Operations manual for the Hall B gas controls software.

The Hall B gas controls software is a National Instruments LabView based controls program which uses the NI Compact RIO platform to control gas delivery to the Hall B gaseous detectors.

The Hall B Gas System controls consists of four NI cRIO 9035s, each has a custom gas controls chassis to interface with a variety of sensors and provide power to gas management hardware (Mass flow controllers and transducers). Each set of cRIOs and chassis are located strategically near the gas hardware which must be controlled or monitored.

- Chassis 1 (Space Frame Level 3 South):
    - DC PID
    - HTCC CO_2 supply
    - SVT N_2 purge
- Chassis 2 (Hall B Gas Shed Control Room):
    - DC Ar and CO_2 mixing
    - DC gas supply
    - LTCC Distillation Recovery
    - MVT Ar, C_4H_{10}, and CF_4 mixing
    - Hall B Gas Controls GUI
- Chassis 3 (Forward Carriage Level 1 South):
    - LTCC PID
    - LTCC gas supply
- Chassis 4 (Forward Carriage Level 3 North):
    - RICH N_2 supply
    - RICH compressed air monitoring

cRIO Operation

Ensure all cRIO systems are on and GUI screens are operating. All software starts operating once the cRIO is powered on using the power button. All gas supplies will automatically recall the saved flow demand values and immediately begin flowing gas. In the case that cRIO fails or software is not functioning properly, resetting it will restart the programs within five minutes.

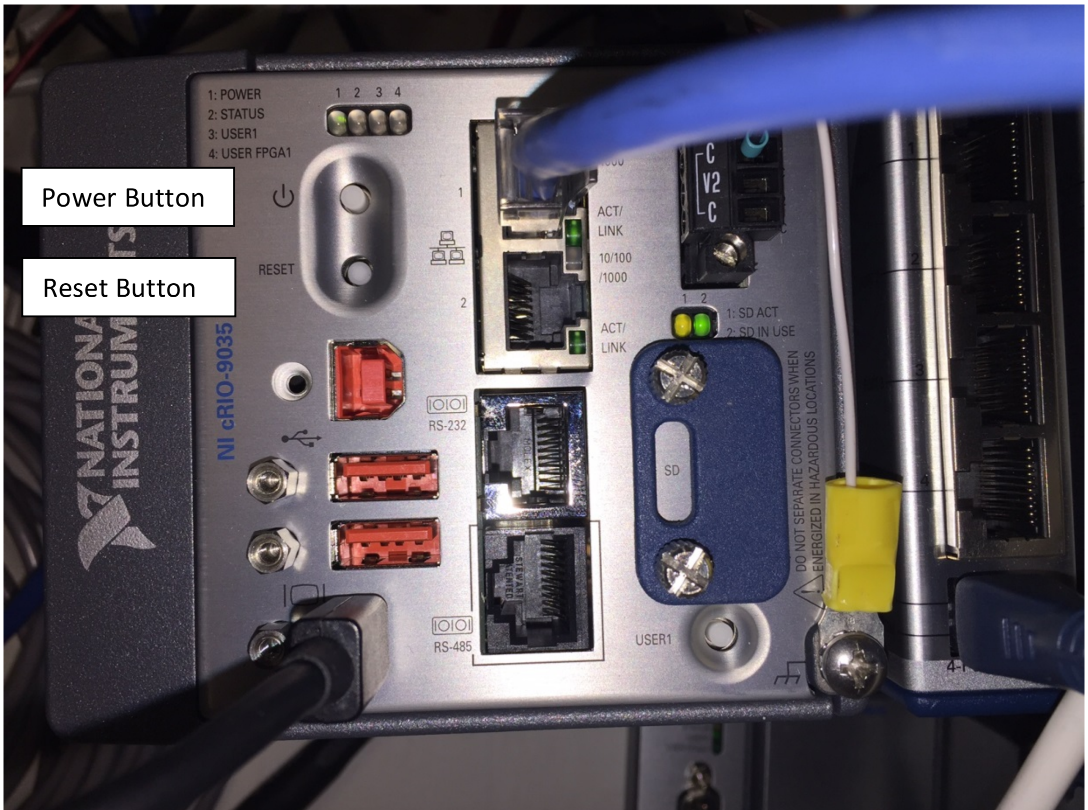


Figure 1 National Instruments cRIO 9035 controller. The power and reset buttons are accessible in this location.

Drift Chamber Gas Operations

All gas controls and monitoring is operated from the gas shed control room. DC gas operations are controlled using the Gas Controls GUI displayed on the touchscreen. The first tab of the controls GUI is the DC gas controls.

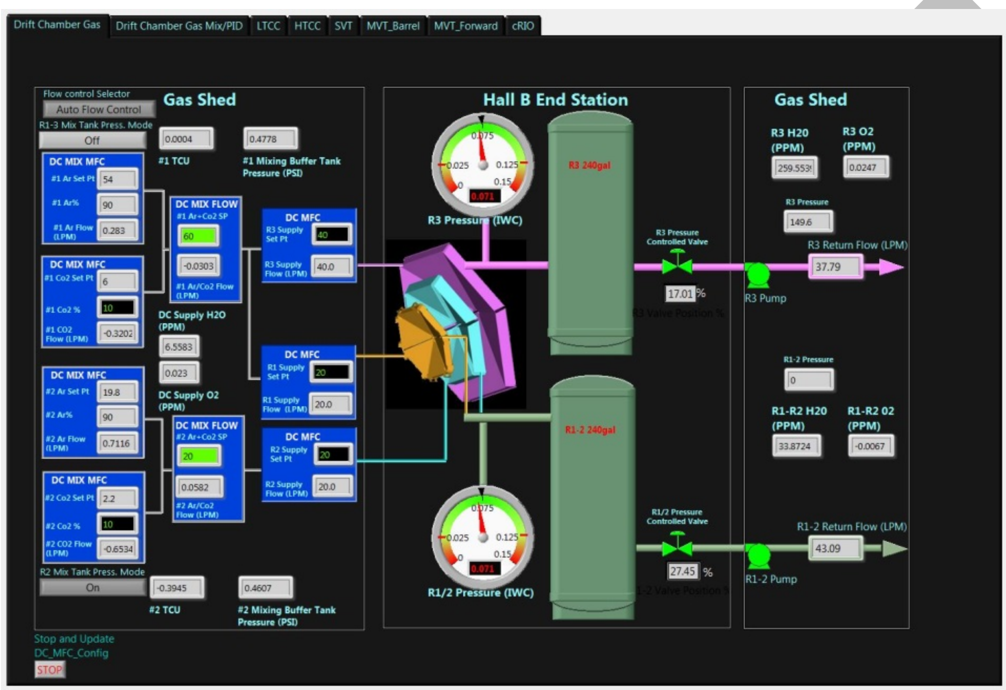


Figure 2 Hall B Gas Systems Controls GUI. The DC gas controls tab is shown.

Drift Chamber Gas Operation

Flowing and mixing gas

The DC gas system software provide flow control to the chambers by providing set points to three mass flow controller (MKS GE250), one for each DC region.

Flow Controls Operation (MFC Supply Set Point):

1. **Select the desired DC region, enter the value in the black lit set point field, and press return.**

2. **Observe the flow readback.**

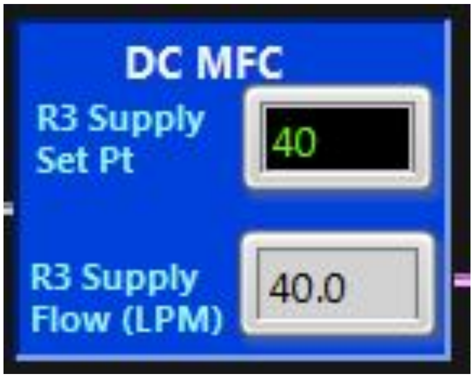


Figure 3 DC gas controls MFC control. All Hall B systems using MKS GE50/250 MFCs have similar controls interface.

Automatic Flow Control (**Regional Supply Set point** and **CO2%** are the operating controls)

During standard operations automatic flow control is used to control the flow of DC gas to the detector, the regional mass flow controller set points govern the mix flow controller set points.

Operational Steps:

1. **Switch the Flow Control Selector to Auto Flow Control by clicking it.**
   a. **Mix Tank Pressure mode switch will already be on.**
2. **Enter the desired amount of flow to the region in the black lit fields.**
3. **Ensure the CO2% of mix is set (10% is standard).**

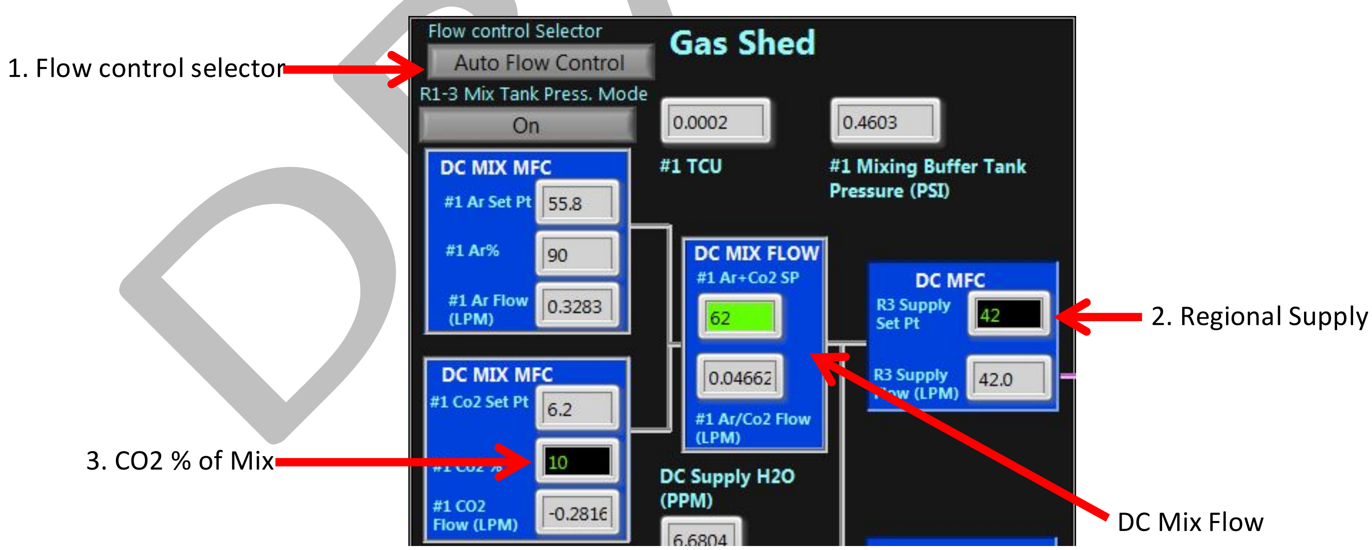


Figure 4. DC Gas Supply and Mixing using Automatic Flow Control.

Manual Flow Control (**Ar and CO2 Set points** are the operating controls)

All mass flow controller set points must be manually set to the desired flows. The operator must calculate the mix flow set points to match up with the regional supply flow set points.

Operational Steps (Gas Mix Change):

1. **Switch the Flow Control Selector to Manual Flow Control by clicking it.**
   a. **Mix Tank Pressure mode switch will already be on.**
2. **Enter the desired amount of flow to the appropriate Ar MFC in the black lit fields.**
3. **Calculate 10% of the total for the particular mix set (#1 or #2) and input this number to the CO2 set point.**
   a. **The flow percentage will display in the Mix MFC CO2% indicator. Verify the ration (90/10), and adjust accordingly.**
4. **To change the total mixture flow rate, adjust only the Ar. The CO2 will automatically adjust to maintain the ratio.**
5. **To adjust the ratio, change the CO2 flow rate. The Ar flow rate will not change; however, the mix flow rate will reflect the change.**
   a. **The gas percentages of the mix will display the new ratio.**

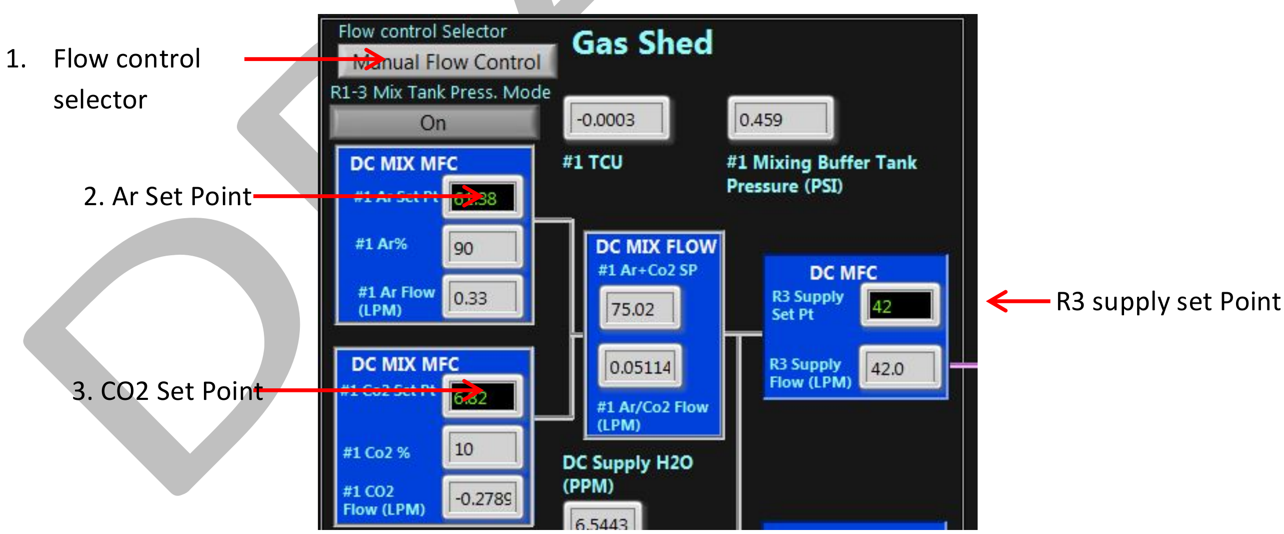


Figure 5 DC gas supply and mixing using Manual Flow Control.

Mix Tank Pressure Mode

During the all standard gas mixing and supply procedures the Mix Tank Pressure Mode selector is in the “ON” position. During certain operations (ie…the initial filling of the drift chambers) this mode should be switched to the “OFF” position by clinking the button.

During standard operations, Ar and CO2 gas flow is dependent on the pressure of the mixing buffer tanks. This mode monitors the pressure value, which is displayed with the #1 and #2 Mixing Buffer Tank Pressure, and adjusts the flow of the respective MFC. When the mixing buffer tank pressure is too high the gas mixing MFCs (Ar and CO2) flow amounts will decrease by 10%, if the pressure is too low the flow amounts will increase by 10%.

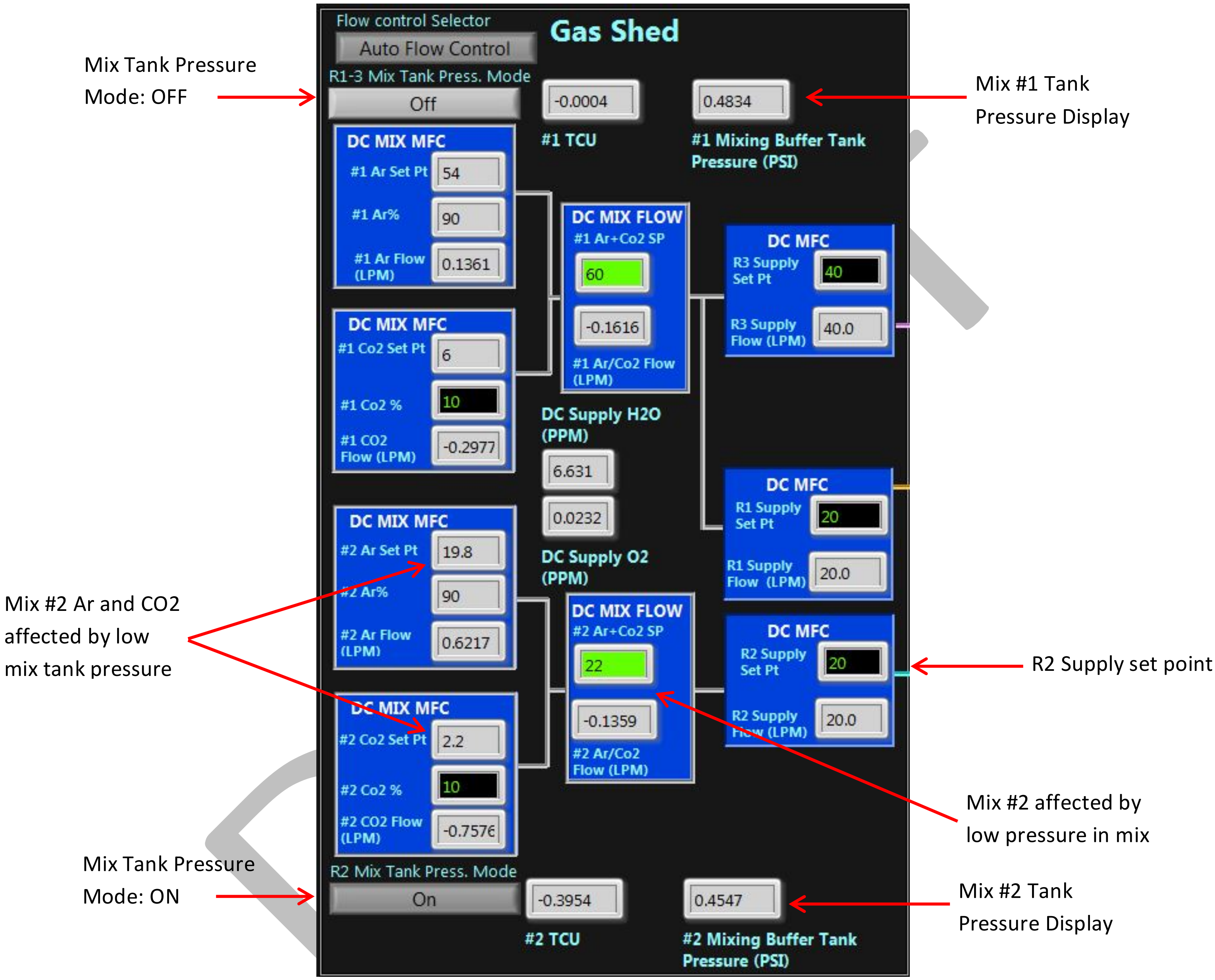


Figure 6 Mix Tank Pressure Mode effect shown. Low pressure has increased flow on Mix #2.

Pressure and Flow Controls

The Hall B 12GeV Drift Chamber gas system controls handle gas delivery and pressure controls using a set of National Instruments based controls platforms (cRIO 9035) which are independent of network or continuous human interface. Once the system is on and the parameters for flow and PID pressure control values have been set and optimized the system will run and maintain pressure and flow within the set points entered.

When properly shutdown the system controls will record the necessary values in configuration files to restore set points after a reboot of the system.

The drift chamber gas system is pressure controlled by a PID loop deployed on Chassis 1 (located on space frame level 3 south).The PID loop maintains pressure by controlling a parallel pair of valves per exhaust circuit. There are two exhaust circuits for the drift chamber R1-2 and R3. Each exhaust has a set of vacuum pumps located in the Gas Shed which continuously run. The PID controlled valves constant adjust to allow the vacuum to maintain the desired differential pressures between the chambers and the atmosphere of Hall B.

On the DC Gas Controls GUI, pressure controls can be observed by monitoring the pressure control gauges and the pressure controlled valves.

The gauge will display differential pressure in (inH2O), the pressure set point marker and high and low limit markers. The limit markers may be used as guidelines for good pressure which is controlled well within the limits of the DC Gas Pressure Safety System. **Currently, there is no alarm handling performed by the DC Gas Controls System software. These are handled by EPICS.** In addition to the gauges, the pressure control valve position can be monitor. These values constantly fluctuate during operation. There are vacuum pump controls on the GUI these should stay on (green) during normal operations.

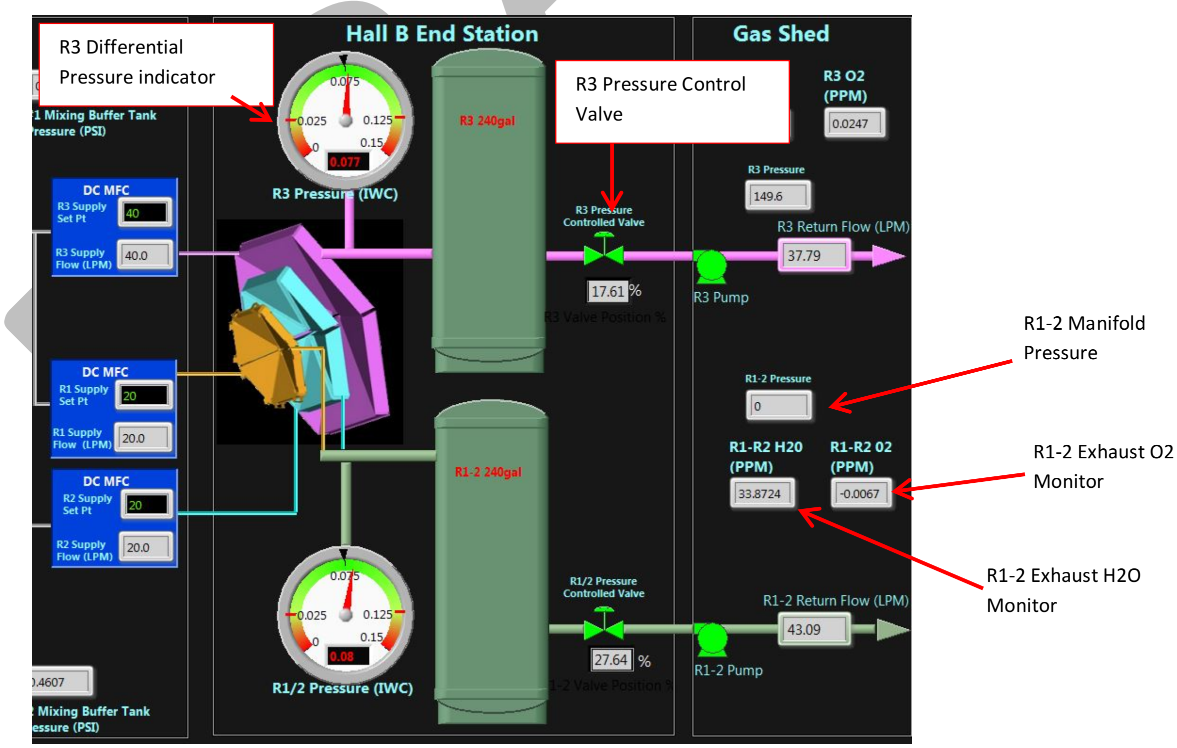


Figure 7 Supply controls and pressure controls instrumentation.

Other monitored values include supply and return O2 and H2O content. These values are used to confirm the quality of the mixture. Return flow and differential pressure from the manifolds can also be observed.

PID Control

Figure 8 PID Controls on Space Frame cRIO.

Two PID loops govern the DC gas pressure controls system. These loops are subroutines coded into the Space frame cRIO which read the differential pressure from the transducers on the gas panel and adjust the valve sets on the exhaust buffer tanks which are under vacuum from two banks of pumps in the gas shed. The vacuum creates the low side pressure needed to flow gas through the detector.

During commissioning set points for the differential pressure and PID gains will be established. Once set these gains should only be changed under the direction of the DC gas system subject matter expert. The set points will be contained and recalled from a configuration file installed on the Space Frame cRIO.

The set points will be changed by using the DC PID and Mix Calibration Tab on the DC Gas System Controls GUI.

Gas System Expert Tab (DC PID Controls and Mix Calibration)

This tab should only be used by qualified system experts. The system expert will use this page to change certain parameters which govern the PID and calibrate the gas mixtures.

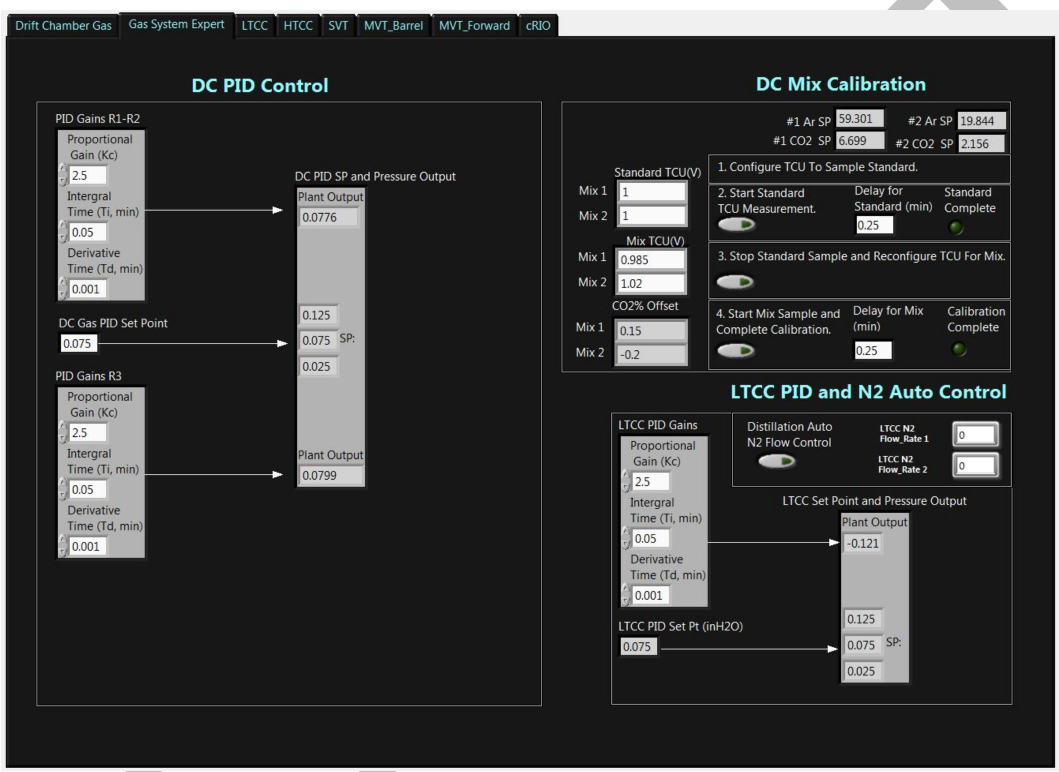


Figure 9 Gas system expert tab

DC PID Settings

Differential Pressure Set Point

The PID set point is the target differential pressure value for the software controls, the values are in inH2O. To change this setting select the DC Gas PID Set Point control and entering the set point.

PID Gains

To change the PID gains settings, simply select the desired control box and enter a value. There is a gain setting for Proportional, Integral, and Derivative for both of the exhaust channels for the drift chamber (R1-2, and R3) and the settings are independent.

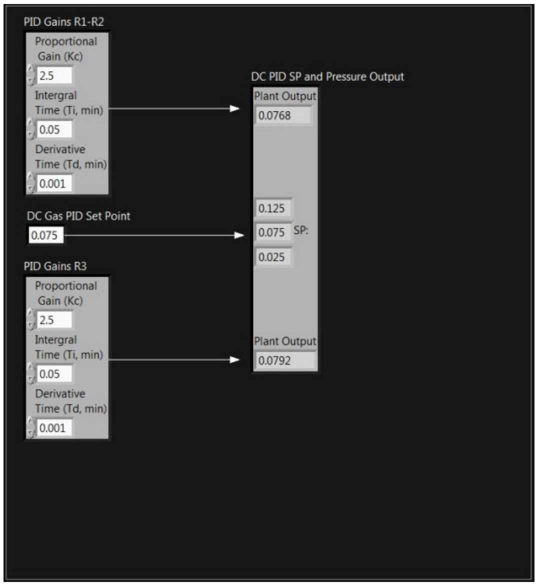


Figure 10 DC PID Controls

DC Mix Calibration

These controls should be used in conjunction with the manual valve operations described in the 12 GeV DC Gas Manual.

Operational Steps in Automatic Flow Control Mode

1. **Refer to the DC Gas Manual and configure the mix panel valves to sample from the premixed standard.**
2. **In the DC PID and Mix Calibration click on the Start Standard TCU Measurement button. After the programmed amount of time (20min) the Standard TCU(I) indicator will register the sample measurement. It will be between 0V and 10V. Upon step completion the indicator will light.**
3. **Click on Stop Standard Sample and Reconfigure TCU For Mix. Refer to the DC Gas Manual and reconfigure the mix panel valves to sample from the mixed DC gas.**
4. **Click on the Start Mix Sample and Complete Calibration button. After the programmed amount of time (20min) the TCU Reading will be registered in the Mix TCU(I) indicator and compared to the sample and produce a CO2% offset value. Upon completion the indicator will light for 3 seconds and all start buttons will deselect. The mix MFCs will be automatically adjusted by the offset and the calibration process will be complete.**
5. **Visually compare the current TCU value on the Drift Chamber Gas tab to the Standard Sample value in the expert tab.**
6. **Repeat from step 1 if necessary.**

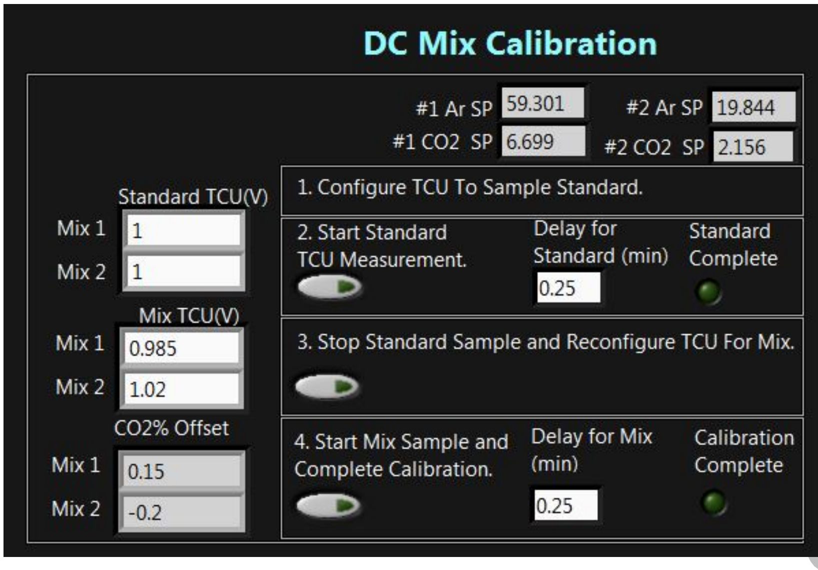


Figure 11 DC Mix Calibration used in Auto Flow Control mode.

Operational Steps in Manual Gas Mixing Mode (see Manual Flow Control Section)

1. Select Manual Flow Control mode by clicking the flow control mode selector.
2. Refer to the DC Gas Manual and configure the mix panel valves to sample from the premixed standard.
3. After 20 minutes record the TCU value.
4. Select the appropriate (Mix #1 or #2) CO_2 flow control and change the flow by entering the desired flow. The change should be in small amounts (a 1% change in flow should alter the TCU current reading by ~0.00016A) and the change is not immediate.

5. **Wait approximately 20 minutes to observe the change in TCU reading.**

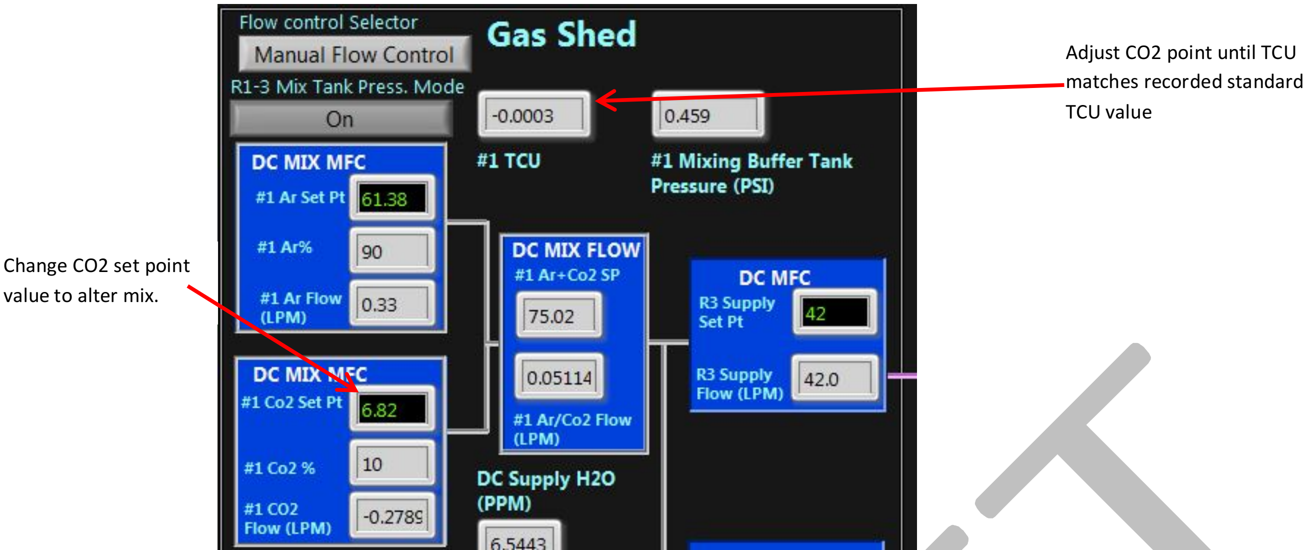


Figure 12 Manual Flow Control method of calibrating mixture

LTCC Gas Operations

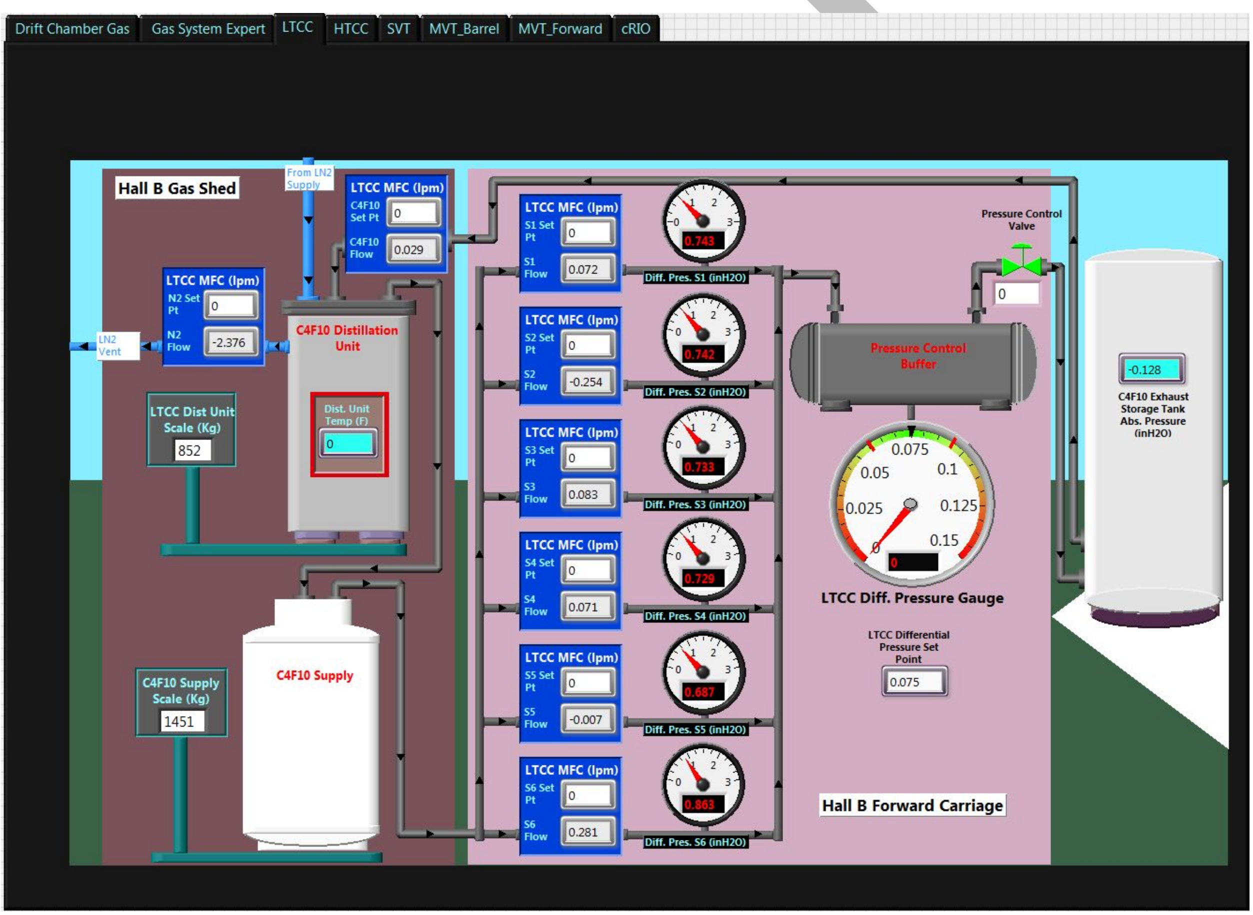


Figure 13 LTCC gas controls tab.

The Low Threshold Cerenkov Counter is a complex gas system which flows C4F10 to six sectors during physics operations, however, the system must be purged with N2 before filling the detectors with C4F10. Additionally, the C4F10 is expensive and must be recovered and recycled to keep operational cost reasonable.

Operating the LTCC requires constant manual operations to run the different modes of the system. The LTCC gas controls portion of the Hall B Gas Controls software will require more human actions in conjunction with the manual steps.

Purging Gas

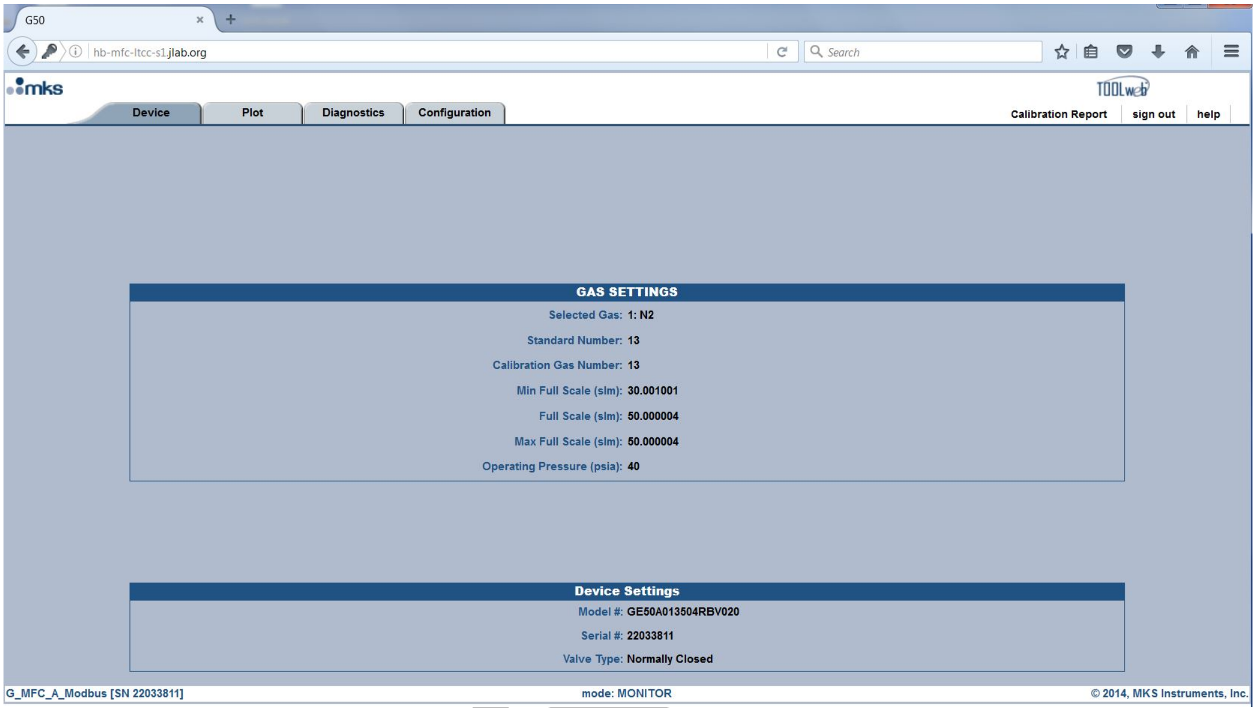
The LTCC needs to be purged with N2. During the purging steps the mass flow controllers **MUST** to be set to flow N2 instead of C4F10. To do this you must log into the mass flow controllers web page and change the selected gas in the gas settings section of the device tab.

FLOWING N2 WHILE THE MFC GAS CORRECTION FACTOR IS SET FOR C4F10 COULD DAMAGE THE DETECTOR WINDOW.

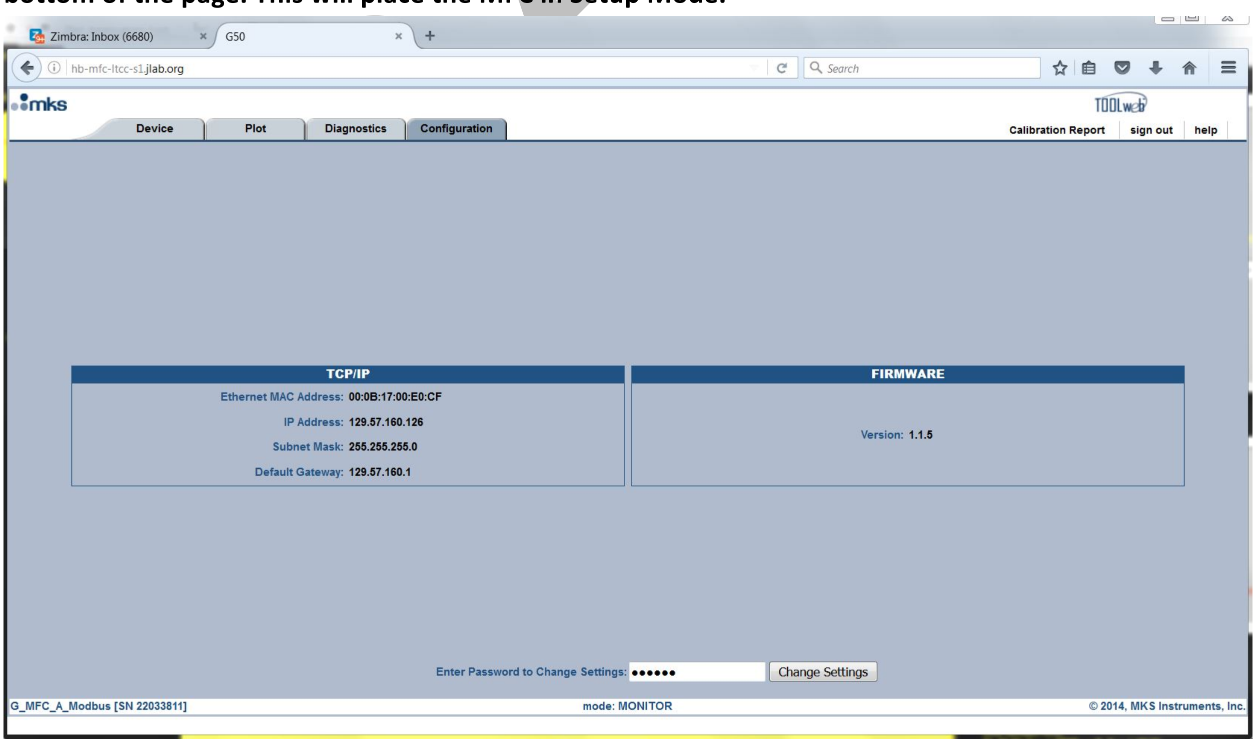
Adjusting MFC Gas Selection

Operational Steps

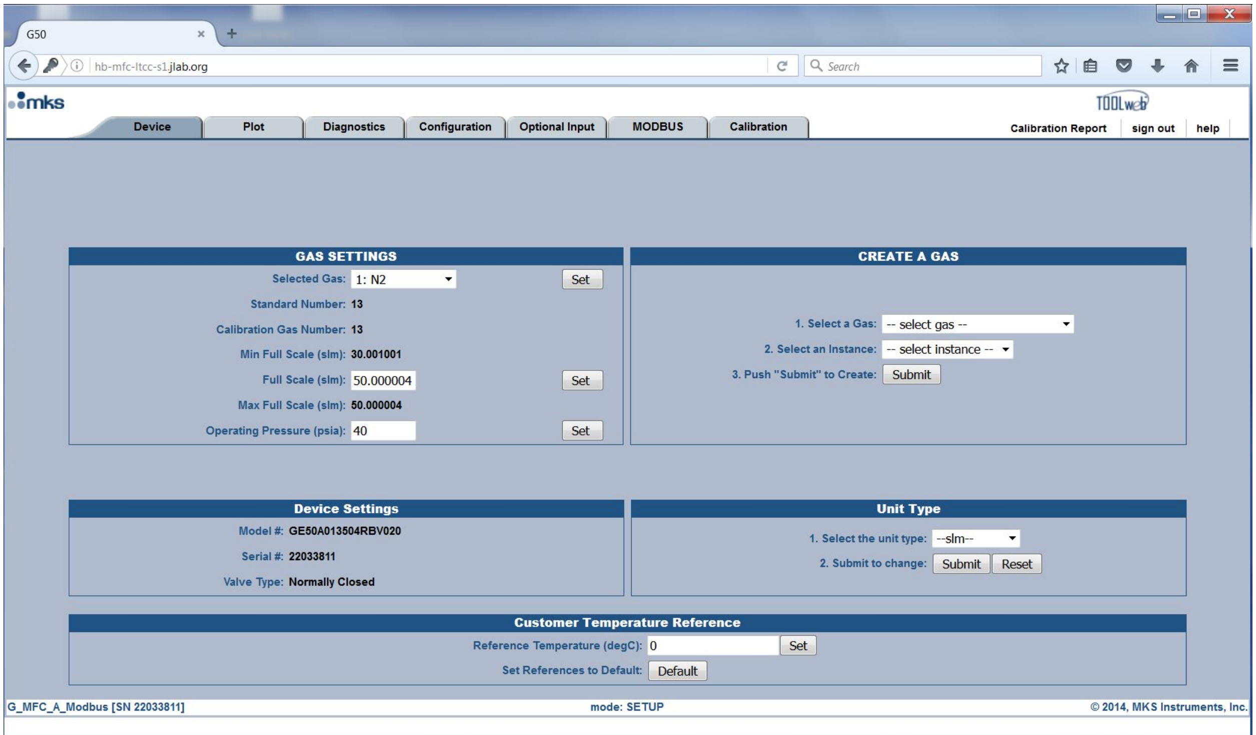
1. **Open a web browser on a computer in the gas shed.**
2. **Type in the address to the mass flow controller in the address bar of the web browser.**
   a. **Example: hb-mfc-ltcc-s1.jlab.org**



3. **Click on the Configuration tab and enter the password "config" in the password box at the bottom of the page. This will place the MFC in Setup Mode.**



4. **Select the Device tab. In the Gas Settings section, click on the Selected Gas drop box, select "1: N2", and click on the Set button directly to the right.**
   a. **A green banner will let you know that the selected gas has been updated.**



5. **Click the Sign Out selection in the upper right corner of the page.**
6. **After purge is complete, follow the same steps to change the gas back to C4F10.**

Gas Supply

The LTCC gas system uses six GE250 mass flow controllers to supply C4F10 or N2 to the six sectors. Operating the mass flow controllers is the same operation used in supplying gas to the Drift Chamber.

Operational Steps

1. **Select the desired LTCC sector, enter the value in the set point field, and hit return.**
2. **Observe the flow readback and sector pressures.**

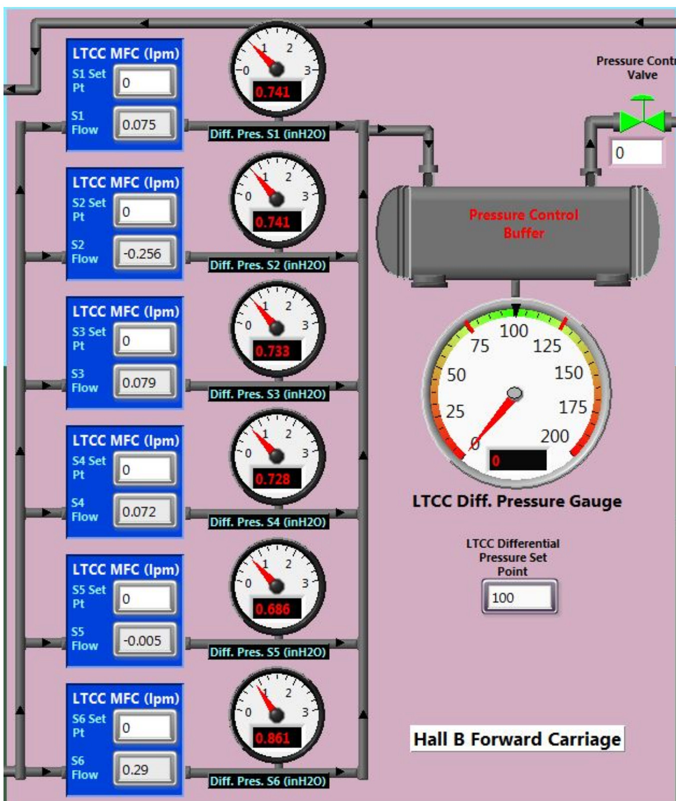


Figure 14 LTCC sector flow controls and differential pressure indicators.

Pressure Control

The LTCC buffer tank controls overall system pressure in the same manner as the Drift Chamber system, using the differential pressure signal from a single MKS223 pressure transducer and a PID loop to control a valve.

PID Gains

The LTCC PID gain settings are located on the Gas System Expert tab (see fig 16). To change the PID gains settings, simply select the desired control box and enter a value. There is a gain setting for Proportional, Integral, and Derivative for the of the exhaust circuit of the LTCC.

Differential Pressure Set Point

The PID set point is the target value for the software controls, the value is in inH2O.

Operational Steps

To change this setting select the LTCC PID Set Pt control and entering the set point.

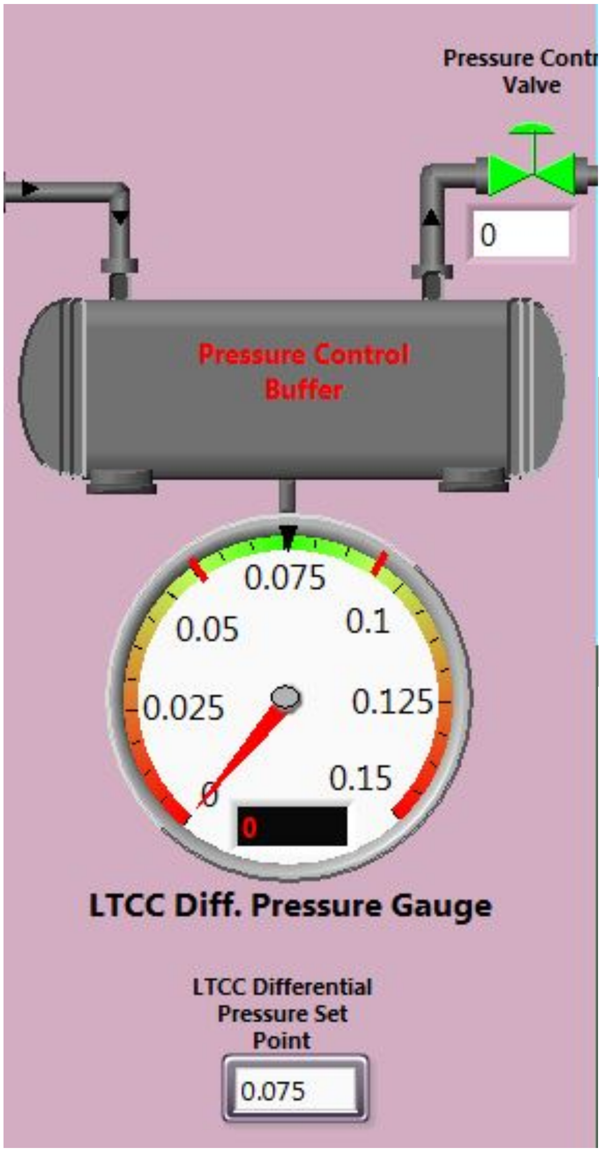


Figure 15. LTCC gas controls tab, PID pressure set point control area pictured.

C4F10 Distillation and Recovery

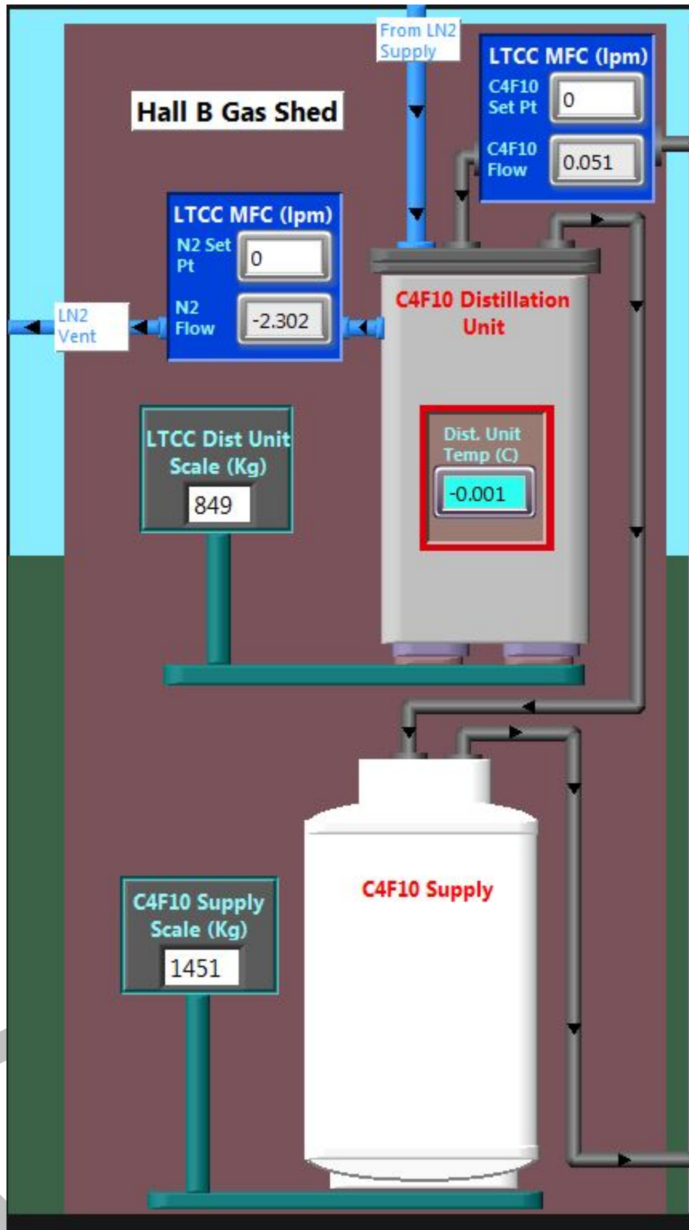


Figure 16 Distillation Unit and C4F10 Supply tank.

Automatic Distillation Control

Distillation and recovery of the C4F10 is an expert level operation, and has many manual steps which are covered in the **LTCC Gas System Manual.** During this process, large volumes of nitrogen must flow beyond the capacity of the LTCC N2 mass flow controller until the temperature of the C4F10 is -1(F). At that point gas controls system can be used to automatically control the flow of the N2 MFC.

During Distillation Auto N2 Flow Control, the N2 has two flow rates LTCC N2 Flow_Rate 1 and 2. These flow rates are will be predetermined by the DSG Gas System subject matter expert.

Operational Steps

To start the automatic flow of N2; locate the LTCC PIC and N2 Auto Control section of the Gas System Expert tab (lower right area) and click on the Distillation Auto N2 Flow Control button.

When the auto mode is selected, Rate 1 flows from -1F down to -35F, at that point the flow changes to Rate 2.

When the mode is not selected the N2 MFC becomes manual and can be set to a desired flow rate.

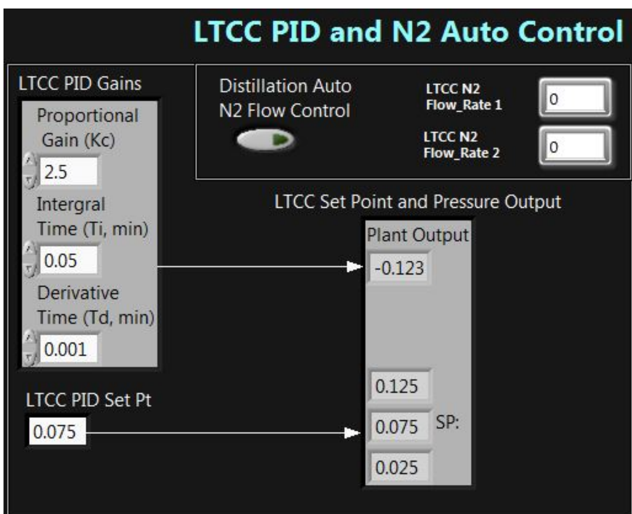


Figure 17 LTCC controls on Gas System Expert screen, Distillation unit automatic flow controls pictured.

When the mode is not selected the N2 MFC becomes manual and can be set to a desired flow rate.

After the temperature in the distillation unit reaches the value prescribed in the LTCC Gas manual, the C4F10 MFC should be adjusted to flow gas into the distillation unit.

Operational Steps

Enter the desired flow into the set point field of the C4F10 MFC. The maximum flow for this step is 4.5 (SLM).

SVT

The Silicon Vertex Tracker uses a nitrogen purge to mitigate humidity detector. The N2 purge is supplied by the Hall B nitrogen supply, via a GE50a mass flow controller. The flow rate is to achieve acceptable humidity in the detector is relatively low, during the Hall B noise test the flow rate was set to 1.5 liters per minute.

Operational Steps

Setting the flow on the MFC is the same as setting the regional supply flow for the Drift Chamber, by entering the desired flow in the N2 Set Pt. control field.

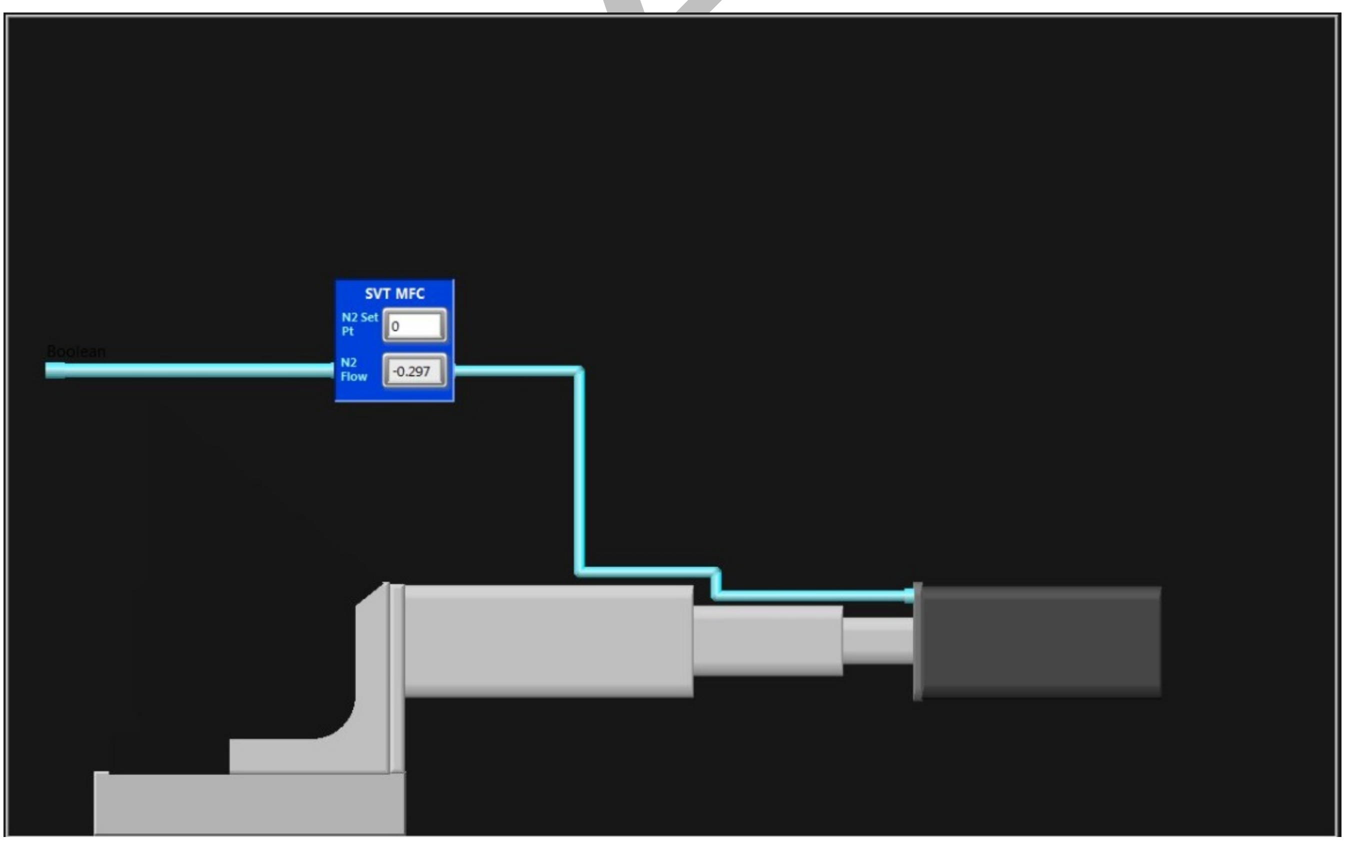


Figure 18. SVT N2 flow controller.

HTCC CO2 Purge

The High Threshold Cherenkov Counter uses CO_2 to maintain humidity and pressure inside the 18K liter detector. The gas controls for this detector includes a GE250a mass flow controller. Differential pressure and moisture are also monitored in the detector volume and displayed on the HTCC tab.

Operational Steps

To change CO2 flow, enter the desired flow in the CO2 Set Pt control field and monitor the flow on the indicator.

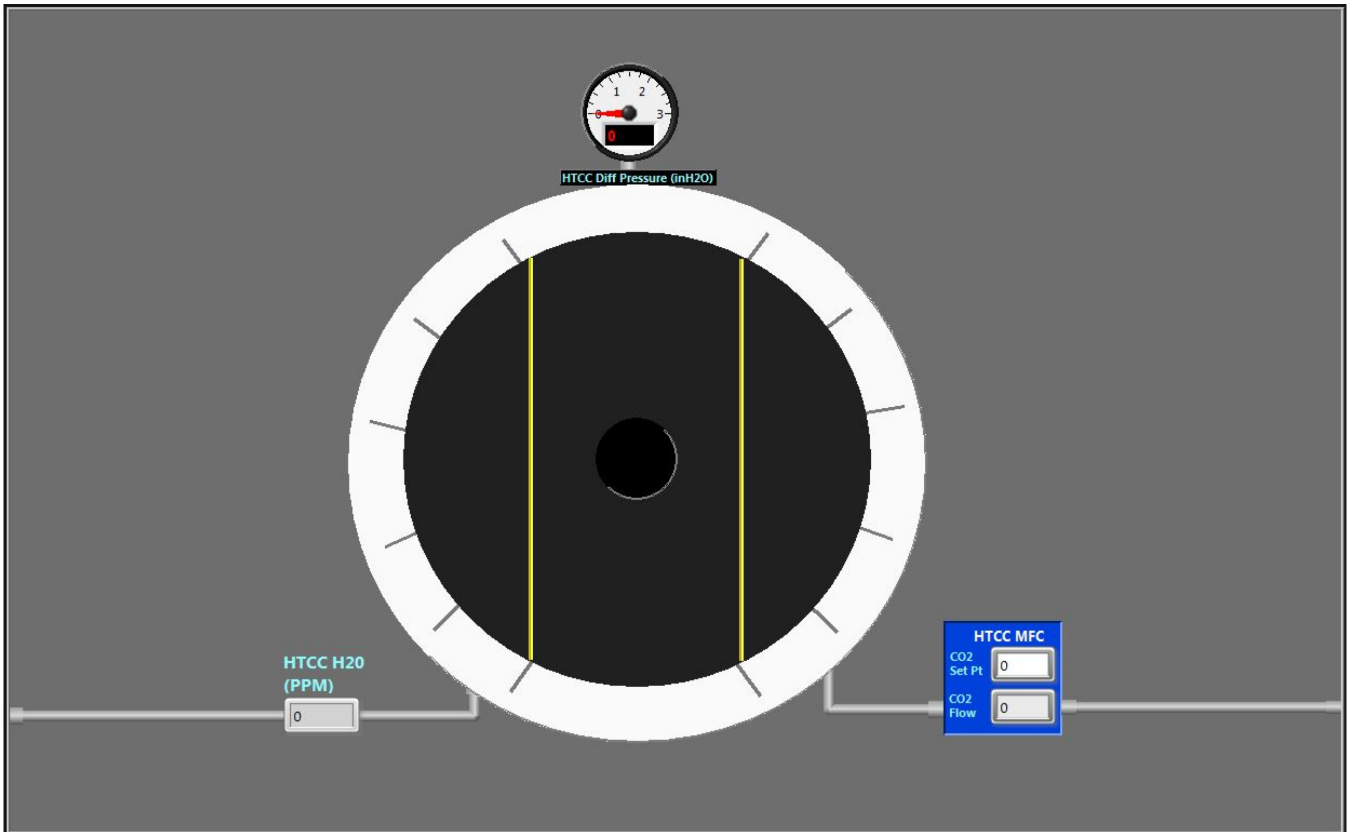


Figure 19 HTCC Gas Controls tab

MVT and FT Gas Supply

The Hall B Gas Controls system will supply a pressure controlled gas mixture to the Micromegas Vertex Barrel and Forward Trackers. Additionally, the Forward Tagger MVT tracker will receive its gas supply from the same mixture as the MVT barrel.

The MVT Forward gas supply mixture consists of a 10% C4H10 and 10% CF4 in a balance of Argon. The barrel mixture is a 10% C4H10 in a balance of Argon.

Both systems are run using automated controls sequencing subroutines to minimize human error. The systems require human interface to start. A sequenced series of gas purges will be initiated from the selection of the start button for both system startup and shutdown. The systems subroutines will monitor the flow of the purging gases and trigger sequence steps based on the metered flow of the gases.

The system will also monitor EPICS signals from the Saclay PLC. The system shutdown sequence will be initiated when a downstream leak is detected by the PLC.

Operational Steps

To start the system press SYSTEM START for the desired subdetector (either MVT Barrel/FT or MVT Forward).

To stop the system down press SHUTDOWN for the desired subdetector.

The system mass flow controllers can be manually adjusted by entering the desired flow in the setpoint field.

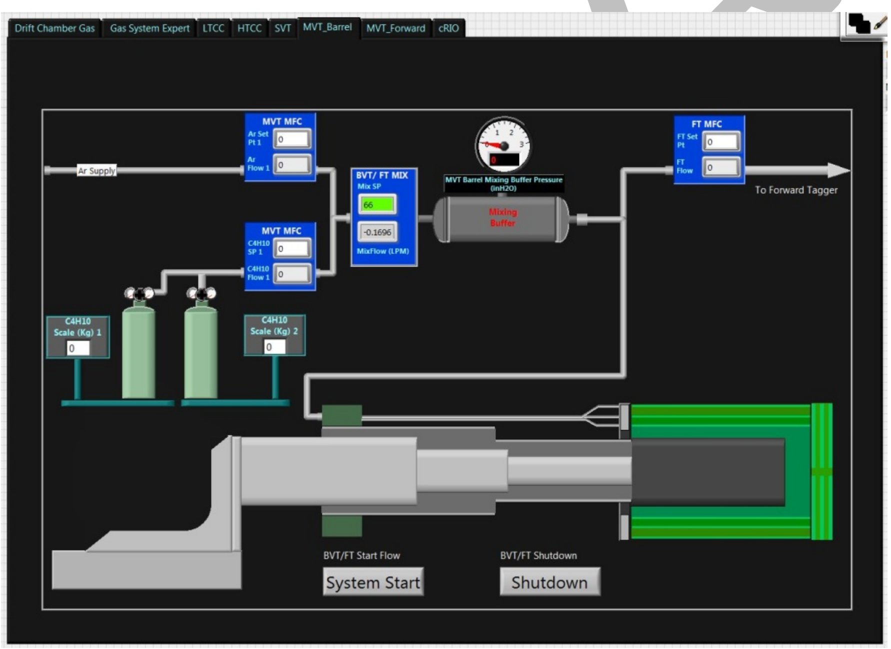


Figure 20 MVT Barrel and FT Controls

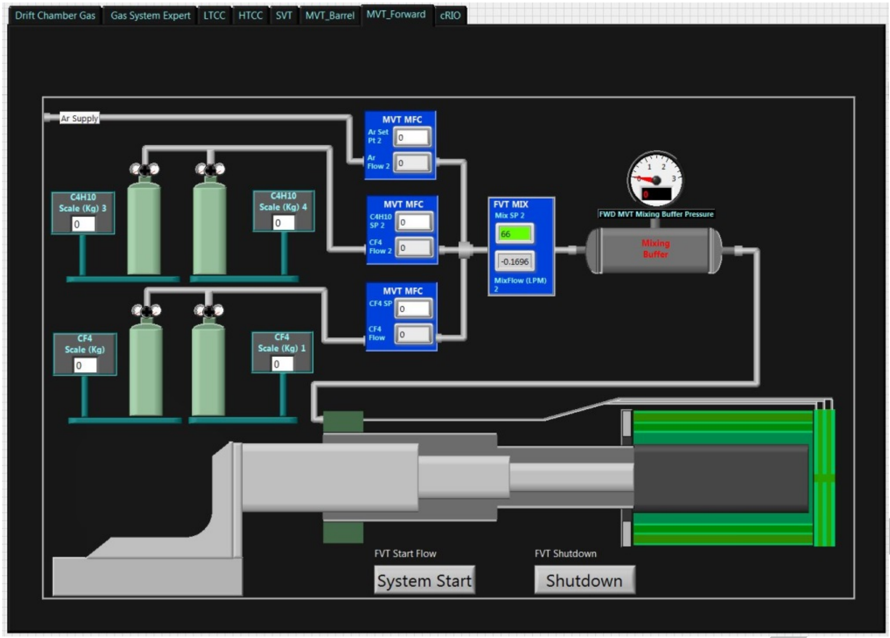


Figure 21 MVT Forward Controls

With the exception of Argon, all MVT gasses are supplied from liquid bottles which must be changed out when they approach empty. The weights of the bottles are displayed on the MVT/FT tabs of the gas controls GUI. Refer to the MVT gas manual for bottle change procedures.

RICH

The RICH detector utilizes two interlock systems for operations. Dry air is delivered from two Atlas Copco compressors via a pressurized storage tank (located on the forward carriage) to cool the electronics. Additionally, dry nitrogen is supplied from the Hall B nitrogen manifold to mitigate moisture saturation of the Aerogel. The functionality of these two systems are displayed by the Hall B gas controls system along with other signals such as humidity, tank pressure, and temperature are displayed on the RICH gas tab.

There are no gas controls for the RICH. All gas flow values are produced by transducers. The displayed signals are originated from the RICH interlock system as displayed by EPICS.