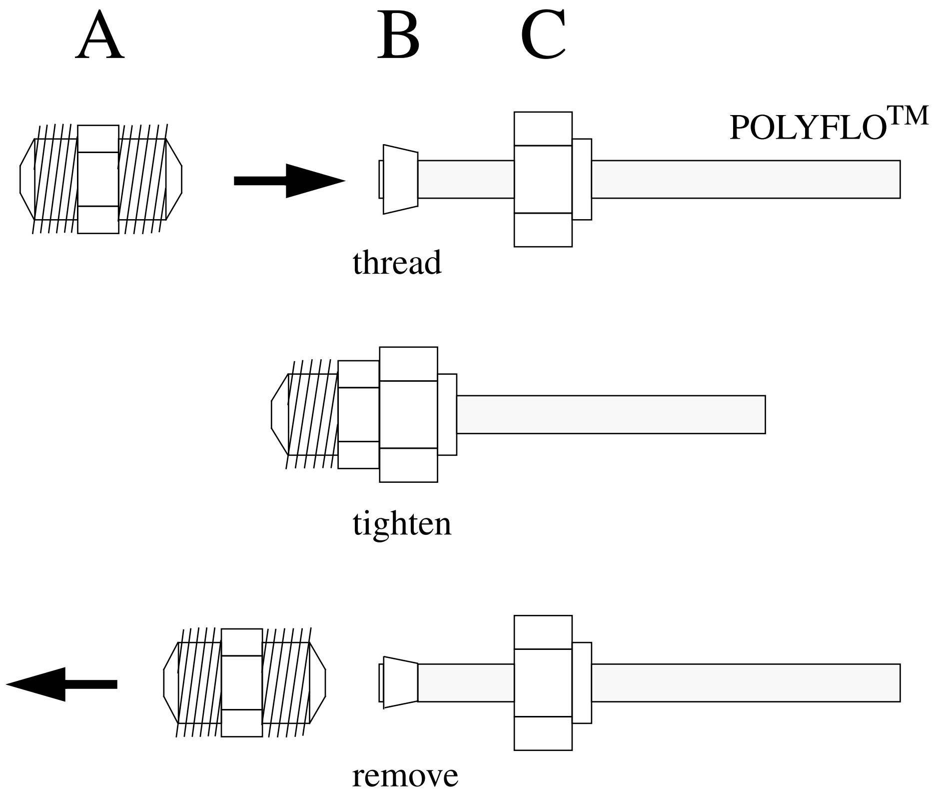


Figure 2.4: Making a gasline.

3. attach the connector to the line.
    - place the threaded connector C on the line with the indicated orientation.
    - place the crimpable endpiece B on the line with the indicated orientation.
    - thread the coupling connector A into the threaded connector C and finger-tighten.
    - use to wrenches to tighten A and C together as tight as possible, in the process crimping B onto the end of the line.
    - disconnect A from C.
4. repeat for the other end of the line.
5. flush gas through the newly-made line for about 30 seconds before connecting it to existing apparatus.

## 2.5 Assembling a VDC truck

Once the chambers are performing satisfactorily, it is necessary to bolt them to a pair of endplates which attach to the sliders that mount on the Thompson rails. Note that the endplates are rather heavy, and that the procedure requires both a forklift and someone skilled in its use.

1. prepare the area.
    - take the doors leading to the detector assembly room off their hinges. This allows both the forklift and the mobile frame better access.
    - ensure that the VDCs are completely disconnected. Gas flow must be turned off, gas lines must be capped, high voltage must be off, and all cables must be out of the way. Further, all protective aluminum plates must be put in position: above, in between, and below the chambers.
    - ensure that the working area is clear. A substantial amount of space is required because the chamber assembly, the mobile Thompson rail and the forklift must all coexist in very close proximity.
    - locate lifting straps and a heavy-duty spreading bar. Note that you will be adding substantial weight to the load midway through the lift, so that the lifting jig must be capable of handling the ultimate weight. This bar must be longer than the long dimension of the chamber rig. Move the forklift into the area such that the tines are perpendicular to the long dimension of the chambers.
2. set up the lifting jig and lift the chambers off the temporary support structure, in this case a pair of tool storage cabinets (see Fig. 2.5).

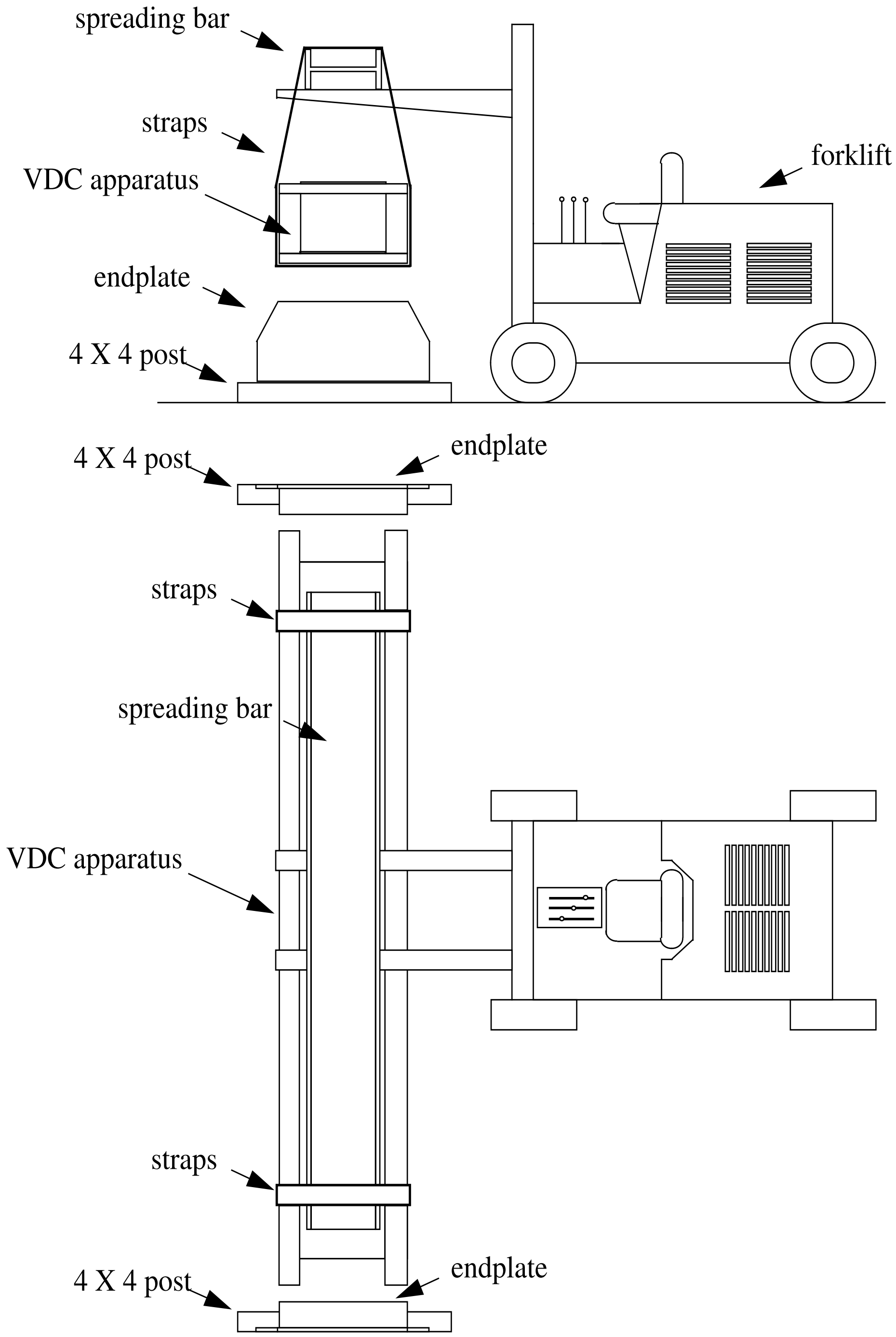



Figure 2.5: Assembling a VDC truck.

- place the spreading bar on the tines of the forklift, parallel to the long dimension of the chamber.
- raise the spreading bar above the chamber apparatus, and roll the forklift forward to position the spreading bar directly above the symmetry axis of the chamber.
- loop the lifting straps under the aluminum support frame of the chamber apparatus and over the ends of the spreading bar. If necessary, protect the straps from sharp edges with cardboard. Make sure nothing will be damaged when the lift occurs and the straps come under tension. Also ensure that the straps cannot slide off the end of the spreading bar.
- lift the chamber assembly and remove the temporary support structure.
- lower the chamber assembly. *Make sure that none of the studbolts which hold it together come into contact with the floor.*

3. attach the endplates.
    - place the endplates on 4 X 4 posts.
    - align the chamber assembly with the endplates.
    - bolt the endplates onto the chamber assembly. Because the aluminum frames have all been twisted in the welding process, bolts slightly smaller than the dimensions of the holes are necessary. There are 8 bolts in all, 4 per end.
4. place the truck on the mobile frame.
    - slip the 4 sliders onto the Thompson rails of the mobile frame.
    - bolt the endcaps onto the Thompson rails so that the sliders cannot accidently slip off.
    - using the forklift, raise the truck and position the mobile frame underneath it.
    - slowly lower the truck and position the mobile frame and the sliders so that the bolt holes in the feet of the endplates line up with those of the sliders.
    - bolt the endplates to the sliders. There are 16 bolts in all, 4 per slider.
5. detach and remove the lifting jig and the forklift.
    - lower the forklift until the lifting straps are slack.
    - remove the lifting straps from the spreading bar.
    - remove the spreading bar from the tines of the forklift.
    - remove the forklift and spreading bar from the room as appropriate.

6. reconnect.

    - tighten all the bolts now that the entire weight of the assembly is self-supporting.
    - reconnect the gas lines and the flow gas for about 24 hours before engaging the high voltage. Signals may not be meaningful for about 72 hours.
    - put the door back on its hinges. It may have to be removed again when the VDC truck is transferred to the Hall.

# Chapter 3

# Maintenance and repair

## 3.1 Fixing solders

*Every so often (hopefully not very often) a solder joining a wire to one of the preamp cards will let go, and have to be redone. The following text details how this should be done.*

1. open up the workspace.
    - remove the protective aluminum Faraday cage plates along the side in question as necessary to gain access to the workspace.
    - disconnect and cap any gas lines as necessary.
    - remove the protective aluminum plates covering the top chamber aperature.
2. disconnect the top aluminum Faraday cage plate. The nuts which must be turned to do this should only be finger tight. *Do not use a wrench on any that are stuck.* This is because the studbolts run through the entire assembly, and turning a stuck nut directly could loosen the assembly.
    - thread two nuts onto the studbolt and tighten them against one another.
    - hold this assembly in place with a wrench and gently turn the stuck nut with another wrench until it rotates freely.
    - remove the pair of nuts which were used to hold the studbolt in position.
    - turn off the previously-stuck nut.
    - remove and store the top aluminum Faraday cage plate. The foil aperature cover is very fragile.
    - replace the protective aluminum plates covering the top chamber aperature.

3. it may be necessary to remove pre-amp cards to gain access to the problem lines. If cards are removed, *bag them.*

4. using a DVM and pin-probes, locate the problem line(s). Note that the first pin in the connector from either side is grounded. Thus, the first potential signal line frome either side of the connector is actually the *second* pin (see Fig. 3.1).

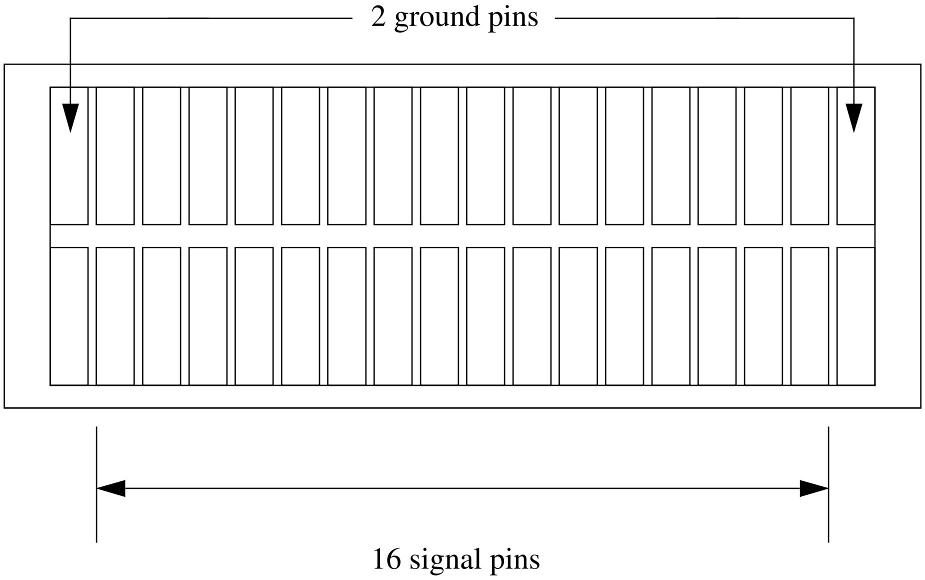



Figure 3.1: Connector pins.

5. perform soldering as necessary. *Do not use solder which has a copper-containing flux.*

6. reassemble.

   - unbag and replace pre-amp cards as appropriate.
   - remove the protective plates covering the top chamber aperature, replace the top aluminum Faraday cage plate, finger tighten the bolts, and replace the protective plates covering the top chamber aperature.
   - uncap and reconnect gas lines as appropriate.
   - replace the protective aluminum Faraday cage plates along the side in question as necessary.

## 3.2 Opening a chamber

*It may become necessary to open a particular chamber for maintenance or cleaning. This is necessarily a clean room situation, and this section outlines the* *procedure. If you have not used the Jefferson Lab clean room before, contact Steve Christo (christo@cebaf.gov, X7178, pager 680-7178) about proper usage. There is a strict initialization procedure for anyone about the enter the clean rooms for the first time which includes both a video and a manual. Access to the clean room is a privilege, not a right. If you abuse it, you may lose it!*

1. prepare the chamber. It is best to identify as accurately as possible all the problems with the chamber before entering the clean room environment, so that the number of openings is kept to a minimum.
   - scan the active area of the chamber with a $\gamma$-source such as $^{55}$Fe looking for dead wires (no signals), shorted wires (signals from a close-lying section of wires having less amplitude than the norm), and hot wires (signal even when the source is removed). A $\gamma$-source, and not a $\beta$-source, is ideal because the former uniformly ionizes the gas in a given cell.
   - identify any gas leaks using a portable gas sniffer and clearly mark the locations of the leaks.
   - if the identified problems are localized to a single chamber face, rotate the chamber on the 180° rotatable chamber cart ("flipper") so that the bad side is up. All chamber repair work should be done in series; that is, identify and repair one problem at a time, finish all the necessary work on a single chamber, and then move on to the problems of the second chamber. Lock the the cart so that spontaneous rotation cannot occur! Note that as the chamber itself is sandwiched between a pair of steel frames when it is mounted on the flipper cart, the top frame must be removed to provide eventual access to the upper surface.
2. collect all the tools necessary to complete the maintenance task inside the clean room. These may be found in the VDC cabinet, located on the Mezzanine of the EEL Building. The ethyl alcohol maybe be found in the flammable liquids cabinet located in Room 122 of the EEL building.

**torque wrenches** 2 standard torque wrenches.

**sockets** 2 standard and 2 deep 7/16" sockets.

**hex keys** 2 1/8" Allen wrenches.

**razor blades** a few new blades.

**pliers** 1 pair of needlenose pliers.

**containers** a few clean plastic cups (to collect nuts and bolts).

**handles** 8 pantry door handles and associated hardware.

**spray bottles** 2 spray bottles

**ethyl alcohol** 200 proof (fully dehydrated) - in the spray bottles.

**KIMWIPES**$^{TM}$ a few lint-free wipes.

**heat shrink** 30 cm each of 1/4", 3/16", and 3/8" heat shrink.

**heat source** a heat gun.

**canned air** 50 psi of purified dry $N_2$ or air.

**spacers** clean metal blocks about 1" thick.

**stands** 6 pieces of PVC pipe on which a chamber may rest.

3. remove the upper of the two steel frames which constitute the sandwich for the chamber on the flipper cart.

4. mount four of the pantry door handles on the top side of the chamber. Note that tapped holes exist for the screws for these handles.

5. clean everything thoroughly using the canned air, KIMWIPES$^{TM}$, and ethyl alcohol. This includes all the items in the above list which you intend to take into the clean room, the chamber, the chamber cart (including the wheels), and yourself! It is best to perform this cleaning on the threshold of entry to the clean room.

6. ensure your hands are clean and that you have powderless gloves to wear while inside the clean room. Your uniform will also include an overall outfit, shoecovers, and a cap. *The dress code must be strictly obeyed!*

7. enter the clean room with the chamber assembly. From this point on, proceed with *extreme* caution. Note that no two jobs will require the exact same steps to be executed, so take from these directions only that which you require.

8. to take apart the gas window and HV window assembly:

    - note that these two windows are held in place by plastic Allen-head bolts. To reach these bolts, it may be necessary to remove the plastic protective sheet that covers the gas window.
    - remove said bolts and carefully lift up the top gas window. There is an O-ring seal that is situated in the groove machined on the bottom side of this window. Do not allow this O-ring to fall out onto the lower window.
    - set the gas window on a clean, flat surface with the Mylar$^{TM}$-side up.
    - *At all times, you must now keep in mind that there are bare signal wires immediately beneath this window, and you do NOT want ANYTHING (especially the O-ring) to touch the wires.* Carefully remove the HV window. Note again that there is an O-ring seal that is situated in the groove machined on the bottom side of this window.
    - set the HV window on a clean, flat surface.

9. to open the main frame of the chamber:

- remove all conducting tape, solder and wire that connects the frame segments together.
- remove any dowel pins which may have been left in the holes.
- again, check to see that the flipper is locked so that spontaneous rotation (disaster) cannot occur. Remove all the long bolts that hold the frames together. Note that these bolts hold the chamber on the flipper.
- before separating the frame segments, disconnect the HV lines from the top wire plane. To do this, one person should lift only the HV end (this should be obvious) of the top wire frame approximately 1", and a second person should insert two spacers (clean metal blocks) in the gap thus produced between the wire frame and the gas containment box. See Fig. 3.2.

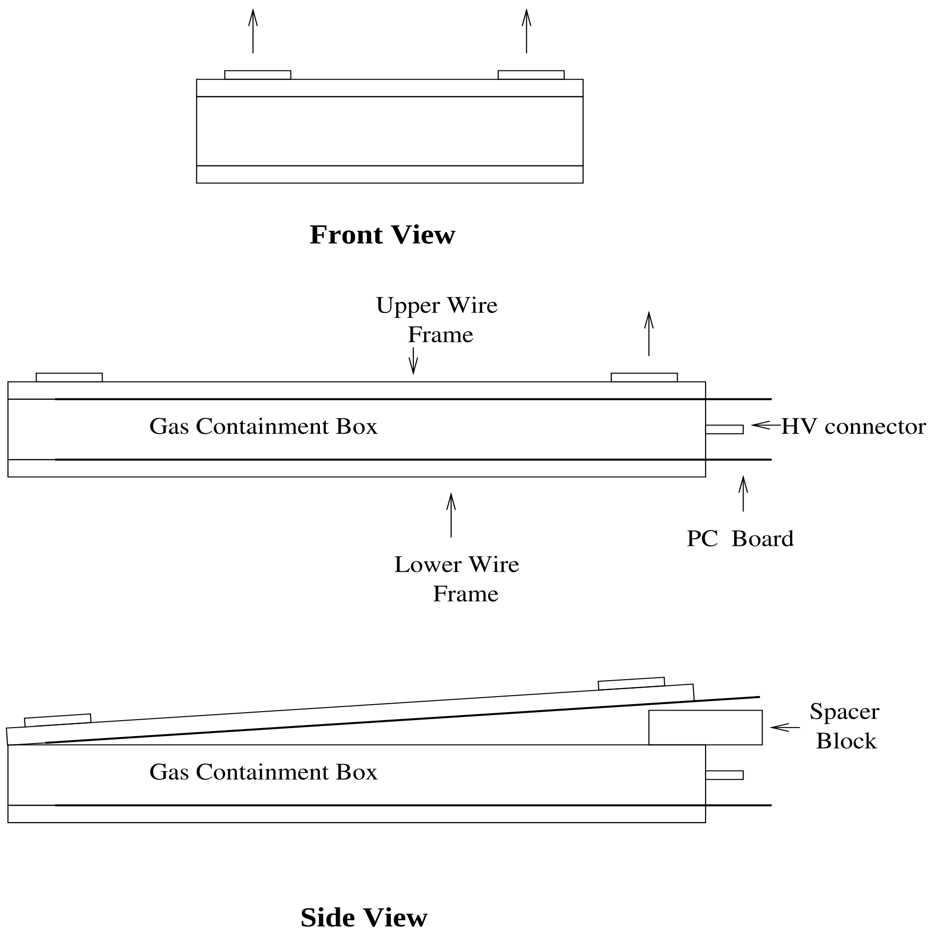



Figure 3.2: Opening the chamber.

- ensure the spacer blocks are stable. With great care, insert your hands into the chamber through the opening. *Note that the weight of the top chamber segment could easily crush both your wrists should it come crashing down.* Locate the HV connection to the top plane. The connection is of "push-in/pull-out" type, but is covered by three layers of heat-shink.
- carefully cut the layers of heat shrink tubing with a razor blade and disconnect the top plane HV.
- remove the support blocks and lower the top chamber to its horizontal rest position on the support frame.

10. the chamber is now ready to be opened. This is *strictly* a four-person job and requires pre-thought and coordination. Note that the chamber weighs over 100 lbs. and has 400 exposed, extremely fragile wires.

    - prepare a separate table on which the frame may be laid. This table should be oriented in parallel to the chamber cart, and should have the six chamber stands placed upon it.
    - allocate one person to each corner of the apparatus. Using the four handles attached to the top frame, lift the frame approximately 10 cm.
    - the next move is tricky. It is necessary now to flip the frame, so that the side currently facing the floor on which the wires are mounted will subsequently point to the ceiling.
    - set the frame on the chamber stands on the table with the exposed wires up.
    - disconnect the HV connections to the middle HV frame and the lower wire frame.
    - on the bottom side of the now-exposed gas-containment box, there is another heavy O-ring. Lift this box up and out of the apparatus, taking care to make sure the O-ring does not fall out on the exposed wires below. The interior of the chamber is now completely exposed.

## 3.3 Stretching Windows

If a new window is being stretched, the whole frame (including the copper-clad area) must first be cleaned with fully-dehydrated alcohol. For the special case of restretching a torn window, the following procedure is applicable.

1. prepare the torn window/frame assembly for stretching.

    - cut away the torn mylar foil with a razor blade. This will leave a ring of mylar which had been glued to the frame.

- again using (probably a large number of) razor blades, carefully scrape away the remaining mylar and glue from the copper sheathing and frame. Note that an O-ring which serves to make the assembly gas-tight lies on top of this copper sheathing, and thus care must be taken not to damage the copper in any way.
- with a very fine grain of sandpaper, sand the copper sheathing until the surface provided for the O-ring is smooth.
- thoroughly clean the frame of all the resulting copper dust with dehydrated alcohol.

2. stretch the new mylar foil across the stretching apparatus.

   - ensure that the conducting surface is up if it is single-sided foil that is being stretched.
   - continue stretching until all wrinkles have been removed from the foil. Note that excessive stretching can in fact distort the foil. Some care must of course be taken.
   - relocate the foil/stretcher assembly to a safe place for temporary storage.

3. attach the foil/stretcher assembly to the frame.

   - set the frame in the middle of the workspace. The copper side should face up, and the top of the frame should be 0.5 cm higher than the stretcher (a flat piece of styrofoam used as a spacer will suffice.
   - prepare approximately 30 g of “Stesalite” glue, which can be found in the VDC cabinet. Detailed mixing instructions are written on the side of the can.
   - apply a thin layer of glue to the copper sheathing using a razor blade. Do not put any glue in the region where the O-ring will sit (approximately 1 cm around the outside of the copper sheathing). Ensure this layer of glue is both continuous and uniform.
   - lower the foil/stretcher assembly onto the frame, ensuring that it is centered. Using a folded KIMWIPE$^{TM}$, carefully press down on the foil along the glue line to ensure a good bond.

4. prepare the apparatus and allow it to cure.

   - using a clean sheet of clear mylar, cover the foil. Ensure that there are no wrinkles in this cover sheet.
   - place the prepared cardboard frame over the cover sheet so that it is over top of the glue line.
   - place an empty frame (or uniform metal or wooden strips) over the cardboard frame.

- place a load of approximately 10 standard lead bricks, evenly spaced, on the frame.
- allow the glue to dry for 24 hours.

5. after the assembly has cured for the appropriate period of time, prepare to cut the newly-dried frames off the stretcher apparatus.
    - remove the lead bricks and curing apparatus.
    - using a sharp razor blade and leaving approximately 5 cm of foil outside the edge of the frame, cut the window from the stretcher.
    - using a sharp razor blade and a steel ruler, cut a line parallel to the edge of the copper sheathing so that the glue from the outermost 1 cm of copper may be removed.
    - using razor blades, carefully scrape off any excess foil and glue. Again, sand any exposed surfaces until they are smooth to the touch.
    - thoroughly clean the now-finished frame and exposed copper sheathing with dehydrated Alcohol and KIMWIPES$^{TM}$. Clean the mylar foil with compressed Nitrogen.
    - store the frame if appropriate in the frame storage rack located permanently in the Jefferson Lab clean room.

# Chapter 4

# Installation and removal

## 4.1 Disconnection

It is assumed that both the VDC apparatus is located on the fixed rails inside the spectrometer house, and the instrumentation rack is present. It is also assumed that gas for the chambers is on. If these assumptions are incorrect, modify the following procedure accordingly.

1. stop any data-taking which currently is taking place. This is important since it maintains the Data Acquisition System in a well-defined state during all subsequent power downs and disconnections.

2. power down the apparatus. In this case, "apparatus" includes several distinct units:

   - the orange Bertan high voltage unit located in the upper portion of the instrumentation hut. Once this has been turned off, disconnect the HV patch cables which connect the Bertan unit to the Hammond HV distribution boxes ($10\mathrm{M}\Omega$).
   - the FASTBUS crate housing the wire chamber TDCs in the lower portion of the instrumentation hut. It is important to turn the crate off even though no modules will be disturbed, so that no lines are shorted together in the process of disconnecting the cables.
   - the low voltage power supplies located in the lower portion of the instrumentation hut for the $\mathrm{HRS_e}$ and the upper portion of the instrumentation hut for the $\mathrm{HRS_h}$. Note that there are both pre-amp power supplies ($\pm 5$V nominal) and discriminator threshold power supplies ($+2.5$V), and both must be turned off.
   - the temporary cooling fans mounted on the aluminum plates of the Faraday cage. Remove these fans once the power is off.

3. isolate the wire chambers from the outside world. It is *extremely* important that the wire chamber gas connections are closed, so that the chambers themselves do not become contaminated by room air (which is particularly foul). Be sure to use two wrenches when making any connections or disconnections of gas lines so as not to damage anything.

    - disconnect the gas lines running between the space frame gas panel and the chamber isolation panel. *Immediately* close off both the disconnected line and the chamber isolation panel using clean end-cap pieces.
    - only if necessary, disconnect the chambers from the chamber isolation panel one line at a time, and *immediately* close off the disconnected line using the clean end-cap pieces.
    - coil up the various hoses and tie them off in safe locations where the ends will not get crushed and the hoses will not get pinched.

4. disconnect the TDCs. Note that the connection need not be broken at the chambers, but rather only at the TDCs. The connection schematics are shown in Figure 4.1 and Figure 4.2.

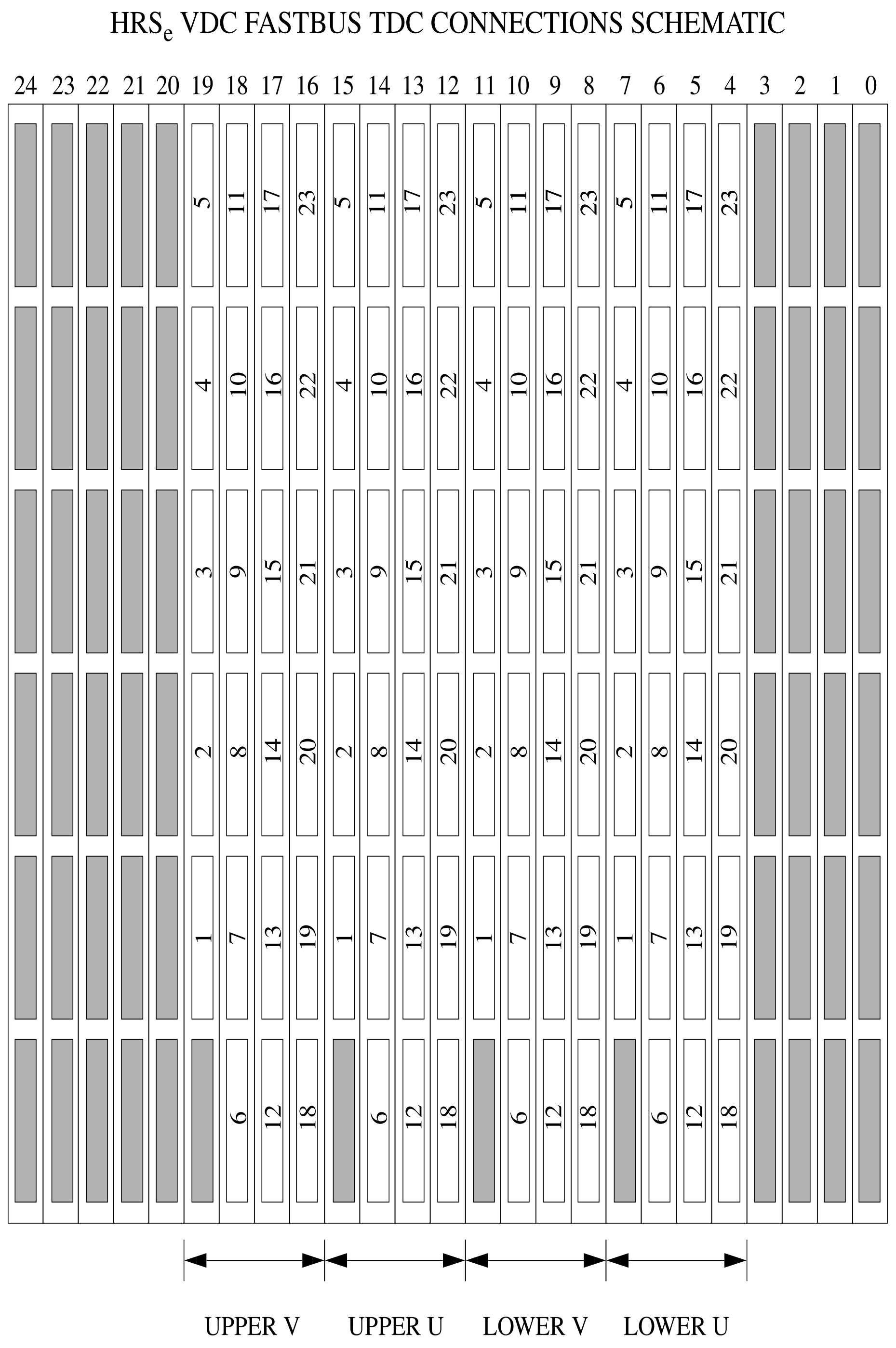



Figure 4.1: Connection schematic for the $HRS_e$ TDCs.

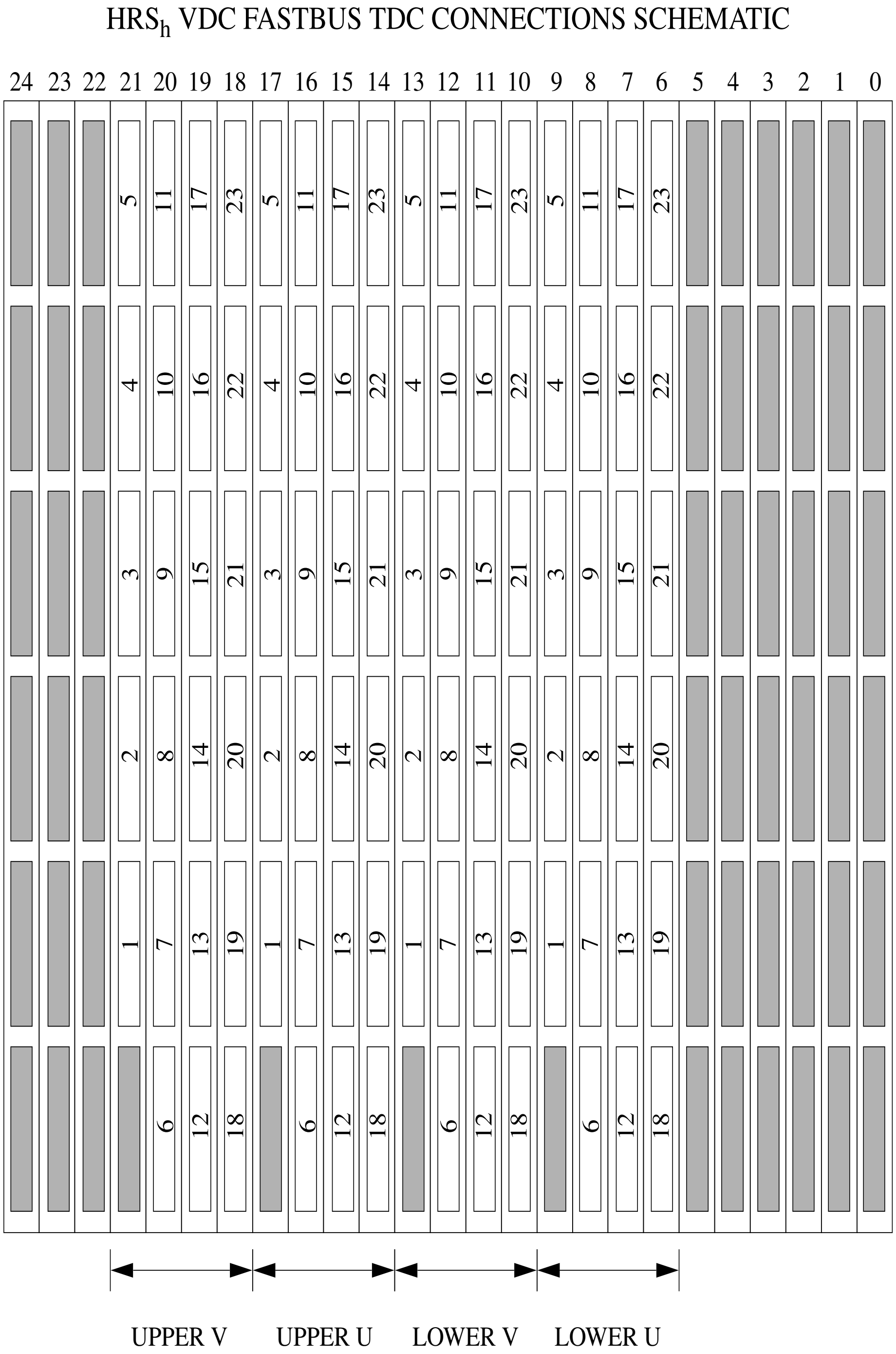



Figure 4.2: Connection schematic for the HRS$_h$ TDCs.

Also note that the high-density ECL design of the FASTBUS TDCs necessarily requires a large number of relatively fragile pins at the interface between the modules and the 16-conductor twisted-pair cables. Be very careful disconnecting things! Use the minimum amount of force required! In the event of any damage to the TDC pins, contact B. Wojtsekhowski or J. Segal (see 1.5) *before* attempting any repair.

- disconnect each TDC in a systematic fashion and check to make sure each of the 16-conductor cables retains its label. The cables corresponding to each TDC have been hard-mounted on a labeled plastic card for ease of (dis)mounting and organization.
- gather the cards (and thus cables) according to chamber, and place the groups in some sort of protective covering - a plastic bag for example. The purpose of the bag is to protect the electrical contacts from being fouled by dust and the like.
- it is recommended that the cables be gathered into two boxes, with a single box containing the cables corresponding to both planes of a single chamber. This makes the transportation of this large volume of cable much easier, and prevents too great an amount of cable from accumulating in any given box.

5. disconnect the pre-amp and discriminator power supplies. Note that this procedure requires the removal of some of the aluminum plates which constitute the Faraday cage. Before making any disconnections, *double-check* to make sure these power supplies have been turned off.

   - the following convention applies to the pre-amp voltage cables: white -5V, red +5V, green is ground. Disconnect these cables at the clamping bars. Note that some force may be required as the joints are necessarily very snug. Note also that clamping bars exist on *both* sides of the chamber apparatus. See Figure 4.3.
   - the following convention applies to the discriminator threshold voltage cables: a pair of two-conductor black wires connect to the clamping points - one labeled "red", and one labeled "blue". The two conductors in the "red" wire connect to the top bar and those in the "blue" wire connect to the bottom bar. Each two-conductor pair consists of a black and a white wire. The black wires connect to the top screws on their respective points; the white wires connect to the bottom screws. Disconnect these wires. Note that this connection exists on only one side of the chamber apparatus. See 4.4.
   - once all the cables are disconnected, bag the ends. Again, this is to protect the electrical contacts from becoming fouled.
   - *Note: The wire chambers should now be completely disconnected.*

6. disconnect the permanent VDC stops located at the back of the detector hut where the VDC cartridge is bolted to the space frame.

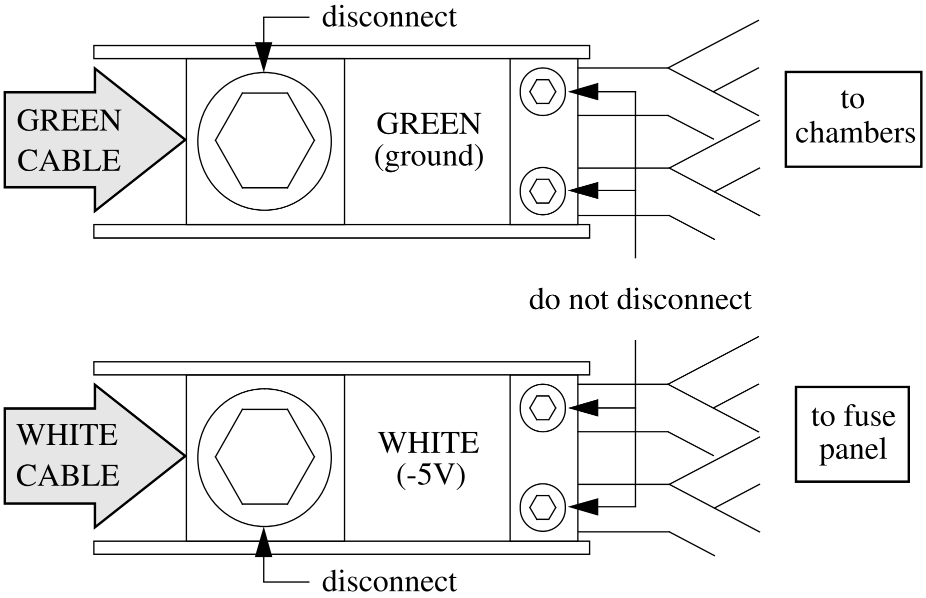



Figure 4.3: Pre-amp only side connection schematic.

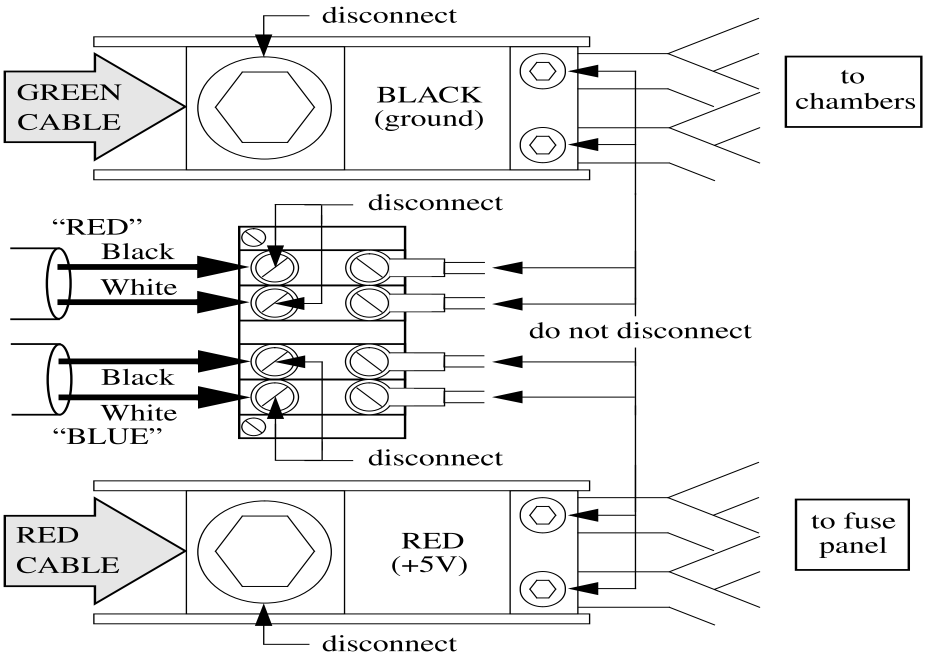



Figure 4.4: Pre-amp/Discriminator side connection schematic.

7. double-check. At this stage, it is wise to spend a few minutes going over the apparatus and double-checking that all of the above steps have been carried out. Also, make sure to coil up, tie off and generally keep out of harm's way any loose or dangling cables or hoses. "An ounce of prevention..."

8. install protective plates. Because of the extremely delicate nature of the VDCs, it is crucial to install all of the protective devices before attempting any lift. These devices include three sets of aluminum plates: one trio for beneath the chambers, one trio for above the chambers (each trio covers the detector aperature), and a pair of plates which slide in between the chambers.

9. cover and store. It is desirable to keep the entire assembly in as localized an area as possible.

10. place the boxes containing the TDC cables on top of the apparatus. Take care that there is no stress put on the connections between the TDC cables and the wire chamber cards. Also, watch out for the input gas spigot on the top plane. Fasten the boxes securely in place.

11. blanket the entire assembly in clean tarpaulin or plastic and make every effort to fix the covering in place.

12. check that the stops on the ends of the Thompson rails are in place to ensure the VDC package will be firmly fixed in position when the assembly is moved.

13. position the assembly in a *SAFE* place - pay particular attention to any objects which could bump into or fall on top of the apparatus.

## 4.2 Raising and lowering

It is assumed that the VDC apparatus has been properly disconnected and packaged as detailed in the disconnection section, and is thus ready to lift as a single unit. If these assumptions are incorrect, modify the following procedure accordingly. Contact qualified personnel such as J. Segal (see 1.5) to oversee the lift and to operate the crane.

1. perform pre-lift diagnostics.
   - remove any storage covering.
   - check that the cable boxes are securely fastened to the frame.
   - check that the stops on the Thompson rails are firmly in place.
   - check that all protective devices are in place.

2. prepare the apparatus for lifting.

- place four eyebolts through the four liftpoints located on the steel VDC support frame.
- thread two lifting straps through the eyebolts, one strap per eyebolt pair. The straps should straddle the apparatus and have an orientation perpendicular to the long dimension of the frame.
- collect the two lifting straps into the crane hook and secure.

3. lift the apparatus.

    - slowly raise the apparatus until the wheels have barely cleared the floor. Check that it is stable and secure in its mounting.
    - lift the apparatus and set it on the spectrometer deck. *It is very important that the male ends of the Thompson rails point toward the shielding house, or the VDC package cannot be safely transferred from the mobile rail to the fixed rail.*

## 4.3 Installation

It is assumed that the VDC apparatus is located on the spectrometer deck with the correct orientation (male ends of the Thompson rails point towards the spectrometer house), and that the fixed rail is in place. If these assumptions are incorrect, modify the following procedure accordingly.

1. translate the mobile VDC frame towards the fixed VDC frame until the respective Thompson rail ends meet. *Note that this is NOT a trivial procedure!*

    - remove the TDC cable boxes from the top of the VDC package and place them on the floor. As the mobile frame is moved towards the fixed frame, these boxes must also be moved. A reasonable stepsize is 1 m.
    - clamp the male ends of the mobile frame with C-clamps and remove the permanent stops.
    - the fixed rails are about 3 cm higher that the mobile rails, so that the mobile frame must be elevated for the two sets of rails to meet. This elevation is tedious and time consuming, but if performed carefully, is straightforward. Use portable jacks to change elevations and 2 X 6 planks as spacers between the wheels of the mobile frame and the spectrometer deck. Work with the mobile frame one end at a time. *Take extra care to make sure that the mobile frame does not roll off the planks. The resulting jarring as the wheels of the frame strike the deck could be disasterous.*

2. carefully align and mate the mobile frame to the fixed frame. Do not force anything or the rails may bend, which is potentially fatal to the procedure.

Once the rails have been mated, wedge the wheels of the mobile frame to prevent surprise decouplings.

3. remove the protective cover for the spectrometer outrun window.

4. transfer the VDC package. *Make very sure that the windows are not going to be damaged in the process.* Also check that any cables or gas lines are properly tied off.

   - make sure that there are stops in place at the scintillator end of the fixed rails.
   - remove the C-clamps from the rails of the mobile frame and slowly transfer the VDC package to the fixed frame.
   - use the C-clamps to secure the ends of the fixed frame, so that the package cannot slide off.

5. remove the mobile frame.

   - replace the temporary C-clamps on the fixed frame with permanent stops.
   - disconnect the chainfalls, and decouple the two frames. It may be necessary to use a portable jack between the steel frames to encourage the separation.
   - remove the mobile frame from the spectrometer deck if appropriate.

## 4.4 Connection

It is assumed that both the VDC apparatus is located on the fixed rails inside the spectrometer house, and the instrumentation rack is present. It is also assumed that gas for the chambers is available.

1. reconnect the gas lines between the space frame gas panel and the chamber isolation panel. Re-enable gas flow. The rotameters should read 30 flow units.

2. allow the chambers to sit in this state for 24 hours before proceding. Monitor and adjust the flow until steady-state has been obtained.

3. connect the TDCs.

   - remove the TDC cables from the boxes they were transported in, and run them to the FASTBUS crate in the instrumentation house one bundle at a time in the cable trays provided.
   - for each bundle, remove the plastic covering the ends of the cables and plug the connectors into the FASTBUS TDCs as appropriate. See Figures 4.1 and 4.2.

- note that the high-density ECL design of the FASTBUS TDCs necessarily requires a large number of relatively fragile pins at the interface between the modules and the 16-conductor twisted pair cables. Be extremely careful when reconnecting things, as it is very easy to bend these pins. If any damage should occur, contact B. Wojtsekhowski or J. Segal (see 1.5) *before* attempting any repair.
- do not discard the boxes the cables were transported in, or the plastic used to cover the connectors. These may be reused.

4. connect the pre-amp and discriminator power supplies. Note that this procedure requires the removal of some of the aluminum plates which constitute the Faraday cage. *Double-check* to make sure these power supplies are off before attempting to reconnect!

   - remove the plastic bags which cover the contacts. Again, save the bags.
   - the following convention applies to the pre-amp voltages cables: white -5V, red +5V, green is ground. Connect these cables at the clamping bars. Note that some force is required to ensure that the joints are necessarily snug. Note also that clamping bars exist on *both* sides of the chamber apparatus.
   - the following convention applies to the discriminator threshold voltage cables: a pair of two-conductor black wires connect to the clamping bars - one labeled "red", and one labeled "blue". The two conductors in the "red" wire connect to the top bar and those in the "blue" wire connect to the bottom bar. Each two-conductor pair consists of a black and a white wire. The black wires connect to the top screws on their respective bars; the white wires connect to the bottom screws. Connect these wires. Note that this connection exists on only one side of the chamber apparatus.

5. enable the chamber HV. Check to see that the orange Bertan high voltage unit located in the upper portion of the instrumentation hut is off, and then connect the HV patch cables from the Bertan unit to Hammond HV distribution (1M$\Omega$) boxes. The trip current is set at 10 $\mu$A.

6. mount the four temporary cooling fans on the aluminum plates of the Faraday cage so that they force air flow over the chamber cards. Locate power for these units and turn them on.

7. remove the protective plates.

8. power up the apparatus and allow it stabilize for about 24 hours. In this case, "apparatus" consists of several distinct units:

   - ramp the HV on the chambers up to the nominal operating voltage of -4.0 kV. *Do not use the auto-reset function.* Manual controls are present on the Bertan unit, and may be monitored from the front panel using a voltmeter. The ramping may also be performed via the control system - see section 5.2.2. In either case, ramp *slowly* or the chambers can trip. Further, do not let the chamber draw currents significantly above 1 $\mu$A during the ramping procedure, or permanent damage may result.

- turn the FASTBUS crate on.
- turn the discriminator and pre-amp power supplies on. Note the setpoints. These power supplies have an overcurrent setpoint. Set this as low as possible by minimizing it when first turning the power supplies on, and gradually increasing it as necessary. This optimization procedure takes approximately 30 minutes.

9. restart the Data Acquisition system and debug the apparatus as appropriate. Note that establishing good contact at each FASTBUS TDC pin can be a tricky business. Bad connections are evidenced by so-called "hot wires". It may turn out to be necessary to disconnect and reconnect a given cable several times before a good connection is obtained. Patience!

# Chapter 5

# Day-to-day operations

## 5.1 Pre-lockup checklists

Before a given run period, it is standard operating procedure to perform a pre-lockup shakedown of the VDCs. This shakedown is summarized in the checklist shown in Figure 5.1. The following sections explain in detail how to fill out the checklist. Note that the discussion below does not illustrate the order in which the checklist is to be performed, but rather deals with the task as it appears. Further, if any of the items on the checklist is not in its expected configuration or functioning properly, lockup must be suspended until the problem can be addressed. Completing the pre-run shakedown of the VDCs takes about 30 minutes per spectrometer if all goes well.

## VDC Pre-Run Checklist

Initials: ☐ Date: Time:

SET ALLOCATION: $HRS_e$ ☐ $HRS_h$ ☐

Gas Type: Ar ☐ Ar $CO_2$ ☐ Ar $C_2H_6$ ☐

bubblers:
top ☐
bottom ☐

Ar supply ________ (psi)
$CO_2$ supply ________ (psi)
$C_2H_6$ supply OK? ☐

flow: top ________(30) bottom ________(30)

| Cooling Fans: | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| | ☐ | ☐ | ☐ | ☐ |

Dhist: ☐ Resets: ☐ HV Interface: ☐

| | | Bertan A | Bertan B |
|---|---|---|---|
| HV: | (-4.00 kV Ar $C_2H_6$)<br>(-3.65 kV Ar $CO_2$) | ________ | ________ |
| $I_{DRAW}$: | (~100 nA Ar $C_2H_6$)<br>(~300 nA Ar $CO_2$) | ________ | ________ |

| LV | | top | bottom |
|---|---|---|---|
| PreAmp/Disc | (+5.0 V): | ________ | ________ |
| PreAmp/Disc | (-5.2 V): | ________ | ________ |
| Threshold (+2.5 V/+3.0 V): | | ________ | ________ |

Figure 5.1: The pre-lockup checklist.

**initials** put your initials in the box.

**date** enter the day on which the checklist is being evaluated.

**time** enter the time at which the checklist is being evaluated.

**set allocation** check the box corresponding to the spectrometer being investigated.

**gas type** check the box corresponding to the type of gas being used in the VDCs. Standard operating configuration uses Ar $C_2H_6$.

**bubblers** visually ensure the VDC bubblers are bubbling. These bubblers are located at the entrance to the first deck of the space frame for both spectrometers, at chest height and on your left hand side if you are facing the back of the shielding hut.

**supply** check the gas supply. The bottles are located in the Hall A gas rack on the north side of the truck ramp into the Hall. The procedure for checking the gas supply is presented in section 5.4. More information about the gas system may be found in the Hall A Basic Experimental Equipment Operations Manual, and the Hall A Wire Chamber Gas System (HAWGS) Manual.

**flow** check the gas flow to the VDCs. This flow rate may be read from the rotameters located at the entrance to the first deck of the space frame for both spectrometers, at chest height and on your left hand side if you are facing the back of the shielding hut. All gas flow rates should be set to 30 rotameter units.

**cooling fans** ensure the four temporary cooling fans are in place and blowing air onto the VDC preamp cards. The temporary fans are clipped to the four corners of the VDC detector cartridge. Permanent fans will be mounted in the same location when maintenance time and resources permit.

**dhist** visually inspect the spectra the VDCs are taking by starting a run on cosmics and looking at the resulting spectra for each arm with the appropriate *DHIST*. If you are unsure of how to start a run or use *DHIST*, documentation exists in the counting house.

**resets** ensure the remote resets for the Bertan HV units work by forcing a chamber trip (drastically and suddenly lower the voltage). The procedure for reseting the HV is presented in 5.3.

**HV interface** ensure the HV control interface is alive and working for all four chambers. The procedure for starting the HV control software and setting the Bertans is presented in 5.2.2.

**HV** for each spectrometer, chamber voltage is supplied by a Bertan 377N HV power supply. These power supplies are bright orange, and are located on the upper deck of the spectrometer space frames. Each power supply has two channels, A and B. For both spectrometers, channel A is connected to the upper VDC, and channel B is connected to the lower one. The procedure for starting the HV control software is presented in 5.2.2. The nominal setpoint for Ar $C_2H_6$ operation is -4.00 kV. The setpoint and the read back are shown in a pair of GUIs, see Figure 5.5. Note the GUIs ignore sign.

**$I_{draw}$** the current monitor portion of the HV GUIs does not work at present, as the sensitivity of the ADCs is too low. To monitor the current draw for the various chambers under cosmic rays, disconnect the LEMO cable at the input to the current monitor spigot on the Bertan unit and use a DVM on the 200 mV scale. The nominal current draw for Ar $C_2H_6$ operation is about 100 nA. Remember to reconnect the cables!

**LV** to check the low voltage being applied to the chamber, one of the aluminum RF shielding plates must be removed from each side of the chamber to provide access. A DVM may be used to check the individually labeled channels on a single preamp/threshold card. *If you are not confident you know exactly what you are doing, do not attempt to check the low voltages, as the currents are potentially lethal.* Instead, contact one of the people listed in 1.5. Nominally, the preamp/disc cards should have +5.0 V and -5.2 V applied to them for all VDCs. On the $HRS_e$, the threshold voltage is set to a nominal value of +3.0 V, while on the $HRS_h$, +2.5 V is applied. Any substantial deviations from these setpoints requires adjustment of the Kepco LV power supplies. The LV power supplies are discussed in detail in 1.2.

## 5.2 The control GUIs

### 5.2.1 Main control

The main control GUI for the $HRS^2$ is shown in Figure 5.2. At the bottom of the display is a box corresponding to the HV interface for the VDCs. The readback voltages for the individual VDCs are shown as a function of spectrometer. If everything is operating properly, the readback fields should all show a nominal value of 4.00 kV. To the right of the readback voltages are the "Detectors" access buttons. To access HV and gas flow controls for a given spectrometer, click once on the appropriate button.

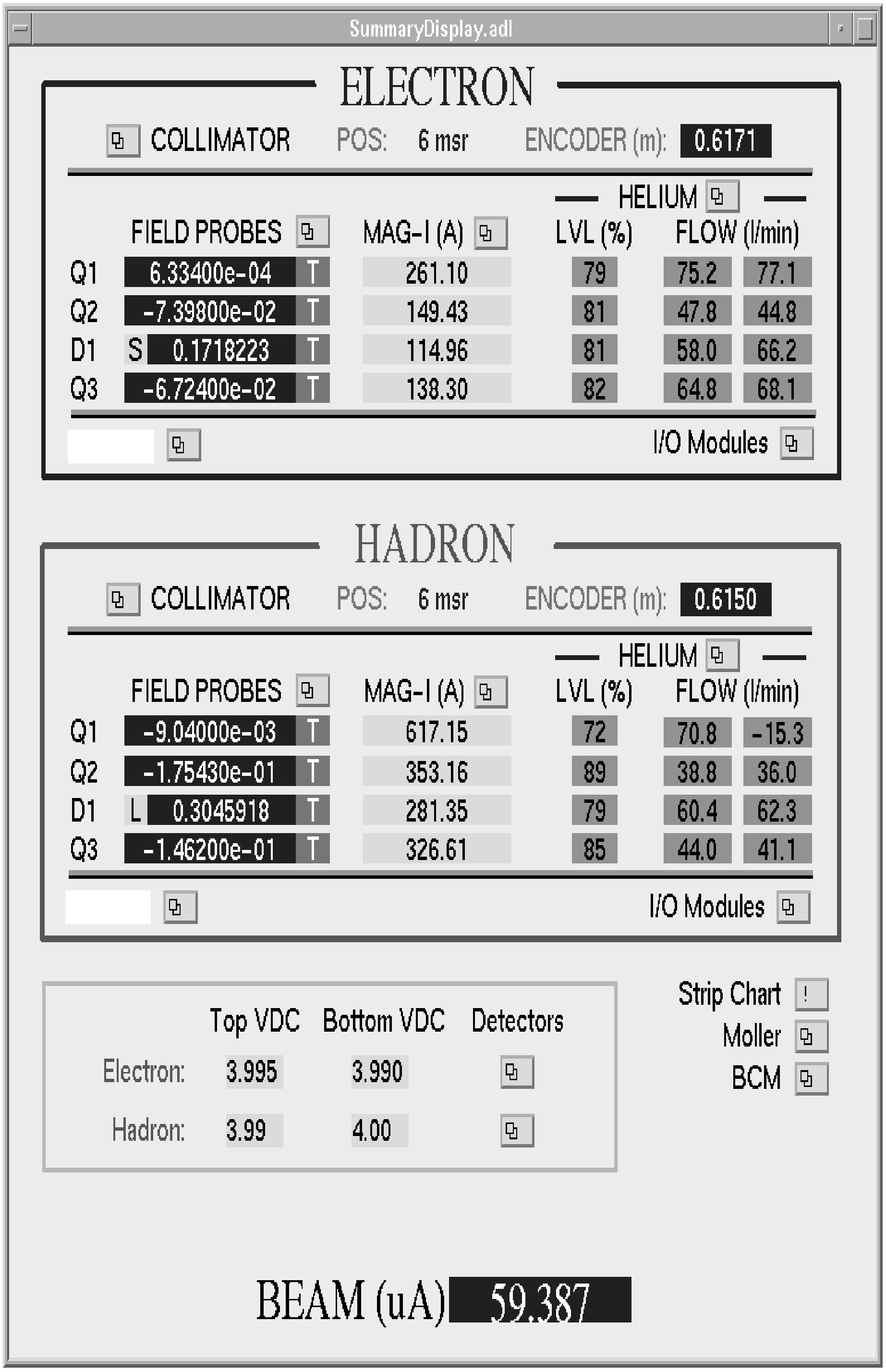



Figure 5.2: The main control panel.

### 5.2.2 VDC access

Clicking on the “Detectors” access buttons causes the GUIs shown in Figure 5.3 to open. The correspondence between button and GUI is obvious. For either spectrometer, select the “VDC” option to access the VDC controls. In doing so, you will be asked to select either the gasflow readback or the HV control GUI.

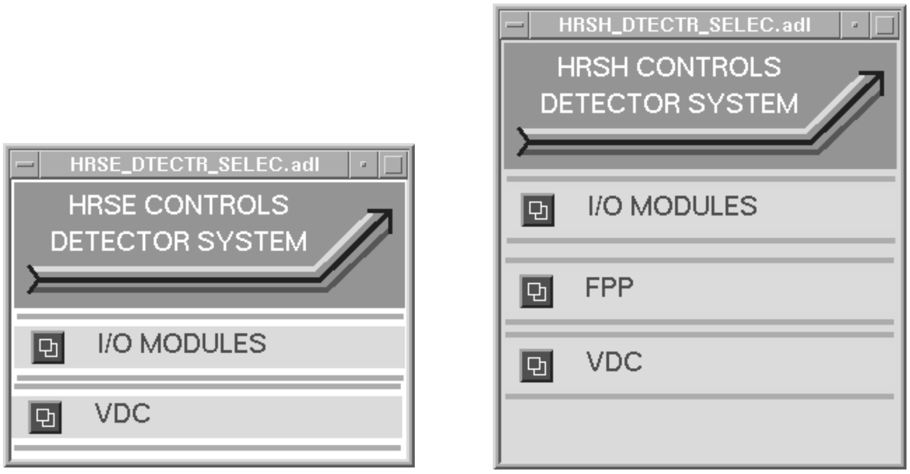



Figure 5.3: VDC control panels.

#### Gasflow

Selecting the gasflow readback from the VDC access GUIs for either spectrometer opens the panel shown in Figure 5.4. No control is provided here; rather, the exhaust flow rates for all the chambers on both the HRS$^2$ are shown. Note that this instrumentation is still in its development stages. In fact, the readback needs to be time-averaged to provide a more meaningful monitor of the chamber exhaust flow rates. Thus, while the numbers shown for the VDC chambers in the figure are typical, do not be alarmed by seemingly wild swings in these values. These swings represent the oil bubbles actually bursting in the monitoring device. The values shown for the FPP chambers are not typical.

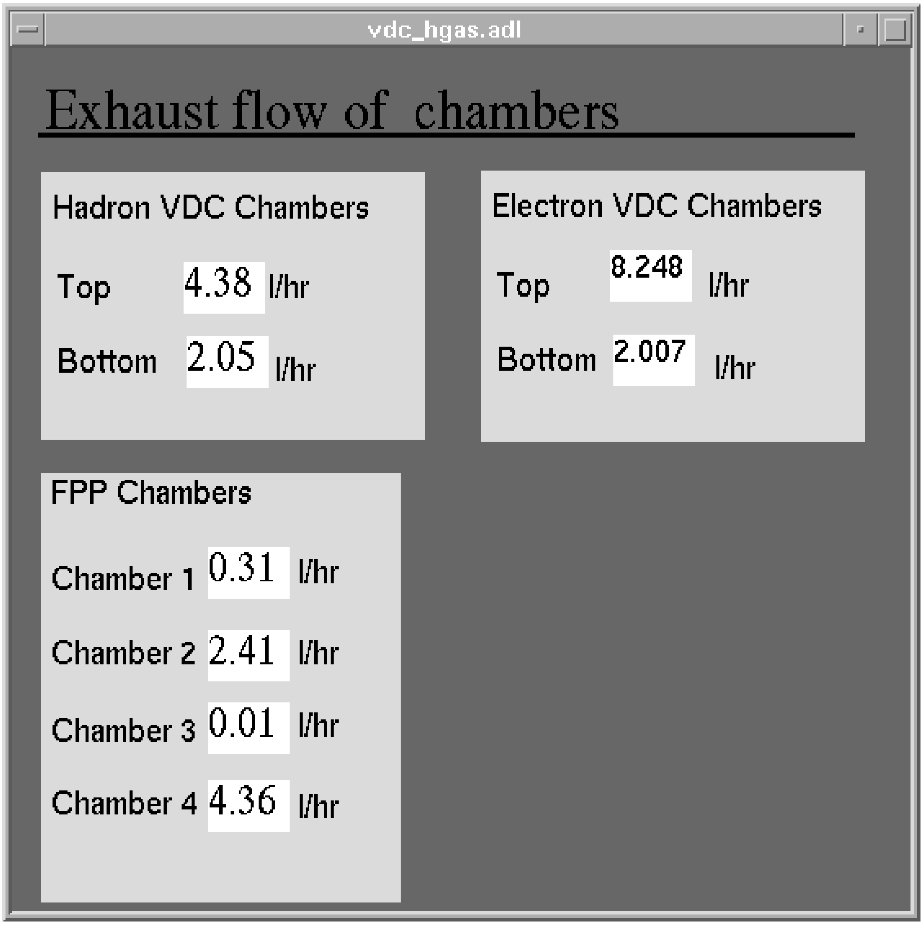
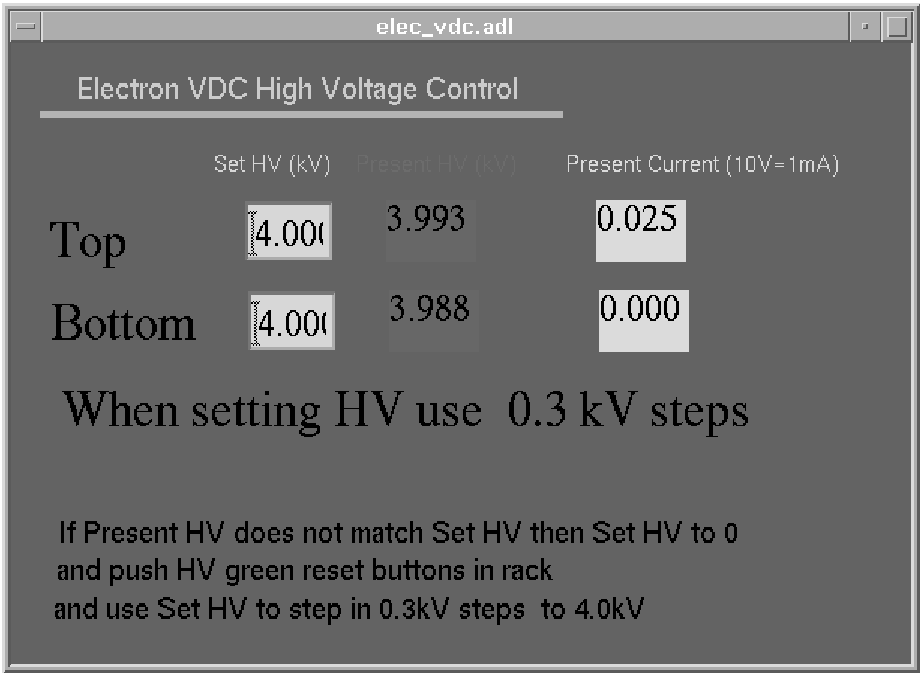



Figure 5.4: Gas readback panel.

### HV

The HV control GUIs for the VDCs are shown in Figure 5.5. The panels have both HV setpoint and readback fields as well as chamber current readback fields. Note that due to the poor sensitivity of the ADCs used, the readback current fields are meaningless.



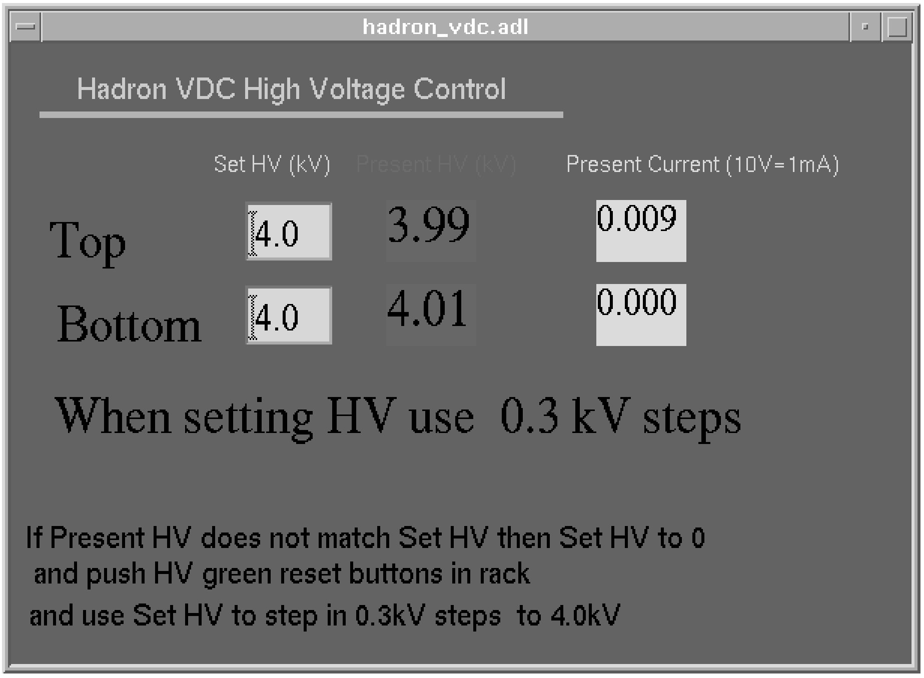




Figure 5.5: HV control panels.

To set the HV using the remote interface:

- ensure the set fields are set to 0.00 kV. Do this by clicking in the appropriate field, backspacing over the incorrect value, typing 0.00, and hitting <RETURN>.
- reset the Bertan HV power supplies. To do this, go to Room 103A (the middle room in the Hall A counting house), and locate the reset panel of green buttons. This panel is situated in rack 3, and is about 70 cm above the floor. There is a "button map" located above the panel. Press the appropriate button(s) and hold for 15 seconds.
- return to the control GUI. Ramp the chamber voltages as appropriate to their nominal operating values of -4.0 kV for Ar $C_2H_6$ and -3.65 kV for Ar $CO_2$ in steps of about -0.3 kV. Note that the GUI ignores the negative sign. To do this:
  1. click on the set field.
  2. type in the desired value.
  3. hit <RETURN>.
  4. wait 20 seconds and repeat.
- once the ramping is complete, close the HV control GUIs.

## 5.3 Chamber trips

Periodically, for whatever reason, a VDC may instantaneously draw too much current from the power supply, causing the power supply to trip off to protect the chamber. The trip thresholds are presently set to 10 $\mu$A. In the standard operating configuration, trip frequency has been about once per month.

If a VDC trips, the procedure outlined in section 5.2.2 should be followed. If the same VDC trips again, or a pattern develops, suspend operation and contact one of the people from section 1.5, as there is something very wrong with the chamber. *Do not try to "force" a chamber to hold voltage through a series of repeated trips, as this will destroy it.*

## 5.4 The gaslog and changing gas bottles

Standard operating procedure for the Hall requires the gas bottles to be checked once every 8-hour shift. When the bottles have been checked, the shift worker is requested to fill in the chamber gas logsheet. An all-weather copy of the chamber gas logsheet is permanently located at the mixing rack (see Figure 5.7). The entries should be self-explanatory.

| Date | Time | Initials | Ar Pressure (psi) | Ar New? (Y/N) | $C_2H_6$ Pressure (psi) | $C_2H_6$ New? (Y/N) |
|---|---|---|---|---|---|---|
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Figure 5.6: The chamber gas logsheet.

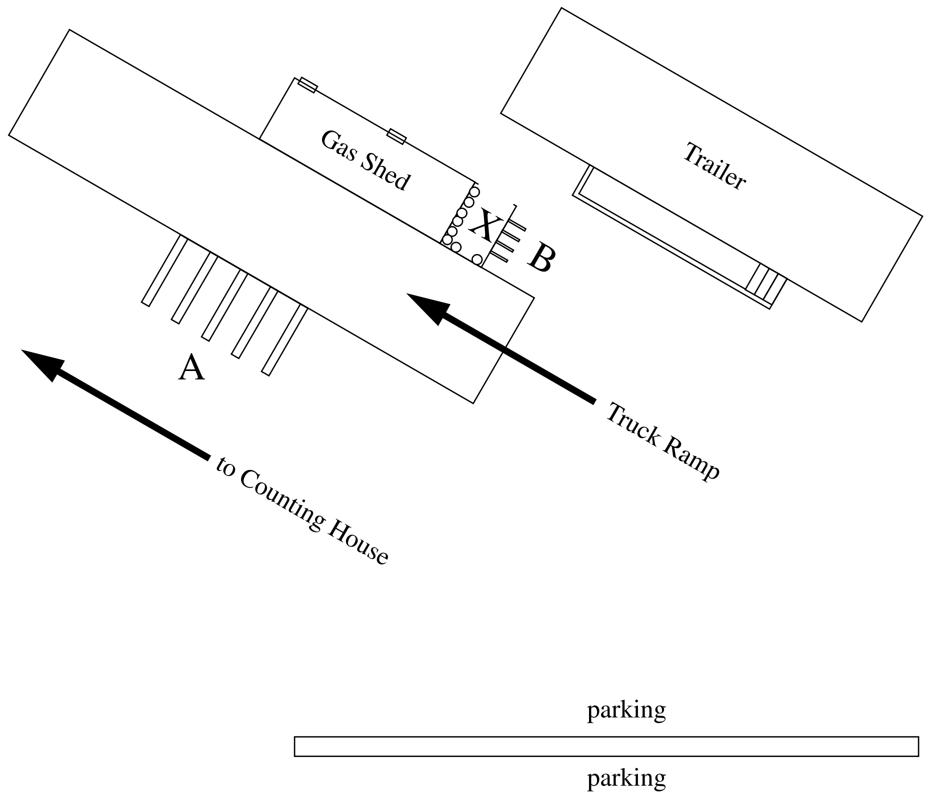


Figure 5.7: The location of the gas rack.

Periodically, it will become necessary to swap out an empty gas bottle. Figure 5.7 is a sketch of the gas storage areas, the mixing rack, and the Hall A access ramp.

There are two gas bottle storage areas, labeled 'A' (the primary) and 'B' (the secondary) in the figure. These areas are on opposite sides of the access ramp. Area 'A' contains both full and empty bottles. The empty bottles in Area 'A' shall be clearly labeled with red empty bottle tages. Area 'B' shall contain only full bottles, clearly labeled with green full bottle tags. Large supplies of these tags exist in both storage areas. They may also be obtained from Jack Segal (see section 1.5).

In standard operating mode, Ar $C_2H_6$ is used in the VDCs. While there are small volume bottles of pre-mixed Ar $C_2H_6$ available in the storage rack for special occassions, in general, we mix our gas. Detector grade Ar comes in a dark blue bottle labeled "UHP Grade 0". Welding grade Ar comes in a light blue bottle and should not be used. $C_2H_6$ also comes in a dark blue bottle, but these bottles have bright red labels. Note that $C_2H_6$ bottles look very similar to $D_2$ bottles. *READ THE LABELS!*

When a bottle in the mixing rack (point X) is empty, the following procedure should be followed to replace it:

- isolate the bottle from HAWGS by closing the two valves between the bottle and the system itelf. *Note: the valves should be turned aggressively! If you are too gentle, the resulting drop in pressure will trip the gas alarm!.*
- enable the backup bottle by opening the two valves between the bottle and the system. *Again, be aggressive.*
- remove and temporarily set aside the green full bottle label from the backup bottle and place a "Bottle in Use" tag on it.
- using the large wrench permanently located at the gas rack, disconnect the empty bottle from the supply line. *Ar bottles have right-handed threads, while $C_2H_6$ bottles have left-handed threads!*
- place the bottle cap back on the empty bottle.
- place the empty bottle on the gas cart and secure it. Take the bottle to storage area 'A', place a red empty bottle tag on it, and store it securely in the empty bottle rack.
- place a full bottle on the gas cart and secure it. *Remember to check the contents of the bottle!* Take the full bottle to the mixing rack and secure it in place with the provided chain.
- remove the bottle hat and the thread plug and connect the new bottle to the mixing system. Again, remember the difference in threads. Place the green full bottle tag on it, as well as a "Ready for Use" label. *Leave the valves between the bottle and the mixing rack closed.*

This procedure is also discussed in the HAWGS manual.