Hall B Gas System Controls Software

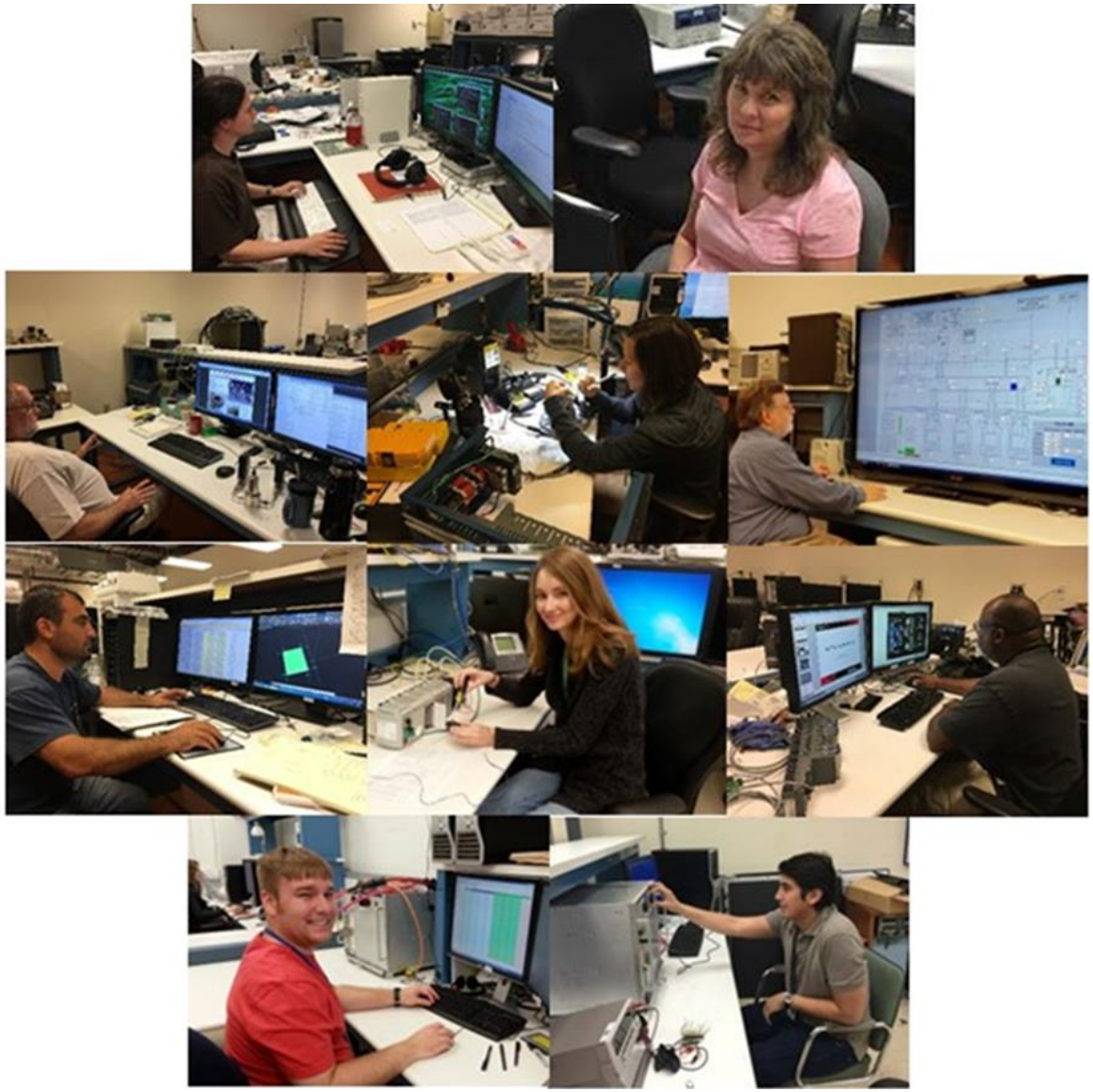
Marc McMullen
Physics Detector Support Group

Hall B Gaseous Detectors

1. Drift Chamber (DC)
2. Low Threshold Cherenkov Counter (LTCC)
3. High Threshold Cherenkov Counter (HTCC)
4. Silicon Vertex Tracker (SVT)
5. Micro-Megas Vertex Tracker (MVT)
6. Forward Tracker (FT)
7. Ring Imaging Cherenkov Counter (RICH)

- Controls developed for detectors 1— 4
  — In development for 5 — 7

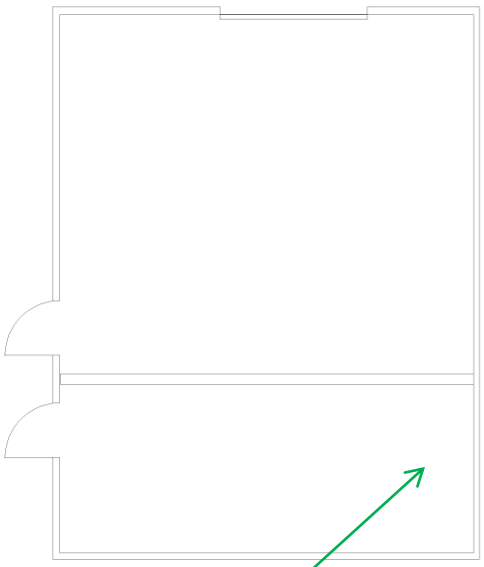
DSG Staff



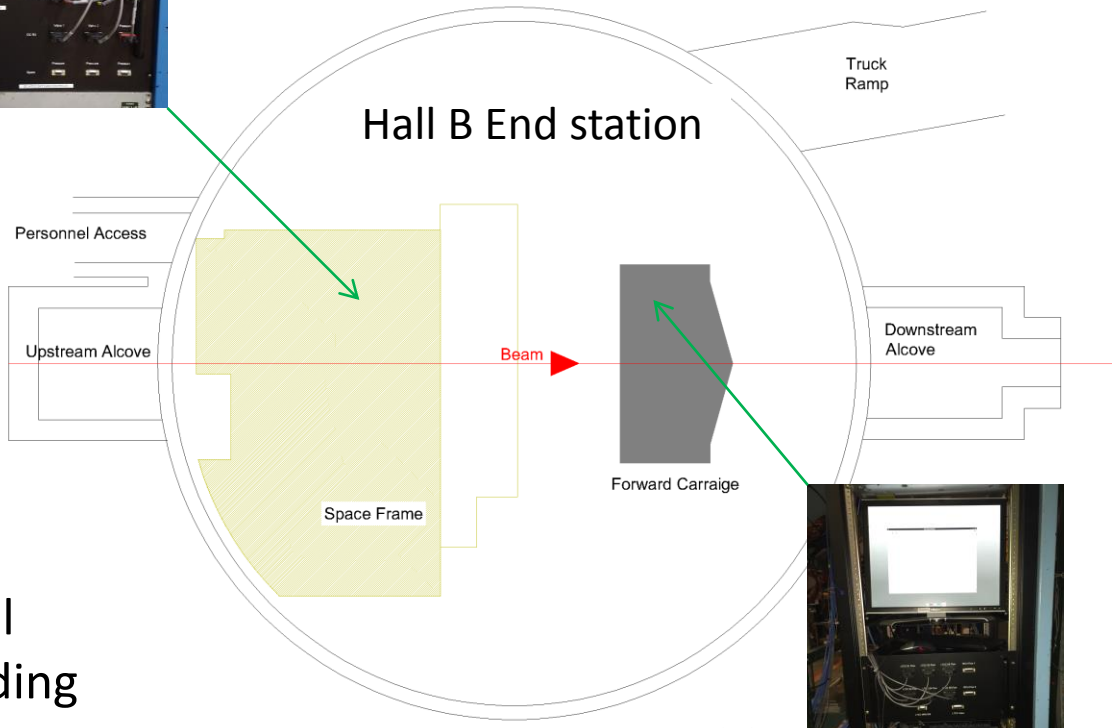
Hall B Gas Controls: Network and System

- Hall B's gas system controlled by three controls and monitoring stations
  - System works over slow controls network (160)
    - Operational control from the gas shed
    - Process variables provided to EPICS (user monitoring, alarms, data logging)

Hall B Gas Controls: System Locations



- DC
- SVT
- HTCC



- Controls for all systems including MVT and FT

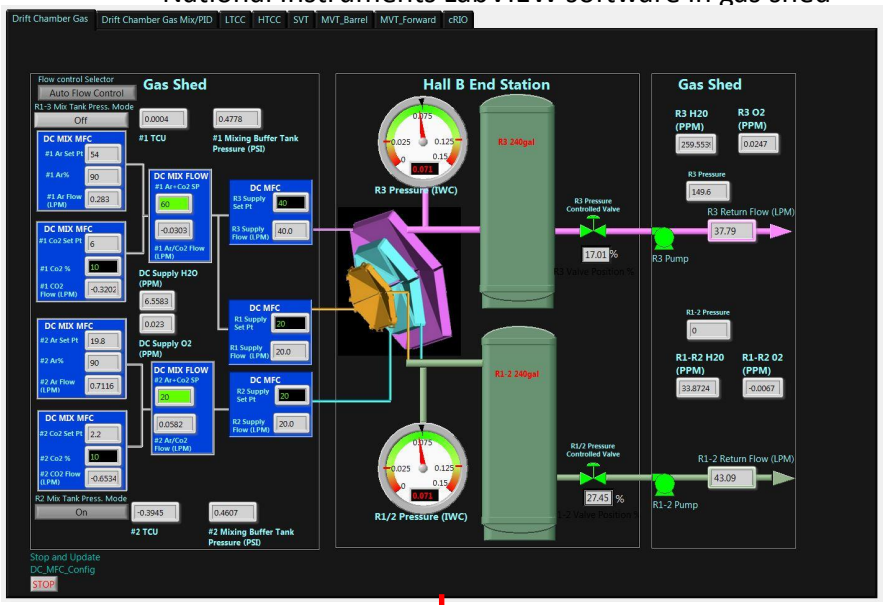
- LTCC
- RICH

Hall B Controls Setup

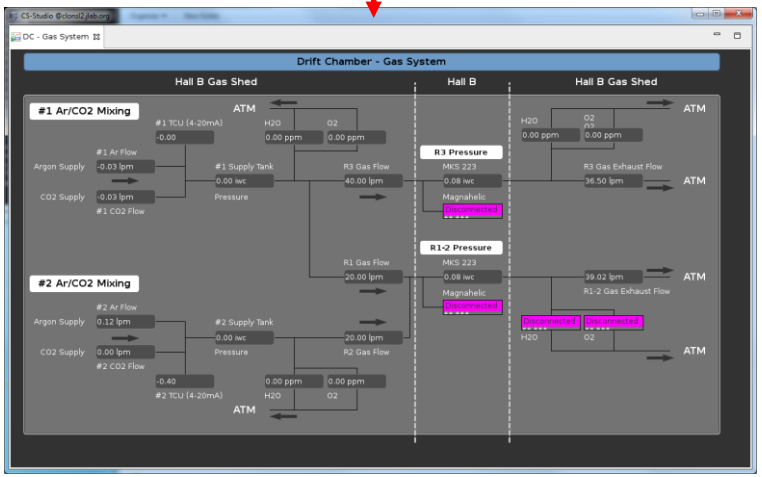
National Instruments compactRIO DAQ and controls

Custom controls interface chassis with touchscreen monitor

National Instruments LabVIEW software in gas shed



Process variables to EPICS

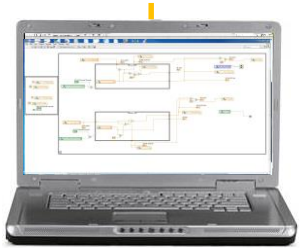


Hall B Gas Controls: Components

Network switch

LabVIEW code

Gas flow control and monitoring



LabVIEW code

Gas flow monitoring

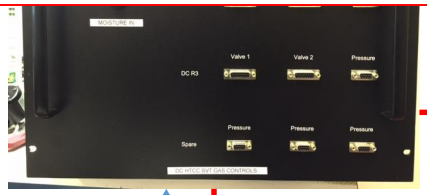
NI 9035 cRIO

PC with LabVIEW software

GUI controls

Compact Reconfigurable I/O: Programmable Automation Controller

Gas controls interface chassis



MFC power

MKS GE50/250 Mass Flow Controller

Sensor signal

Sensor power

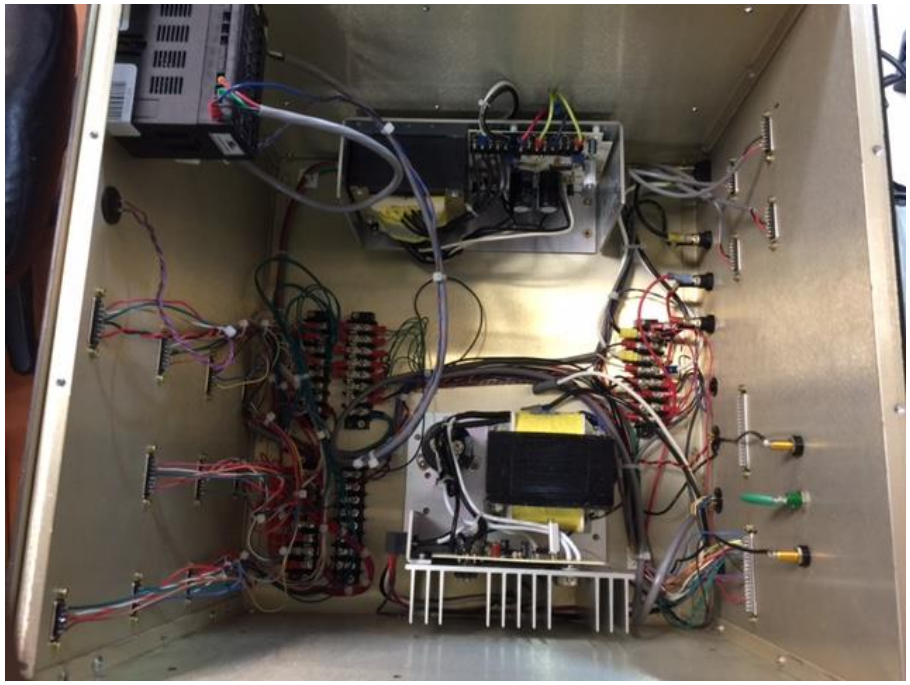
System sensor

Hall B Gas Controls: Interface Chassis

Chassis front panel

Chassis rear panel

- Interface Chassis provides connection between :
  - System sensors and valve controllers to the I/O modules for the cRIO
  - Power to mass flow controllers and system sensors

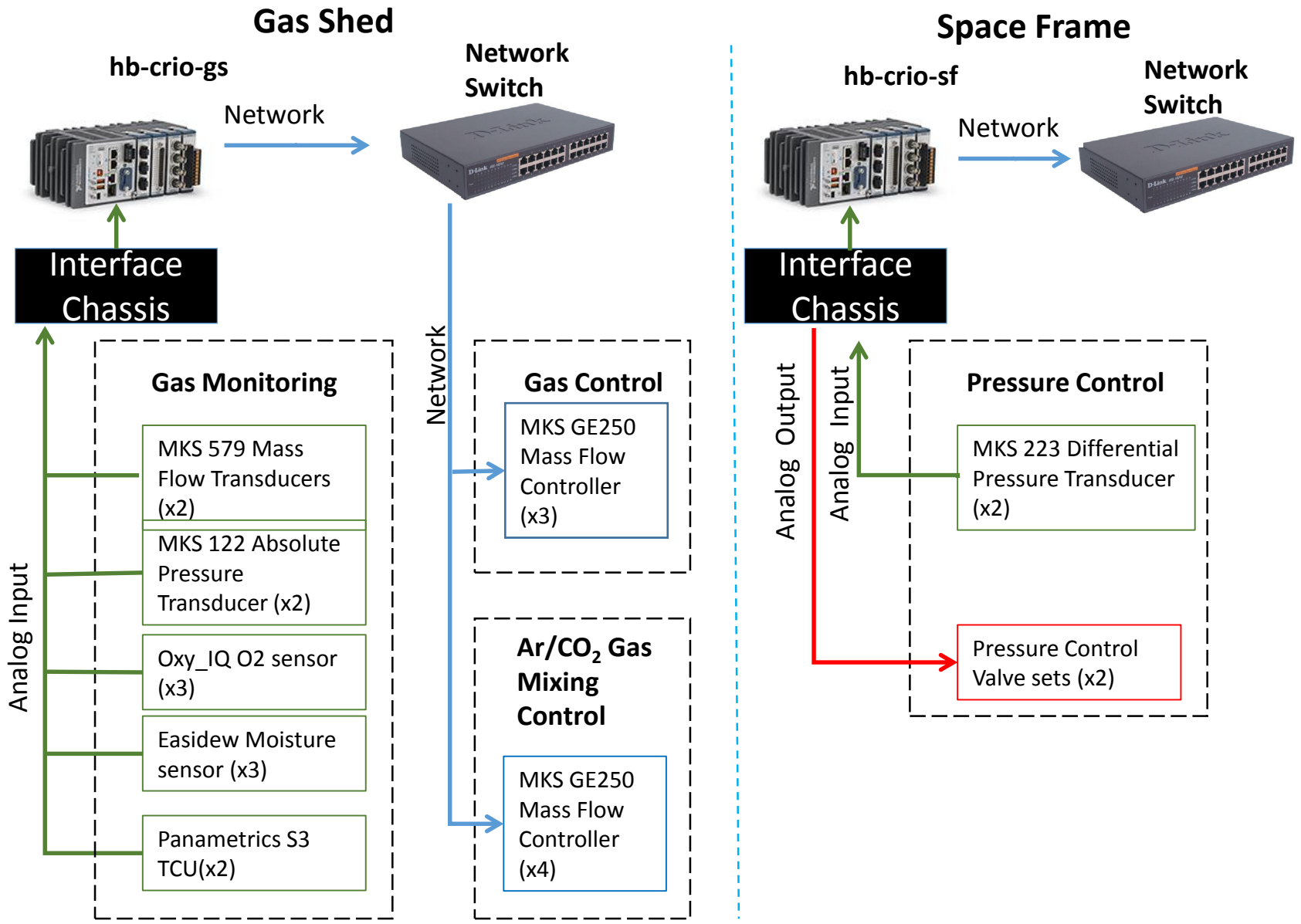


Chassis inside

Hall B Gaseous Detectors

1. **Drift Chamber (Ar and CO_2)**
2. Low Threshold Cherenkov Counter
3. High Threshold Cherenkov Counter
4. Silicon Vertex Tracker
5. Micro-Megas Vertex Tracker
6. Forward Tracker
7. RICH Detector

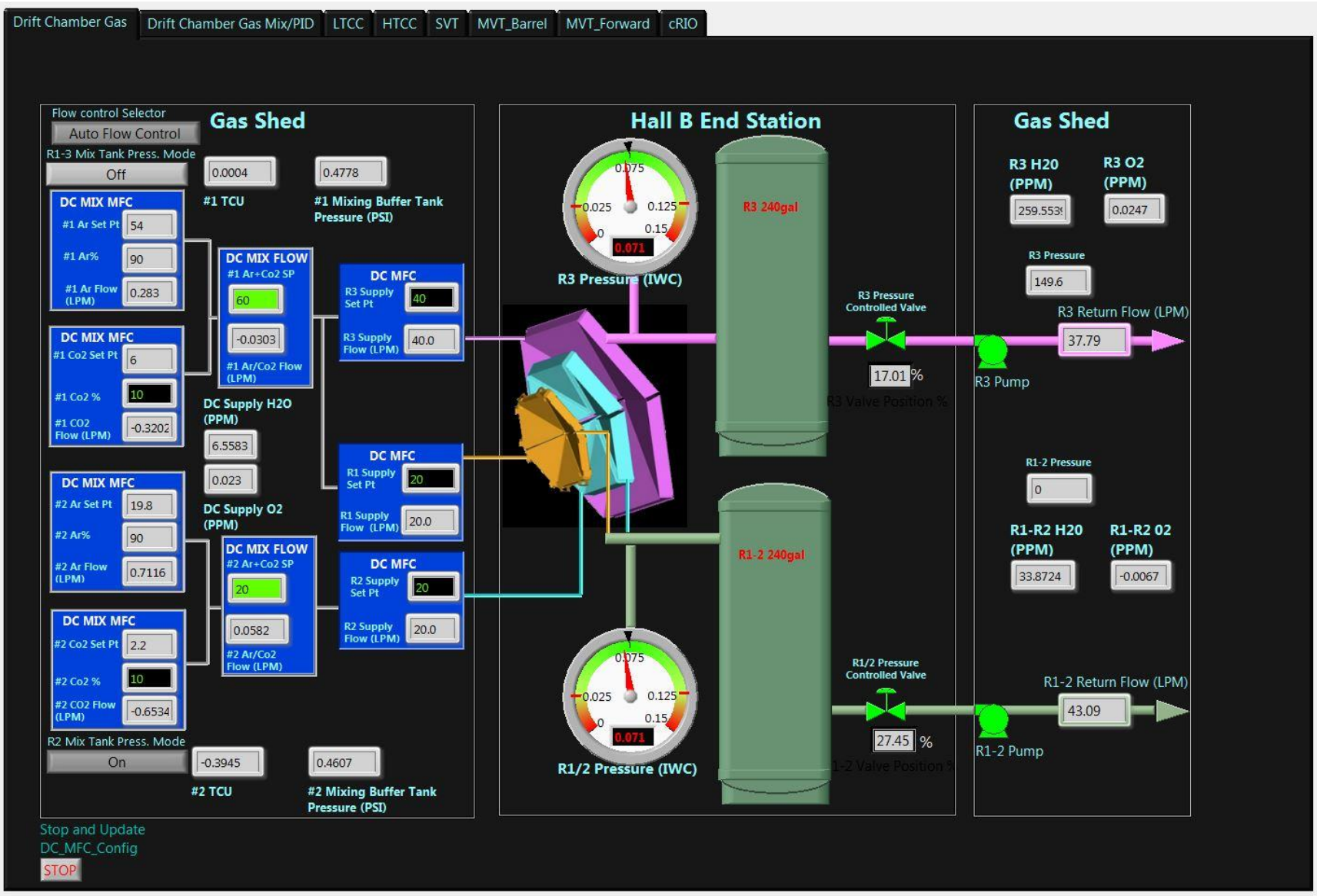
Hall B DC Gas Controls: Instrumentation



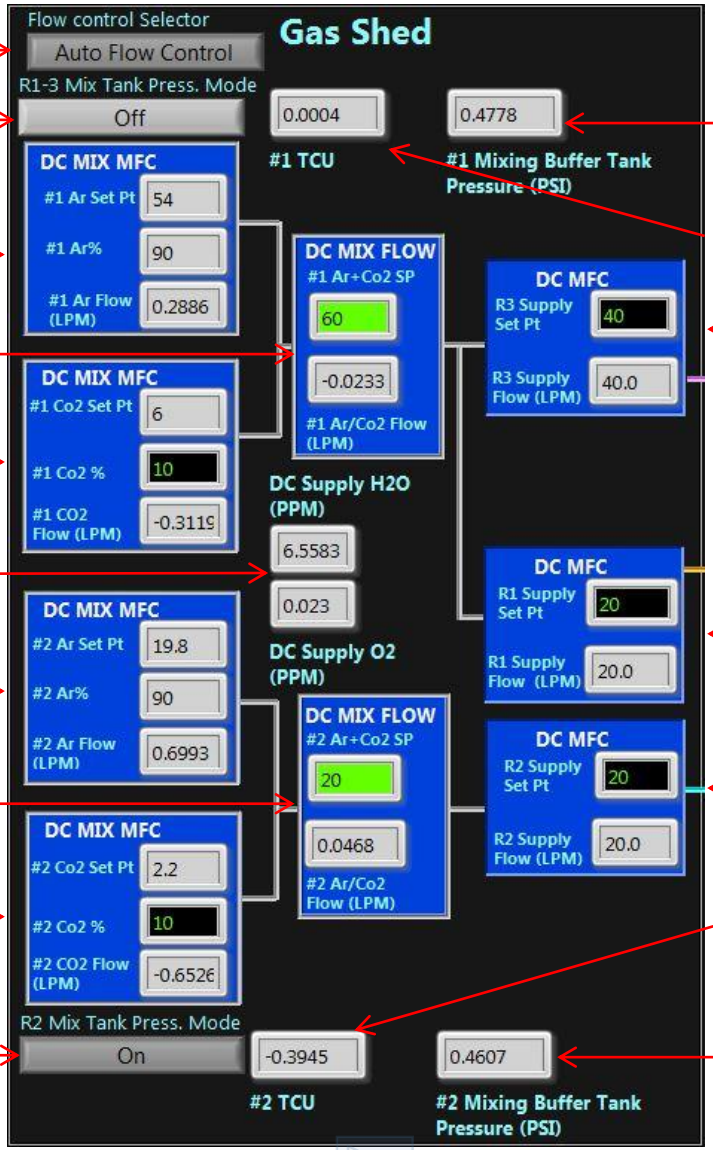
Drift Chamber Gas Controls: Signals

- Mass Flow Controllers (x7)
  - Mix #1 Ar
  - Mix #1 CO_2
  - Mix #2 Ar
  - Mix #2 CO_2
  - R1 Supply
  - R2 Supply
  - R3 Supply
- Moisture Sensors (x3)
  - R1/3 Supply
  - R1/2 Return
  - R3 Return
- Oxygen Sensors (x3)
  - R1/3 Supply
  - R1/2 Return
  - R3 Return
- Mass Flow Transducers (x2)
  - R1/2 Return
  - R3 Return
- Pressure Transducers (x6)
  - R1/2 Return (Differential)
  - R3 Return (Differential)
  - Mix #1 Buffer Tank (Absolute Value)
  - Mix #2 Buffer Tank (Absolute Value)
  - R1/2 Return (Magnehelic)
  - R3 Return (Magnehelic)
- Thermal Conductivity (x2)
  - Mix #1
  - Mix #2

DC Gas Controls: GUI



DC Gas Controls: Gas Shed Controls



Flow Control Selector

Mix 1 Tank Pressure Mode

Mix #1 Ar MFC

Mix #1 Flow

Mix #1 CO_2 MFC

Supply H_2O and O_2 Sensors

Mix #2 Ar MFC

Mix #2 Flow

Mix #2 CO_2 MFC

Mix 2 Tank Pressure Mode

Mix #1 Buffer Pressure

Mix 1 Thermal Conductivity Unit

Reg. 3 Supply MFC

Reg. 1 Supply MFC

Reg. 2 Supply MFC

Mix 2 Thermal Conductivity Unit

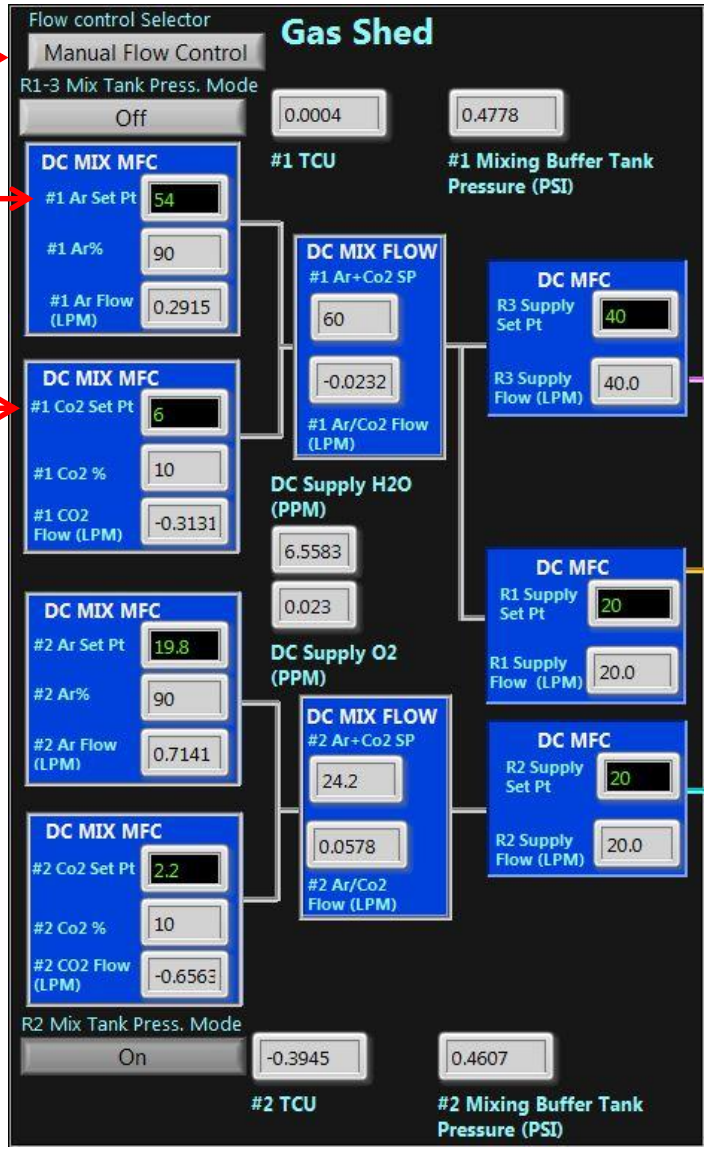
Mix #2 Buffer Pressure

DC Gas Controls: Mixing Gas (Manual Mode)

Manual Mode Selected

Argon set point active

CO_2 set point active



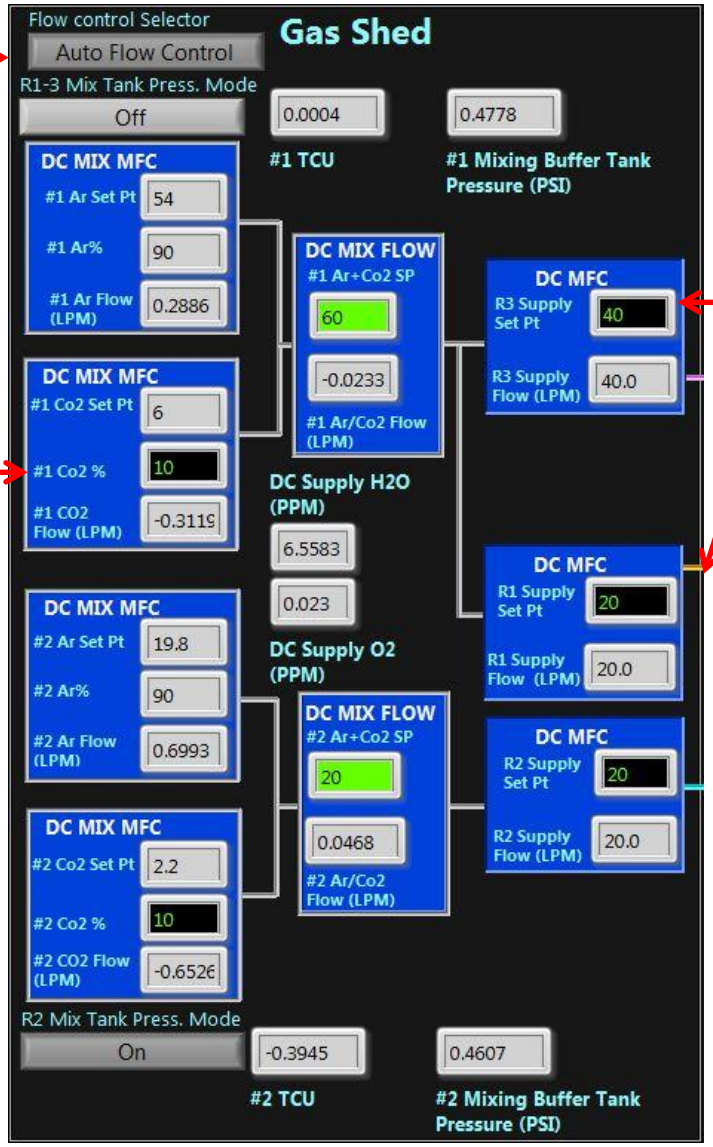
During manual flow control, set points for each mass flow controller are entered via the black lit controls box. Each mix has an argon and a CO_2 flow controller. After initial values are entered for each, mix flow is increased or decreased by changing the value of argon.
The CO_2 value will change to keep the ratio as originally set.

To change the ratio, enter a new value for a desired CO_2 flow controller. The mix ratio will be affected by the amount of change, the percent display will reflect the change. This will also change the mix flow amount, however, the argon set point and flow will stay the same.

DC Gas Controls: Mixing Gas (Automatic Mode)

Auto Mode Selected

CO_2 % set point active



Region supply MFC controller automatically sets mix flows.

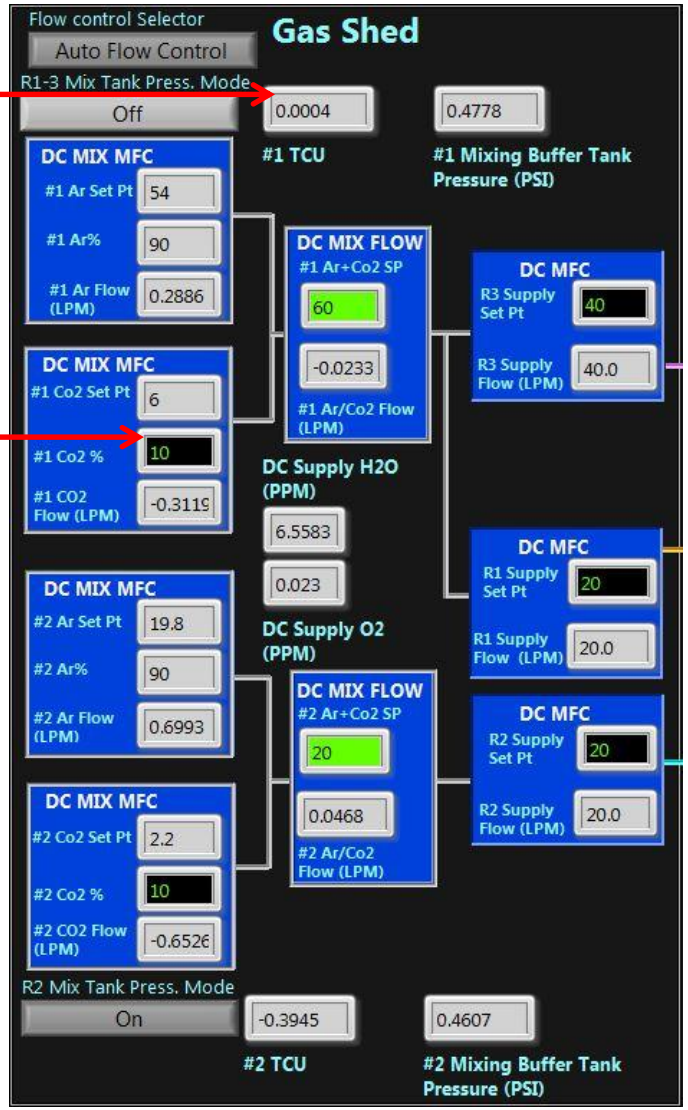
During automatic flow control, the regional mass flow controller set points govern the mix flow controller set points.

The mixture ratio is changed by adjusting the CO_2 % of the mix.

DC Gas Controls: Mixing Gas

Thermal Conductivity Unit (TCU)

CO_2 % control



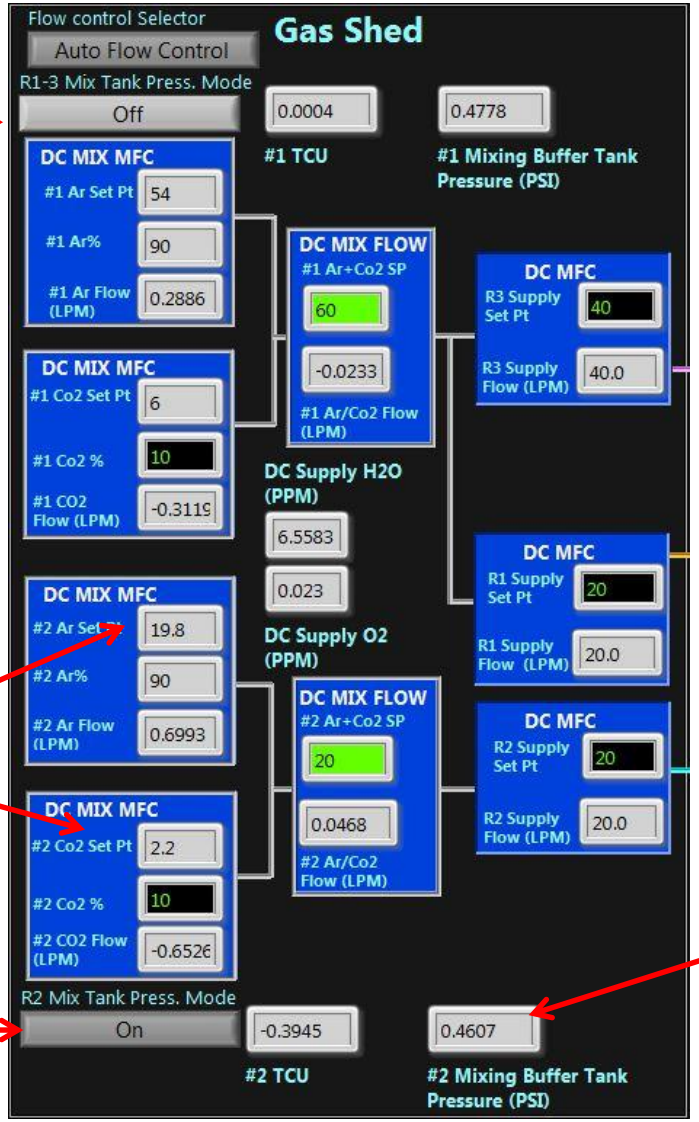
Determining the correct mixture is an advanced operation, to be performed by <u>trained system experts</u>.

The procedure involves obtaining the thermal conductivity of a sample from a calibrated pre-mixed tank and adjusting the percentage of CO_2 in the mixture until the TCU measurements match.

Increasing flow of CO_2 will increase the current in the TCU signal, while decreasing the flow creates the opposite effect.

DC Gas Controls
Buffer Tank Pressure Control

#1 Mix Tank Pressure Mode Selector (Off)



Mix #2 Mass Flow Set Points affected by low buffer tank pressure.

#2 Mix Tank Pressure Mode Selector (On)

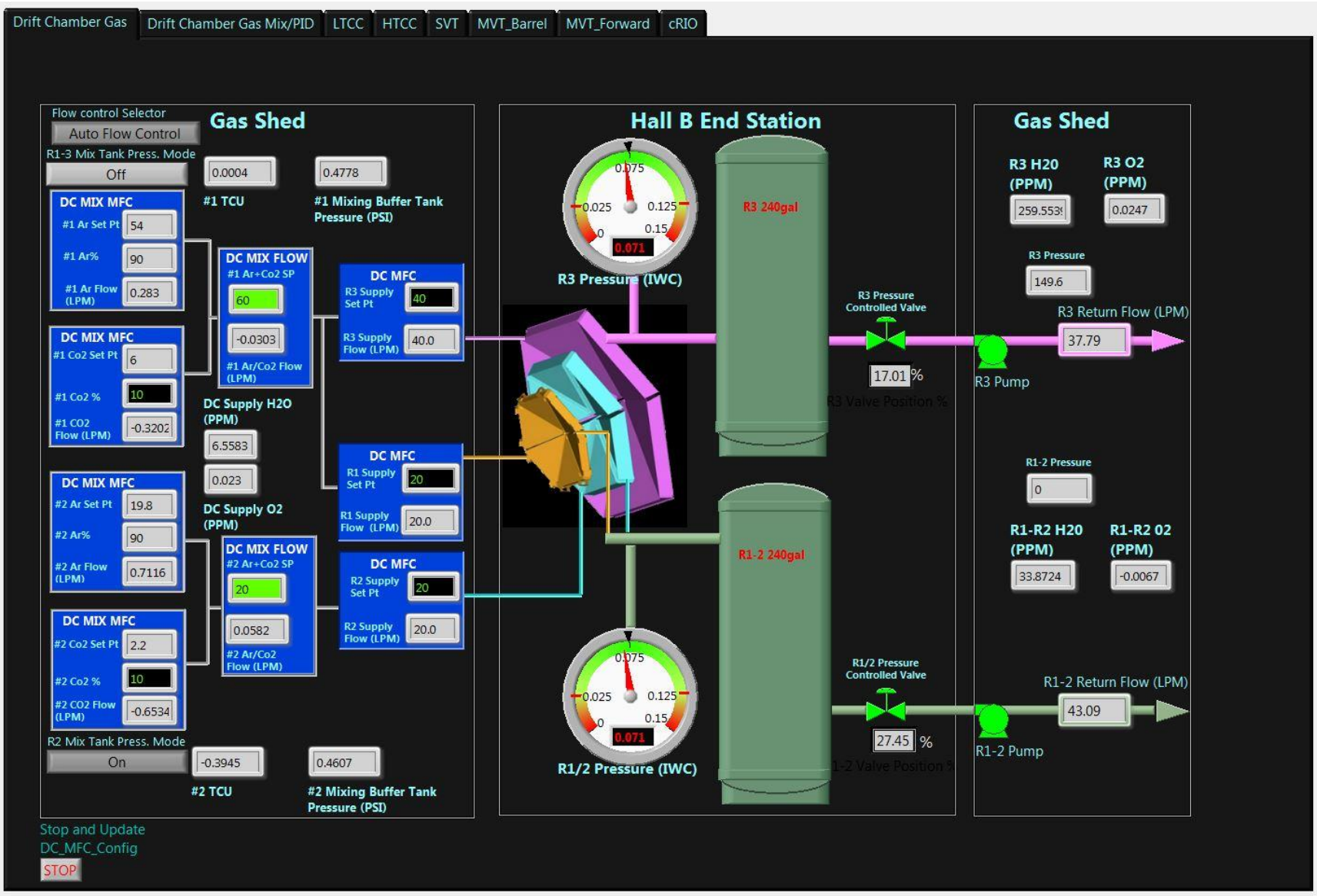
During operation, the mix tank buffer tank pressure is monitored by the system. Should tank pressure measure out of range, the system will automatically increase or decrease flow to maintain the correct pressure.

There are specific tasks when this automatic pressure control is not used, such as the initial fill of the detectors.

Mix #2 Buffer Pressure (Low)

Nominal Pressure
85 to 114 PSI

DC Gas Controls: Flowing Gas



DC Gas Controls: R3 Gas Supply Controls

R3 pressure gauge from MKS 223b

R3 pressure controlled valve

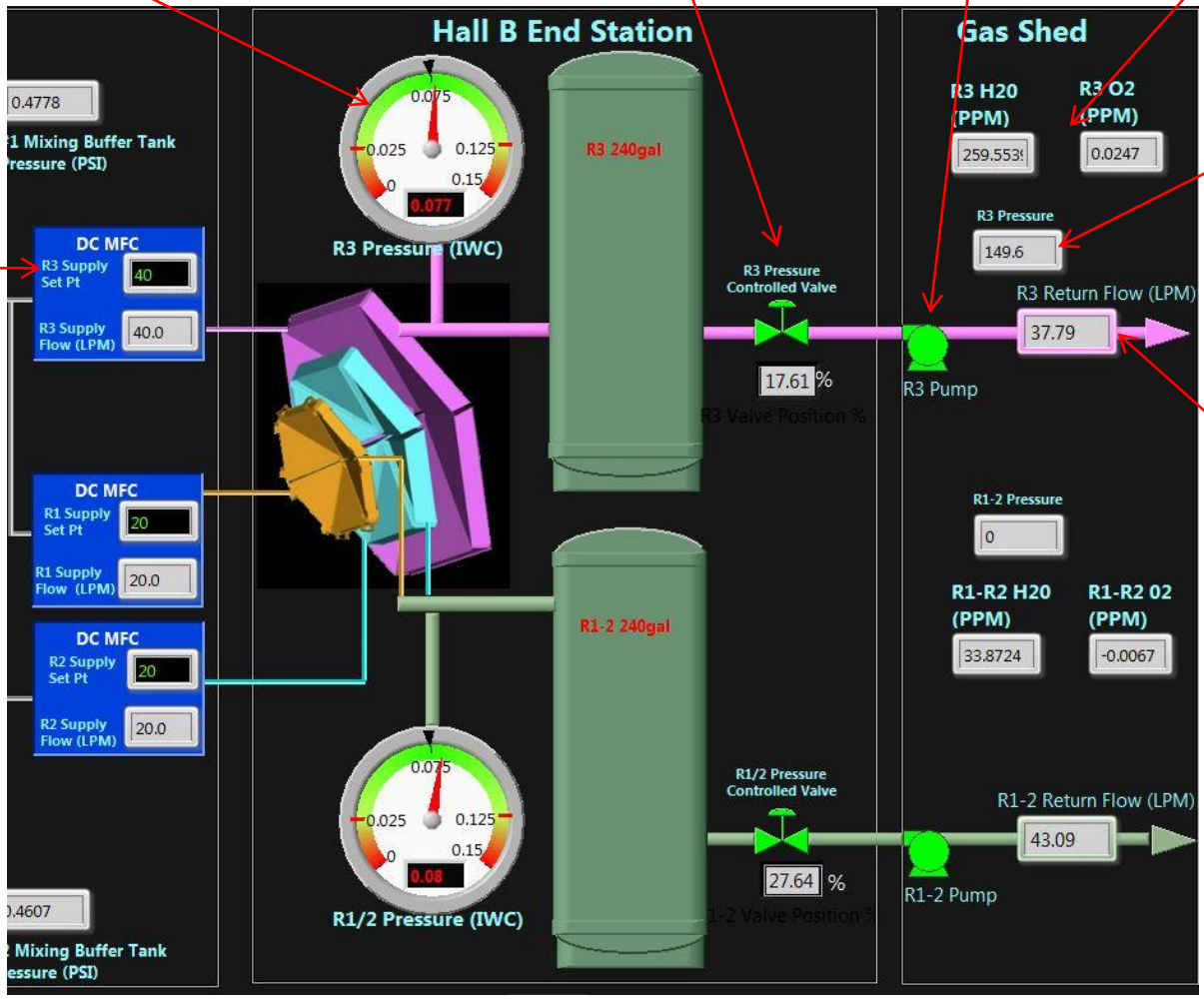
Vacuum pump

Return R3 H_2O and O_2 Sensors

R3 pressure magnehelic

R3 supply set point

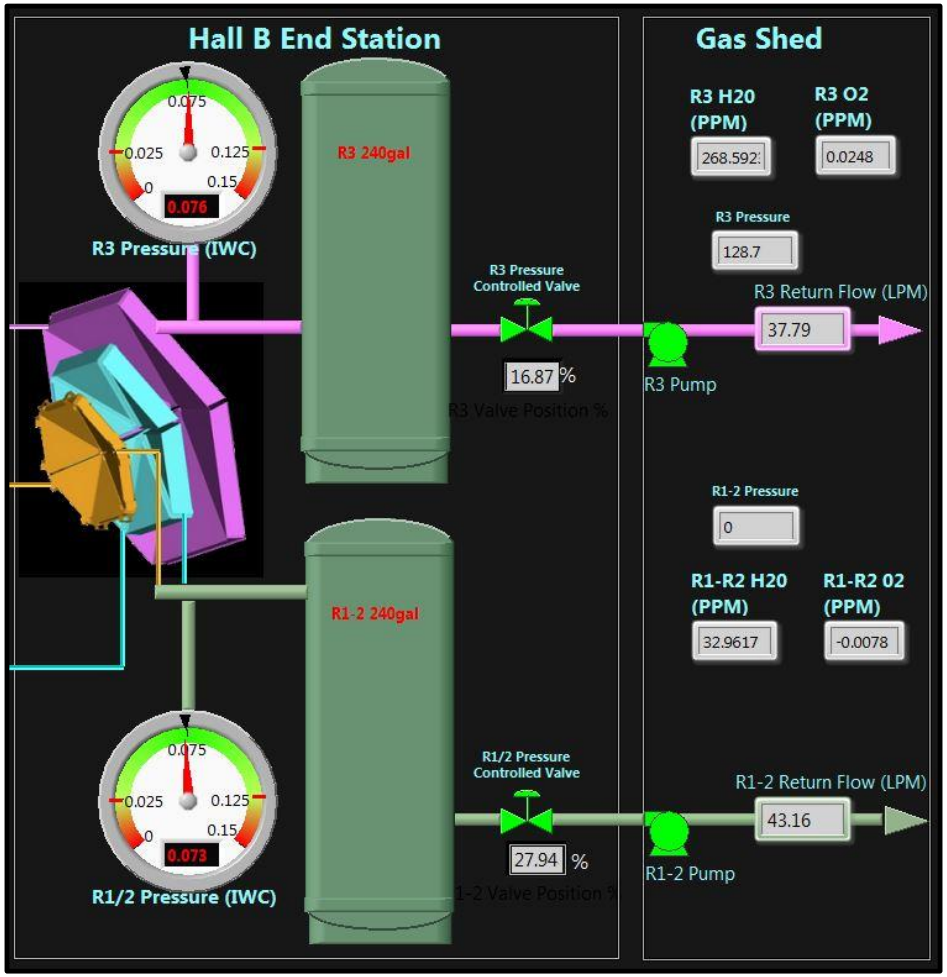
Return flow transducer



With the system running, enter the gas supply set point on the desired mass flow controller.

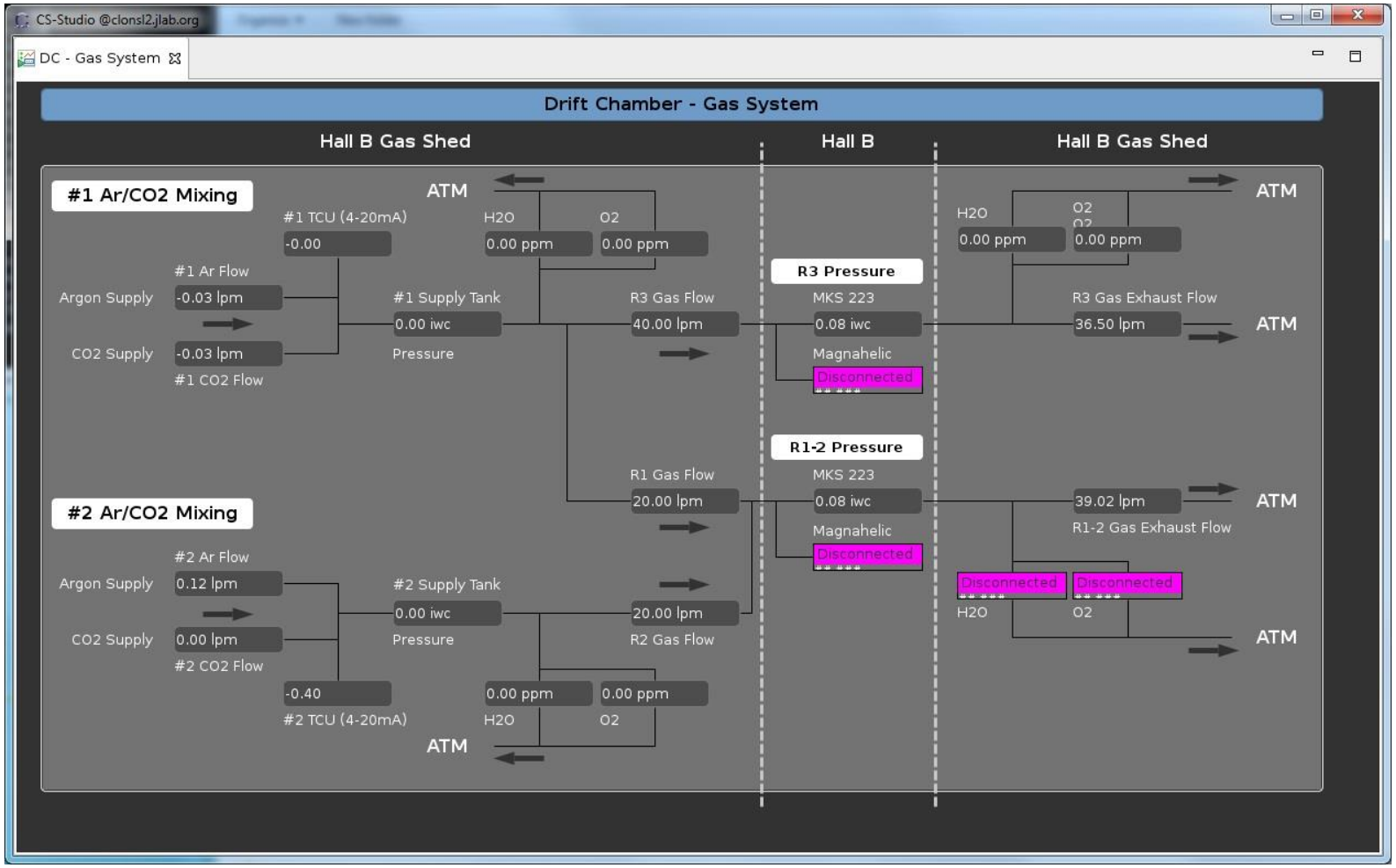
DC pressure will be managed by a PID loop written in the code, which will continuously control the position of the corresponding pressure valve.

DC Gas Controls: Pressure Control



Pressure control system monitors output of two differential pressure transducers (MKS 223b) located on the space frame. Signals from transducers maintain a set pressure by controlling two sets of parallel valves. These valves are inline with a bank of vacuum pumps which provide the low side of the pressure system. Set point used for the DC PID test is 0.075 inches water column. PID settings were used to maintain pressure using two 240 gal tanks.

Hall B DC Gas: EPICS Monitoring Screen

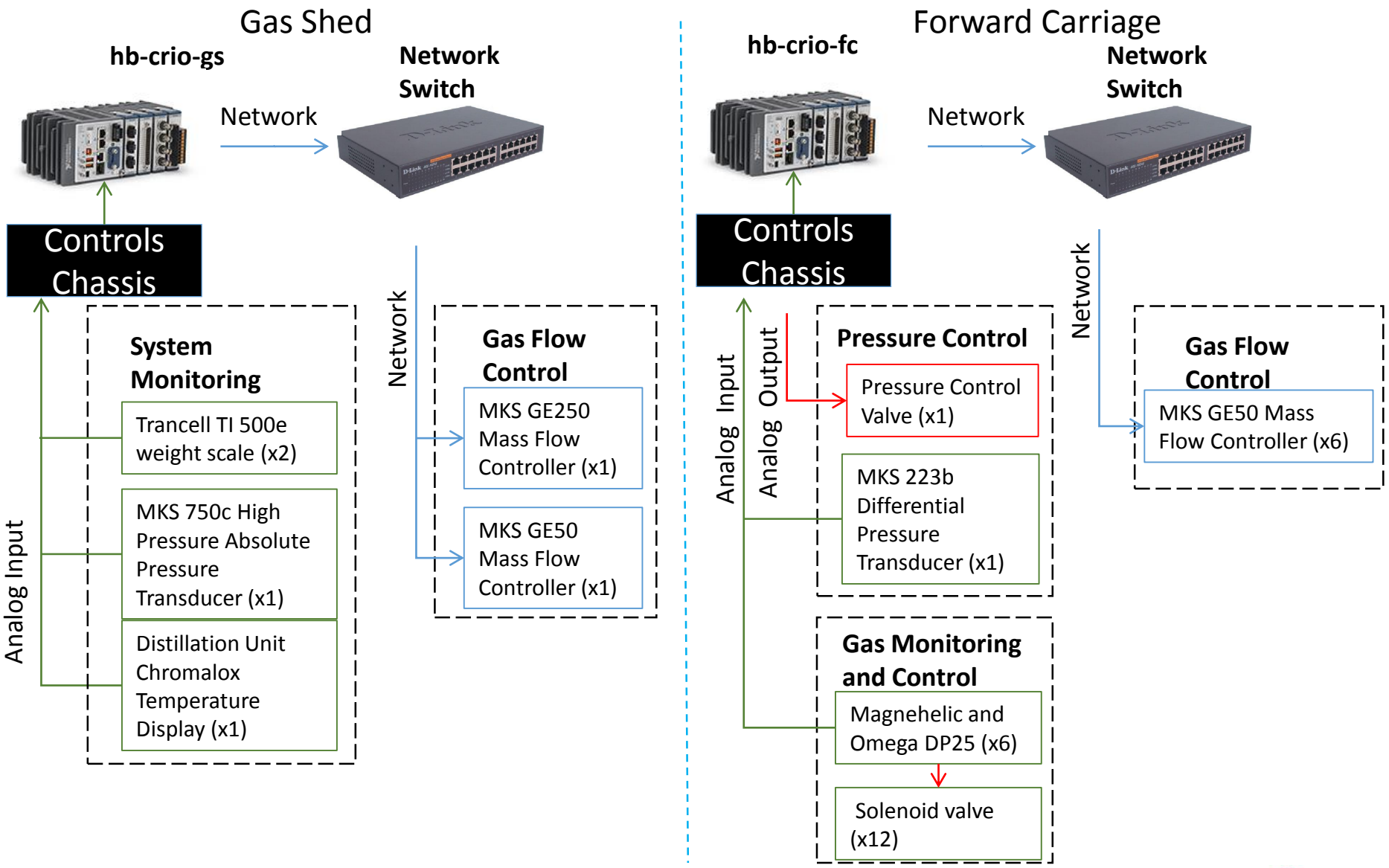


CLAS shifters will monitor the DC gas system via the EPICs GUI. EPICs will provide system alarm handling as well as data logging of the provided process variables.

Hall B Gaseous Detectors

1. Drift Chamber
2. **Low Threshold Cherenkov Counter (C_4F_{10} and N_2)**
3. High Threshold Cherenkov Counter
4. Silicon Vertex Tracker
5. Micro-Megas Vertex Tracker
6. Forward Tracker
7. RICH Detector

Hall B LTCC Gas Controls: Instrumentation



LTCC Gas Controls: Signals

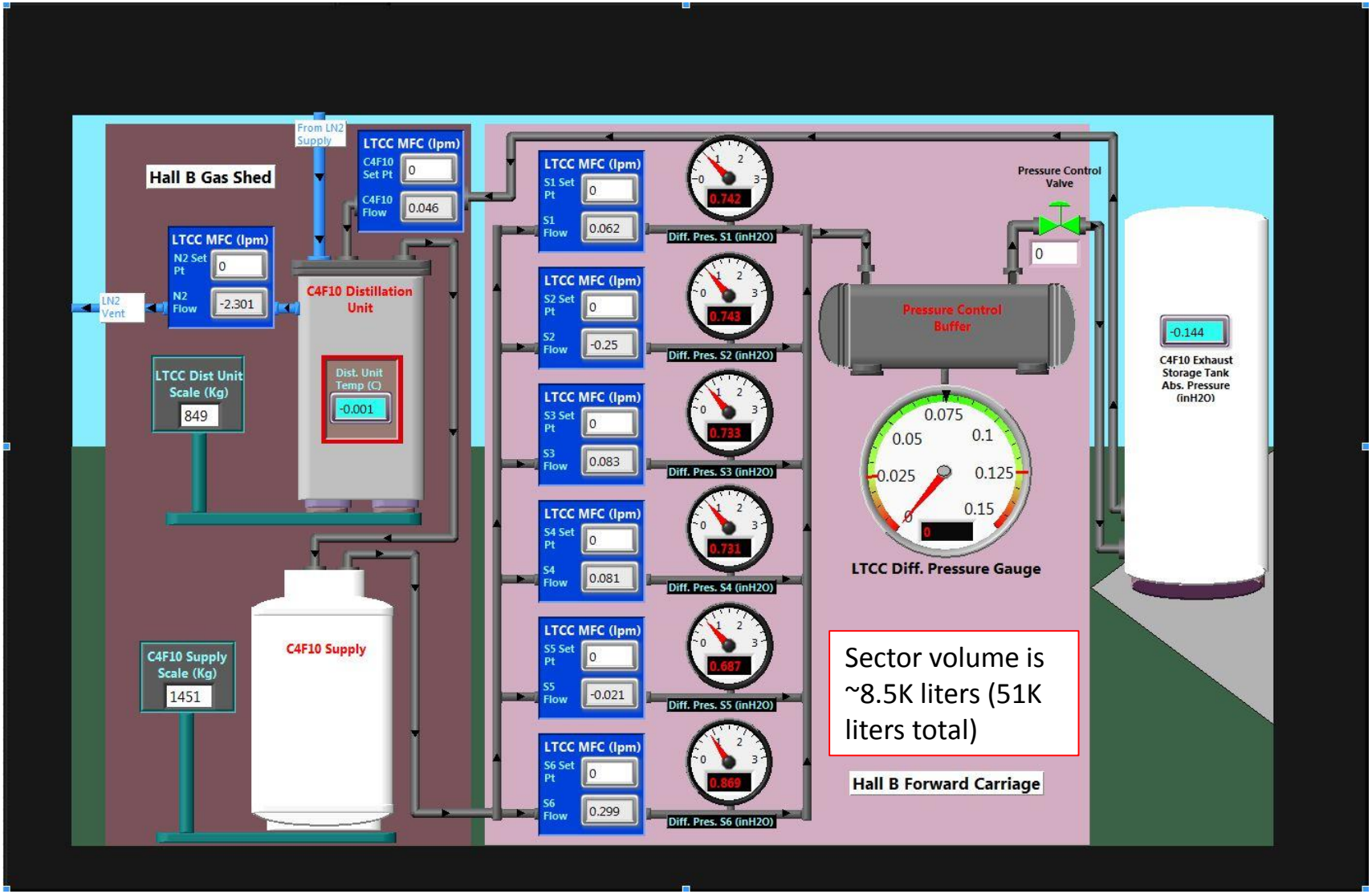
- Mass Flow Controllers (x8)
  - —Sector 1 Flow
  - —Sector 2 Flow
  - —Sector 3 Flow
  - —Sector 4 Flow
  - —Sector 5 Flow
  - —Sector 6 Flow
  - —LN2 Vent
  - —C_4F_{10} Supply

- Pressure Transducers (x8)
  - —Sector 1 Pressure (Magnehelic)
  - —Sector 2 Pressure (Magnehelic)
  - —Sector 3 Pressure (Magnehelic)
  - —Sector 4 Pressure (Magnehelic)
  - —Sector 5 Pressure (Magnehelic)
  - —Sector 6 Pressure (Magnehelic)
  - —Buffer Tank Control Pressure (Differential)
  - —Return Tank Pressure (Absolute Value)

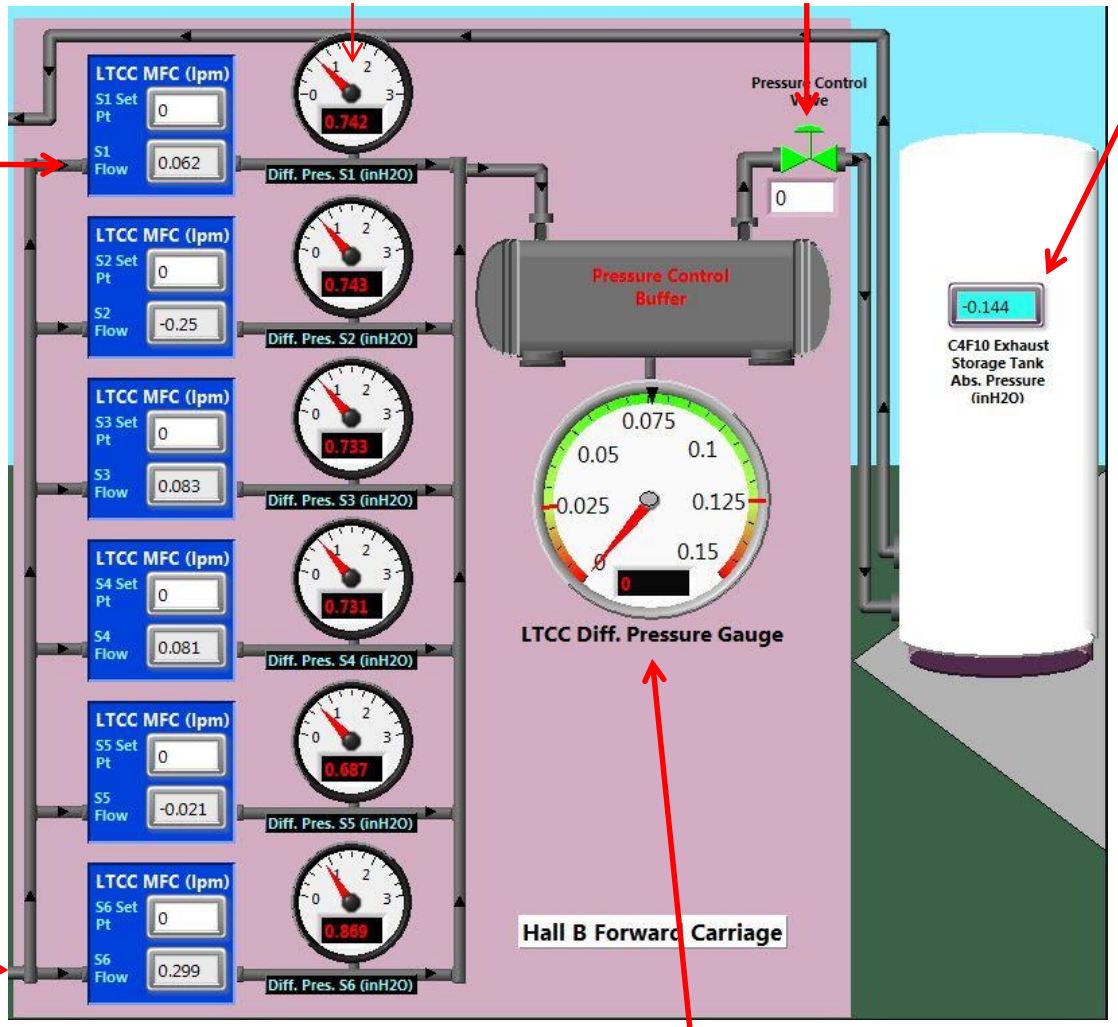
- Temperature (x1)
  - —Distillation Tank Temperature

- Scales (x2)
  - —Distillation Tank Weight
  - —C4F10 Supply Tank Weight

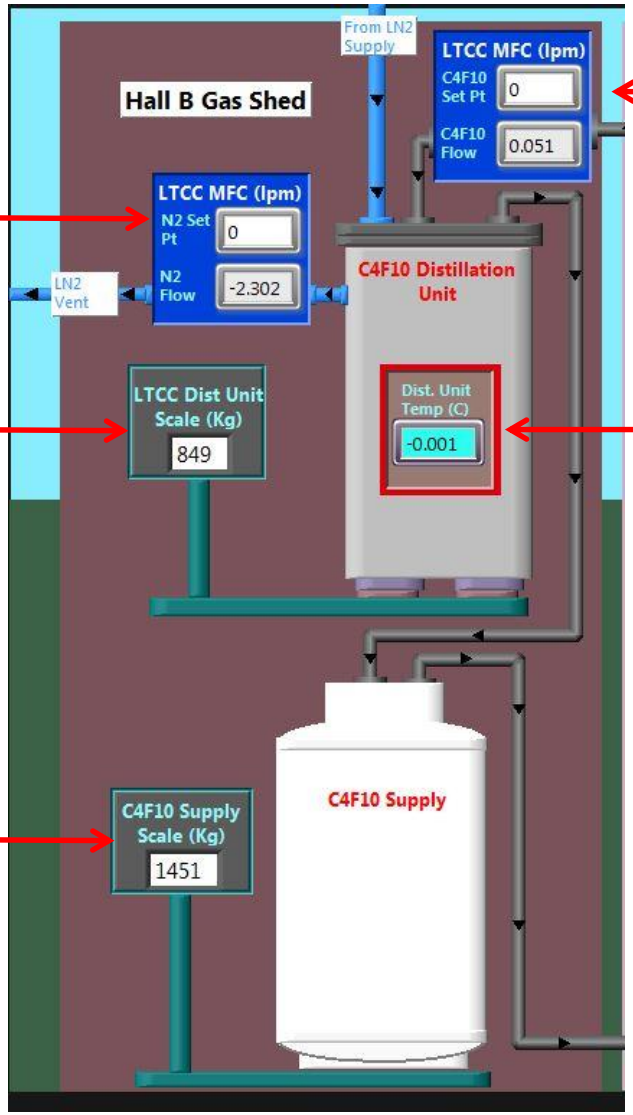
LTCC Gas System Controls: GUI



LTCC Gas System Controls: Gas Supply



LTCC Gas System Controls: Gas Recovery



Distillation unit mass flow controller (C_4F_{10})

N_2 mass flow controller

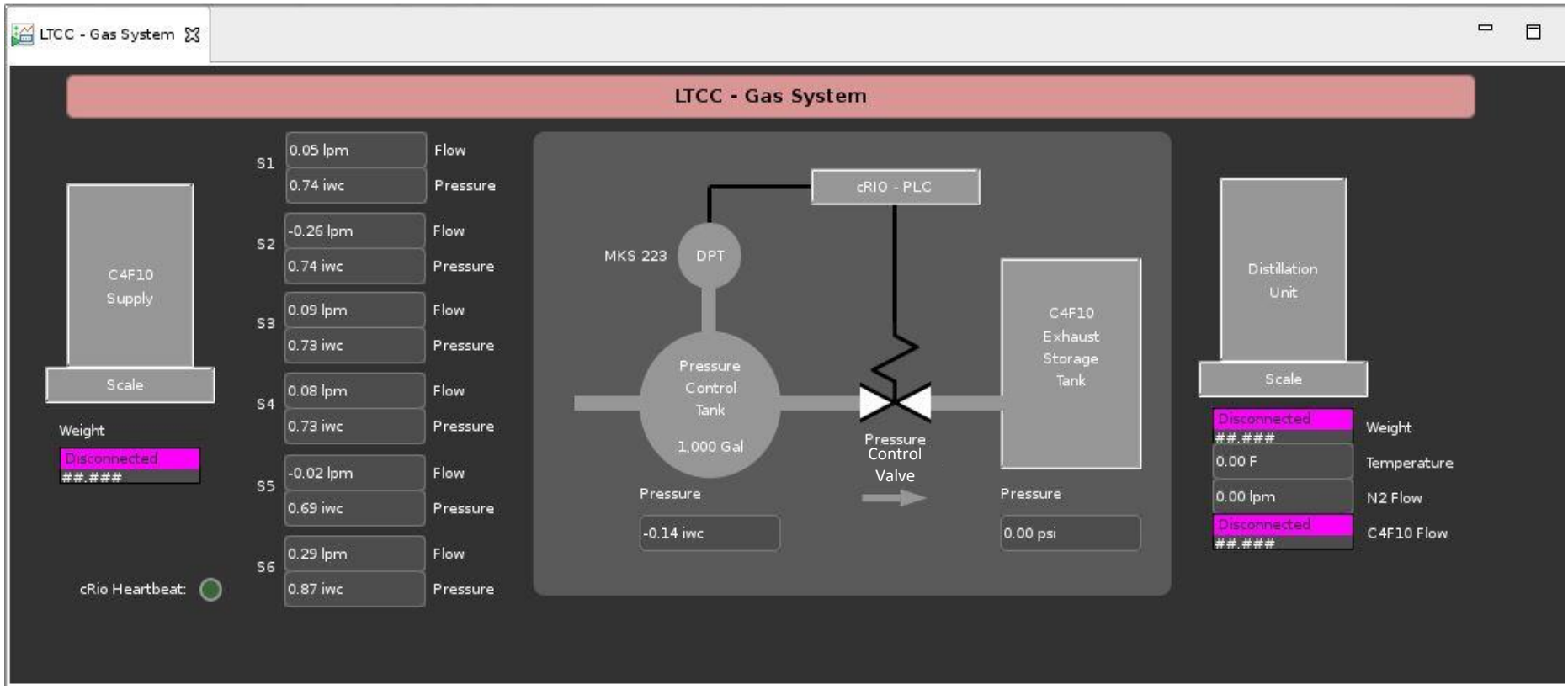
Distillation unit scale

Distillation unit temperature

C_4F_{10} supply scale

Due to cost, C_4F_{10} ($150 Kg) must be recovered every two weeks or as necessary. The procedure for distillation and recovery is not done during operations and is done manually, for the most part.

LTCC EPICs Monitoring

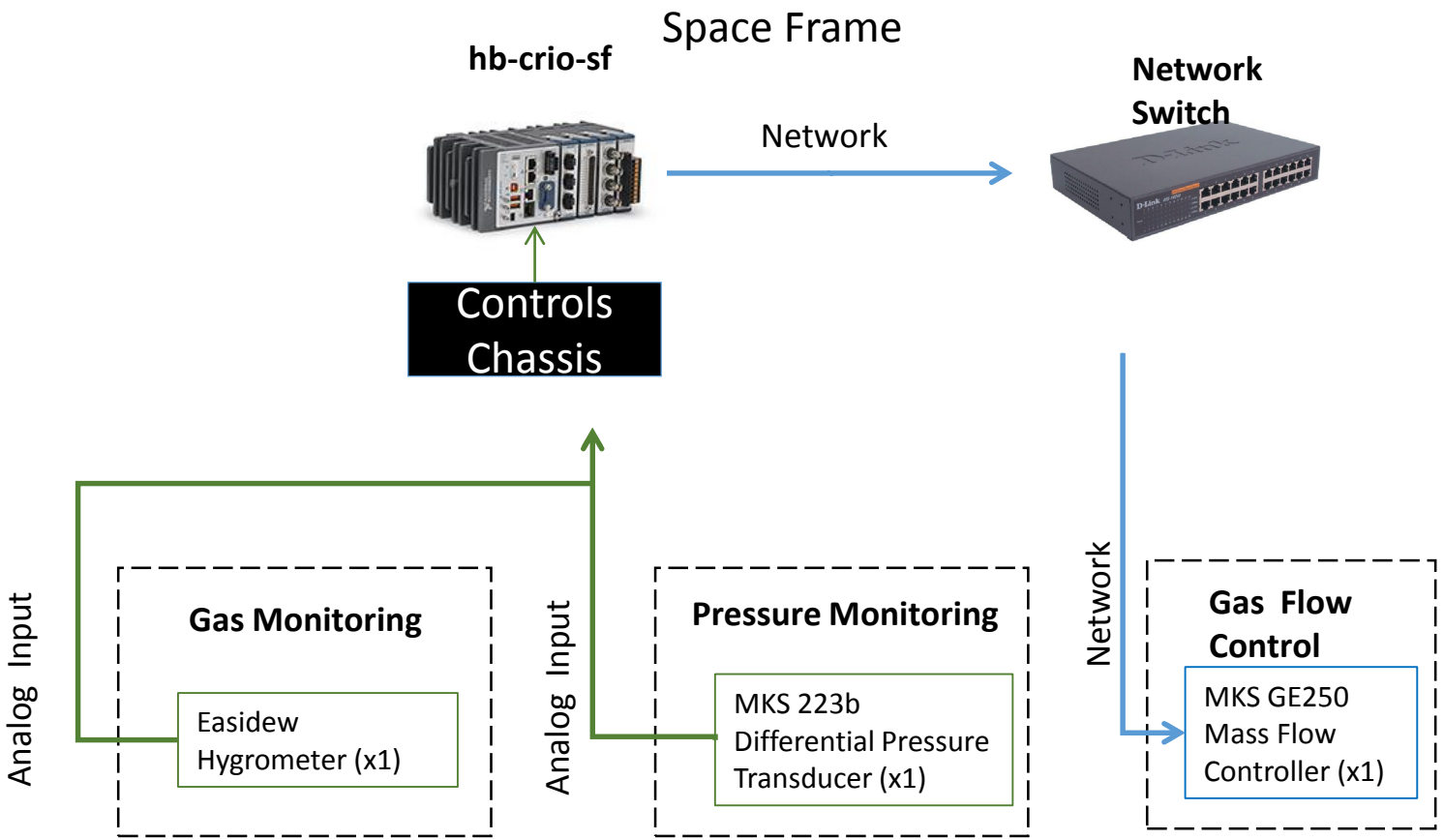


CLAS shifters EPICS monitoring screen

Hall B Gaseous Detectors

1. Drift Chamber
2. Low Threshold Cherenkov Counter
3. **High Threshold Cherenkov Counter (CO_2)**
4. Silicon Vertex Tracker
5. Micro-Megas Vertex Tracker
6. Forward Tracker
7. RICH Detector

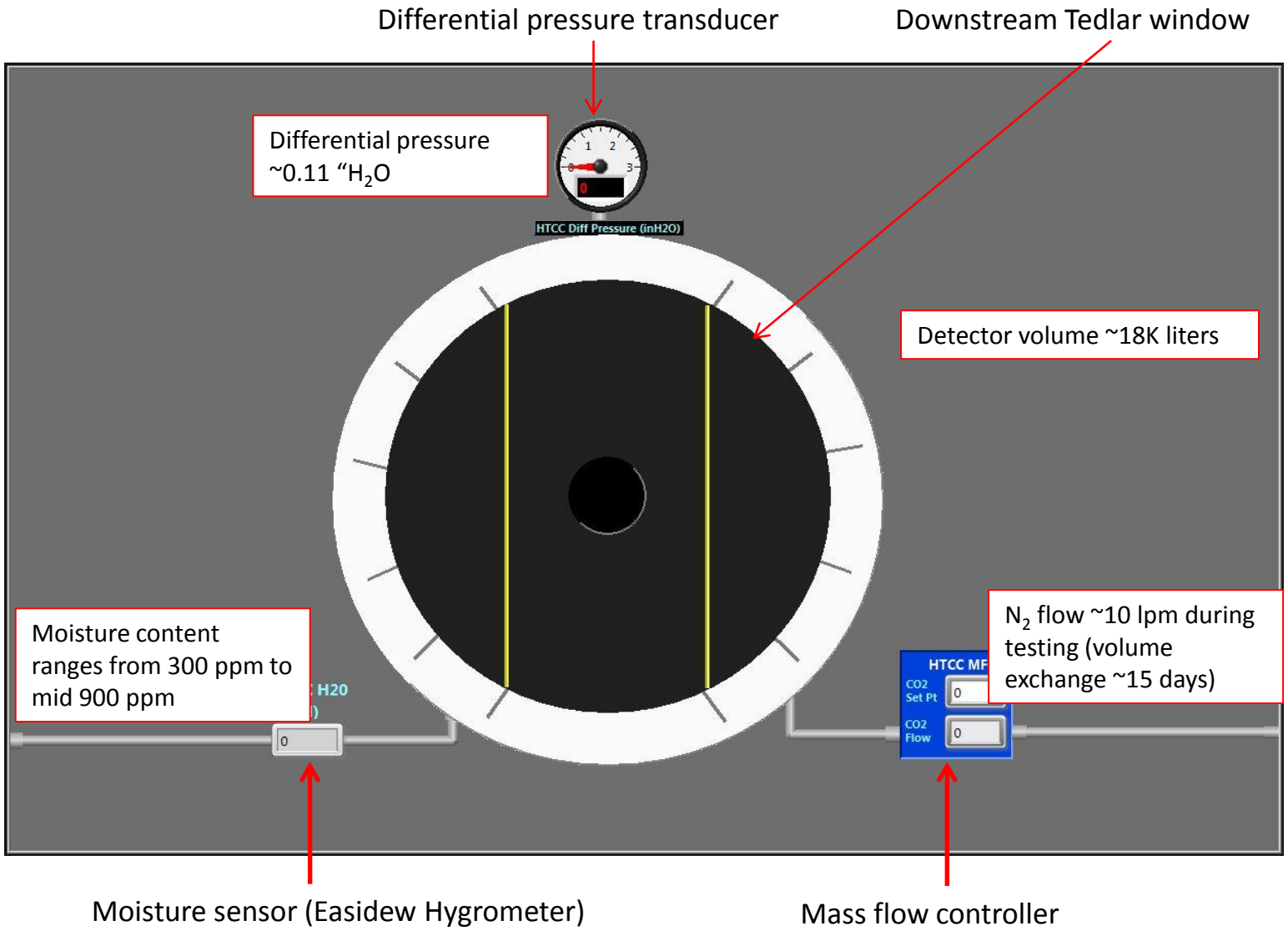
Hall B HTCC Gas Controls: Instrumentation



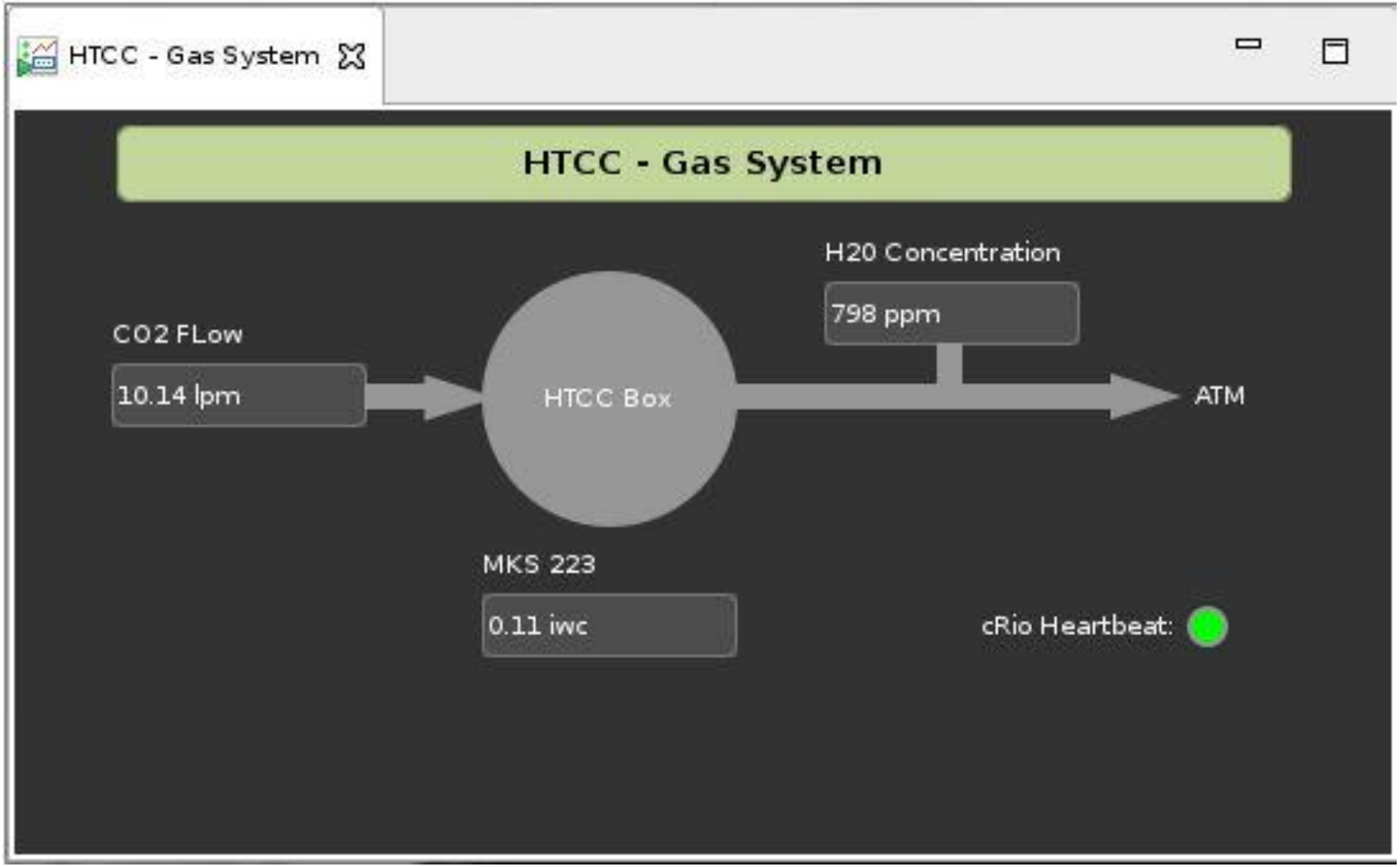
HTCC Gas Controls: Signals

- Mass Flow Controllers (x1)
  - —CO_2 Flow
- Moisture Sensors (x1)
  - —HTCC Moisture
- Pressure Transducers (x1)
  - —HTCC Pressure

HTCC Gas Controls: GUI



HTCC EPICs Monitoring



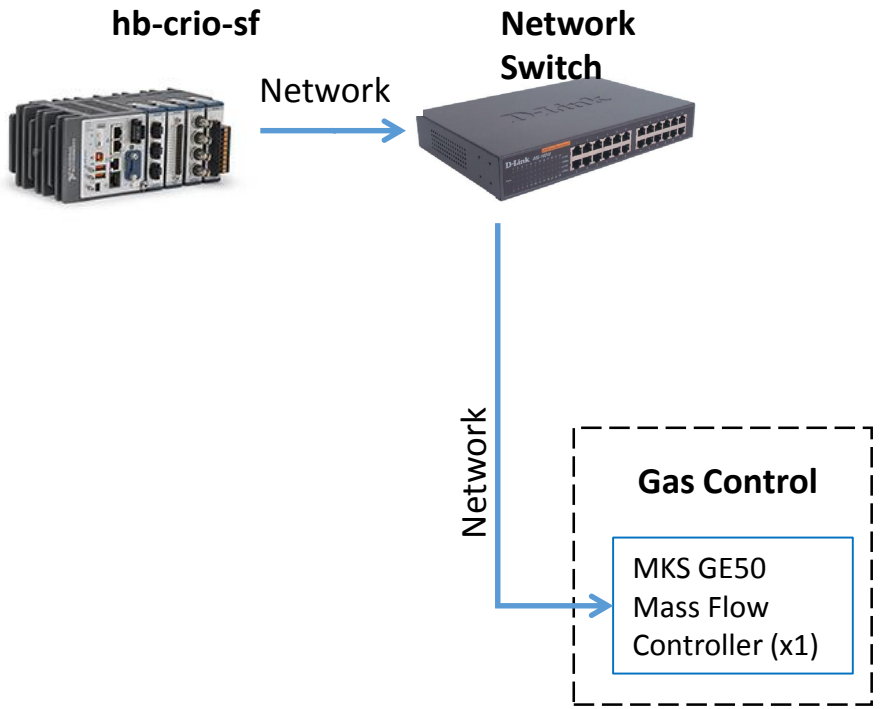
CLAS shifters EPICS monitoring screen

Hall B Gaseous Detectors

1. Drift Chamber
2. Low Threshold Cherenkov Counter
3. High Threshold Cherenkov Counter
4. **Silicon Vertex Tracker (N_2)**
5. Micro-Megas Vertex Tracker
6. Forward Tracker
7. RICH Detector

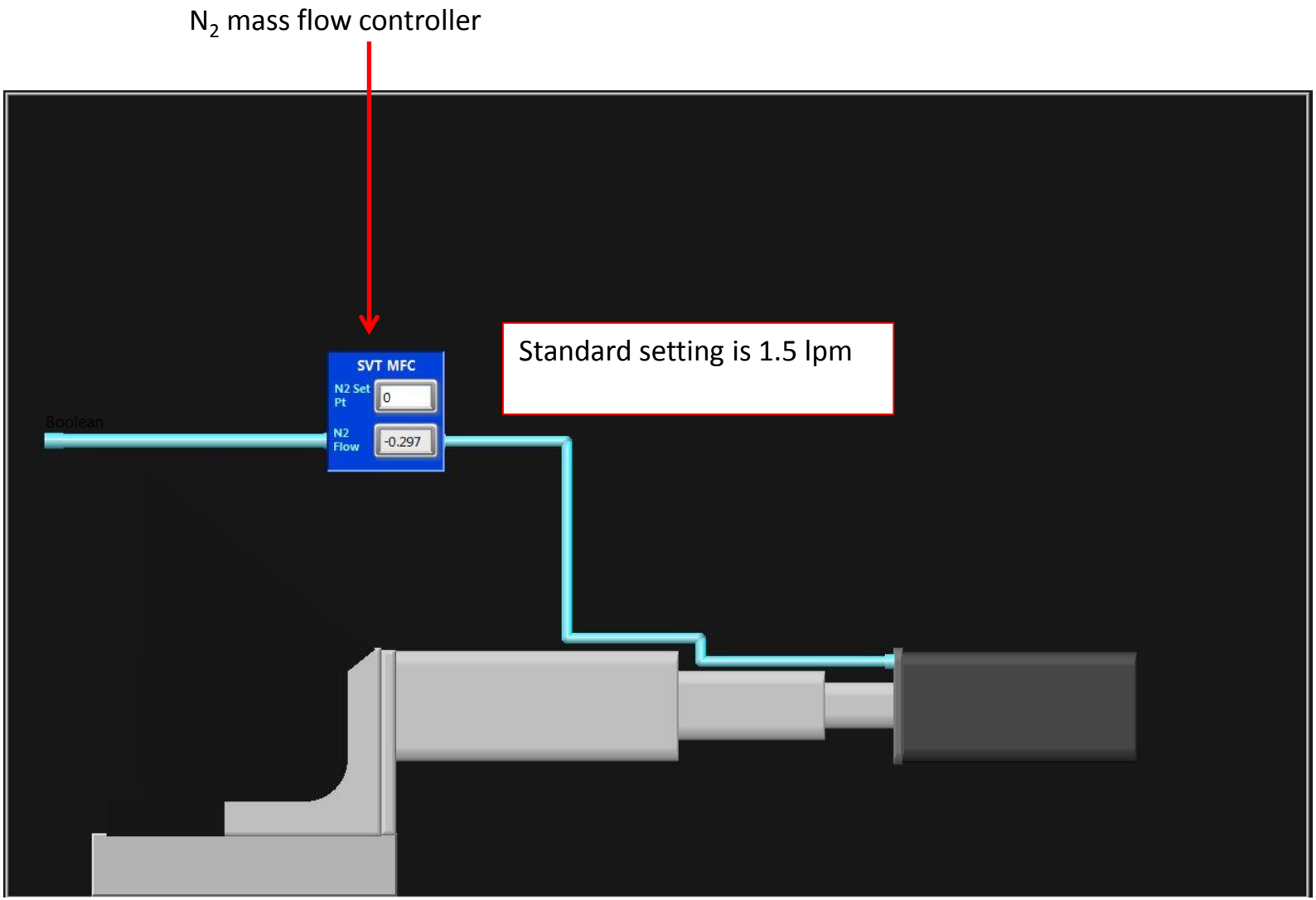
Hall B SVT Gas Controls: Instrumentation and Signals

Space Frame



- Mass Flow Controllers (x1)
  - —N_2 Flow

Hall B SVT Gas Controls: GUI



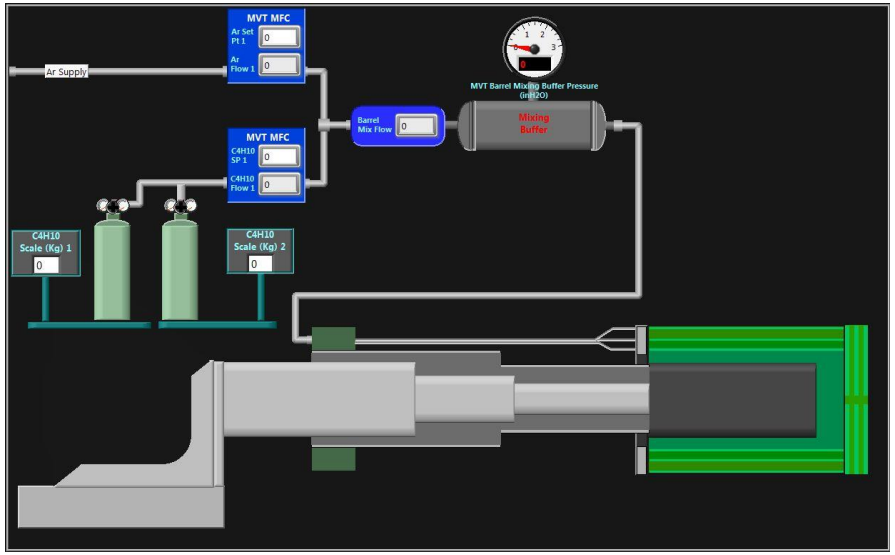
SVT EPICs Monitoring

CLAS shifters monitoring screen

Hall B Gaseous Detectors: Under Development

1. Drift Chamber
2. Low Threshold Cherenkov Counter
3. High Threshold Cherenkov Counter
4. Silicon Vertex Tracker
5. **Micro-Megas Vertex Tracker (Ar, C4H10, and CF4)**
6. **Forward Tracker (Ar and C4H10)**
7. **RICH Detector (N2 and Compressed Air)**

Hall B MVT Gas Mixing Controls: GUI

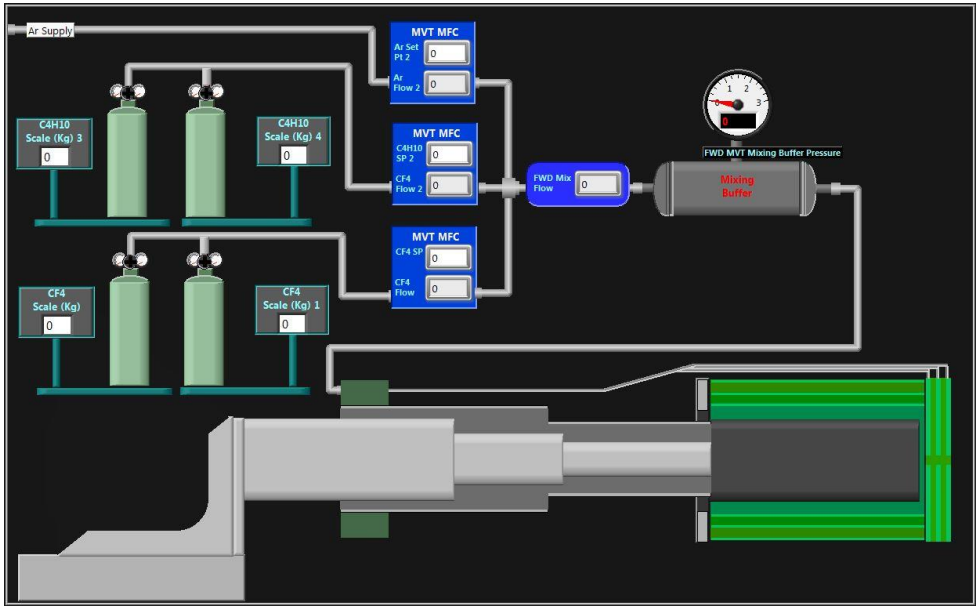


Barrel MVT

Signal List:

- Mass Flow Controllers (x7)
- Scales (x6)
- Pressure Transducers (x2)

Forward MVT



DSG will mix 10% C_4H_{10} with a balance of Ar for the barrel detector and 10% C_4H_{10} / CF_4 with a balance of Ar for the forward detector.

Controls screens for the MVT were developed while writing code for the SVT.

Hall B Forward Tagger Gas Controls: Signals

The FT MVT detect will “tee” off of the supplied C_4H_{10} /Ar along with the MVT barrel detector

Signal List

- Mass Flow Controller (x1)
  - —FTM C_4H_{10} /Ar Flow

Hall B RICH Gas Controls: Signals and Status

Signals List

- Mass Flow Transducers (x4)
  - —RICH 1 N_2 Flow
  - —RICH 2 N_2 Flow
  - —RICH 1 Compressed Air Flow
  - —RICH 2 Compressed Air Flow
- Pressure Transducers (x1)
  - —Air tank pressure
- The gas monitoring is under development with the detector interlocks
- Equipment has been procured

Hall B Gas System Software Status

- Drift Chamber
  - —PID Test complete (February 2016)
  - —Gas Mixing
    - Waiting on completed approval/installation of ASME valve by Hall B Mechanical Engineering and gas delivery in FY 2017
  - —Gas Supply
    - Tested during PID testing
- SVT
  - —Testing completed during SVT noise test in Hall B (September 2016)
- HTCC
  - — Test completed in TEDF (March 2016)
  - — Additional testing to be completed after installation
- LTCC
  - — Test to be completed during leak testing of the detector
    - October – December 2016

Conclusion

- Hall B Gas Controls system will provide controls for the various gas systems to be used during CLAS 12GeV with expansion capabilities for future systems
- Instrumentation for controls already installed in hall and at various test stands, which are currently running
- Testing completed on the SVT
  - —Other installed systems are waiting for detector installation
- All DSG staff contributing to the project

Hall B Gas Controls System: DSG Contribution

- System Design/Development
- Software Code Development
- Component Research
- Procurement
- Chassis Design/Fabrication
- Cable Fabrication/Installation
- Installation
- Testing
- Documentation

The End

Mass Flow Controllers

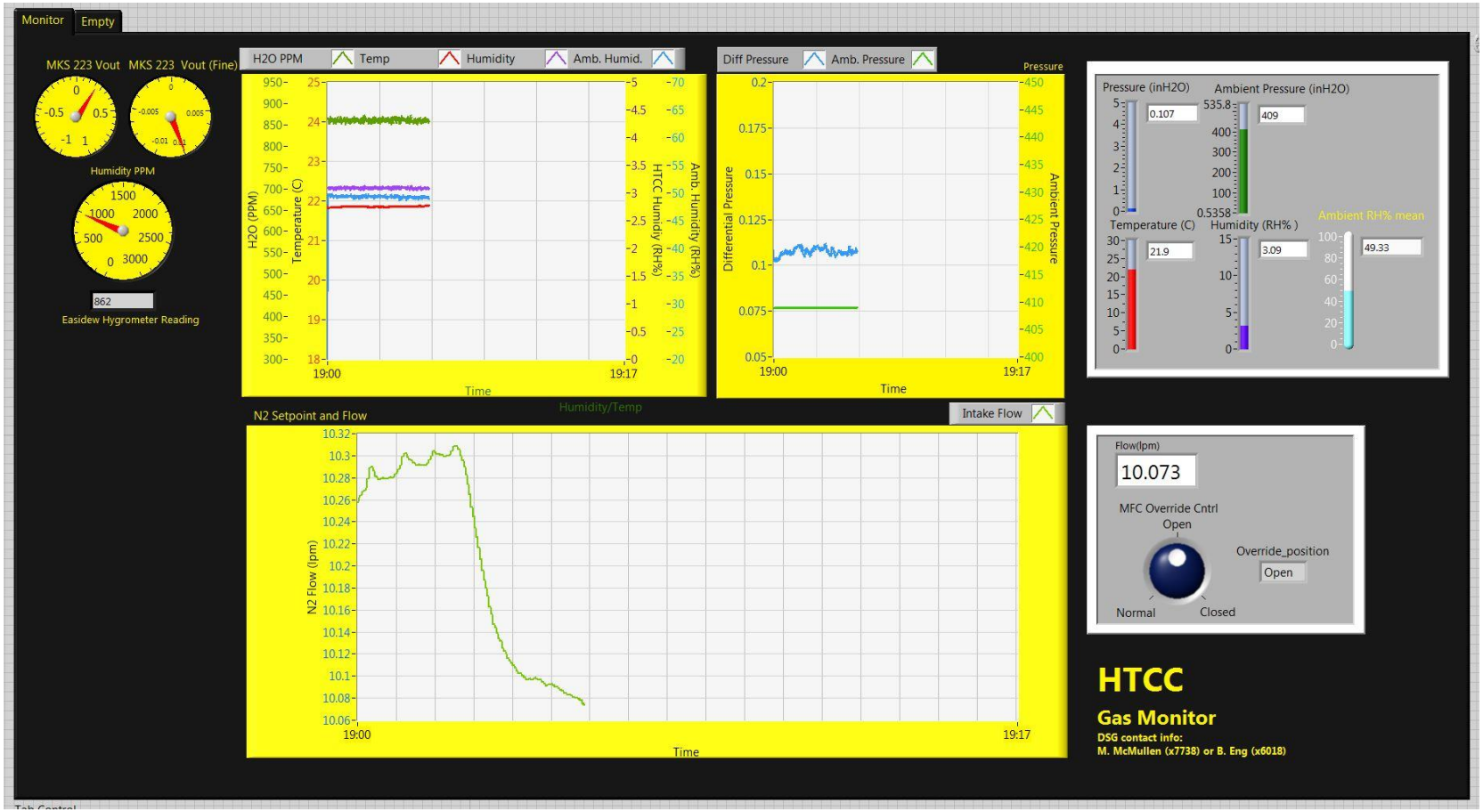
GE50a MFC
Flow range .005 – 50 SLM

Min Operation Pressure
varies (10 – 40 psi)

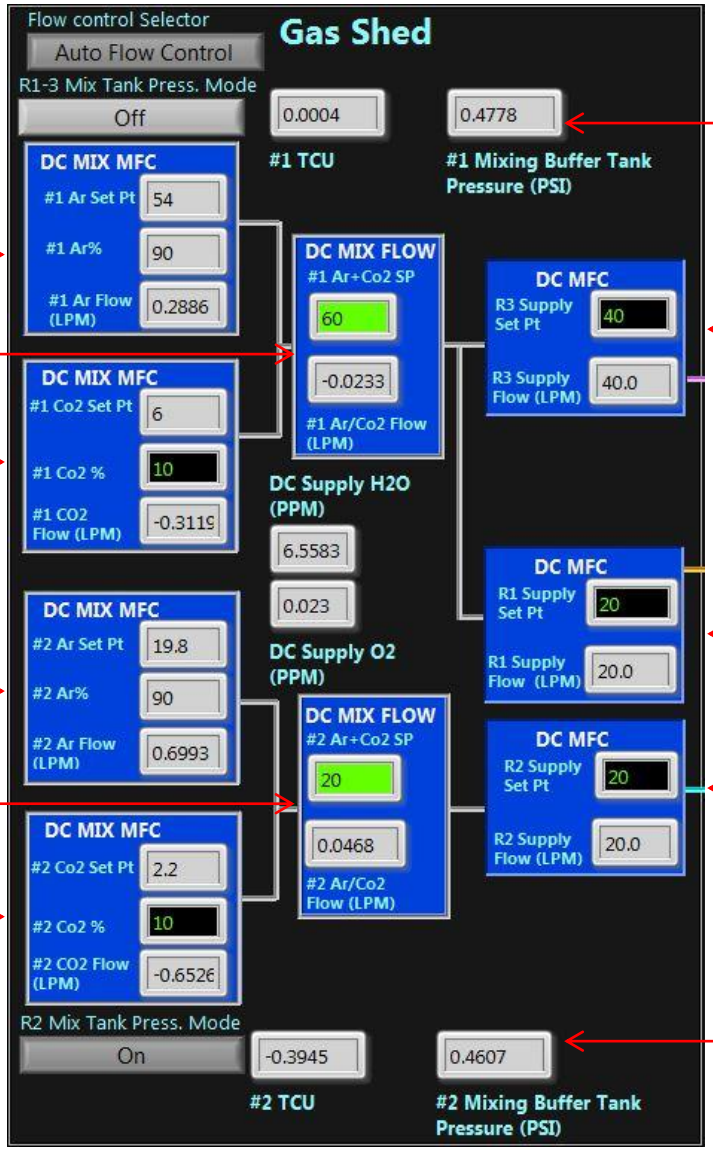
GE250a MFC
Flow range 100– 250 SLM

Min Operation Pressure
varies (30– 55 psi)

HTCC Gas Controls



DC Gas Controls: Mixing Gas



Mix #1 Buffer Pressure

Mix #1 Ar MFC

Mix #1 Flow

Mix #1 CO_2 MFC

Reg. 3 MFC

Reg. 1 MFC

Mix #2 Ar MFC

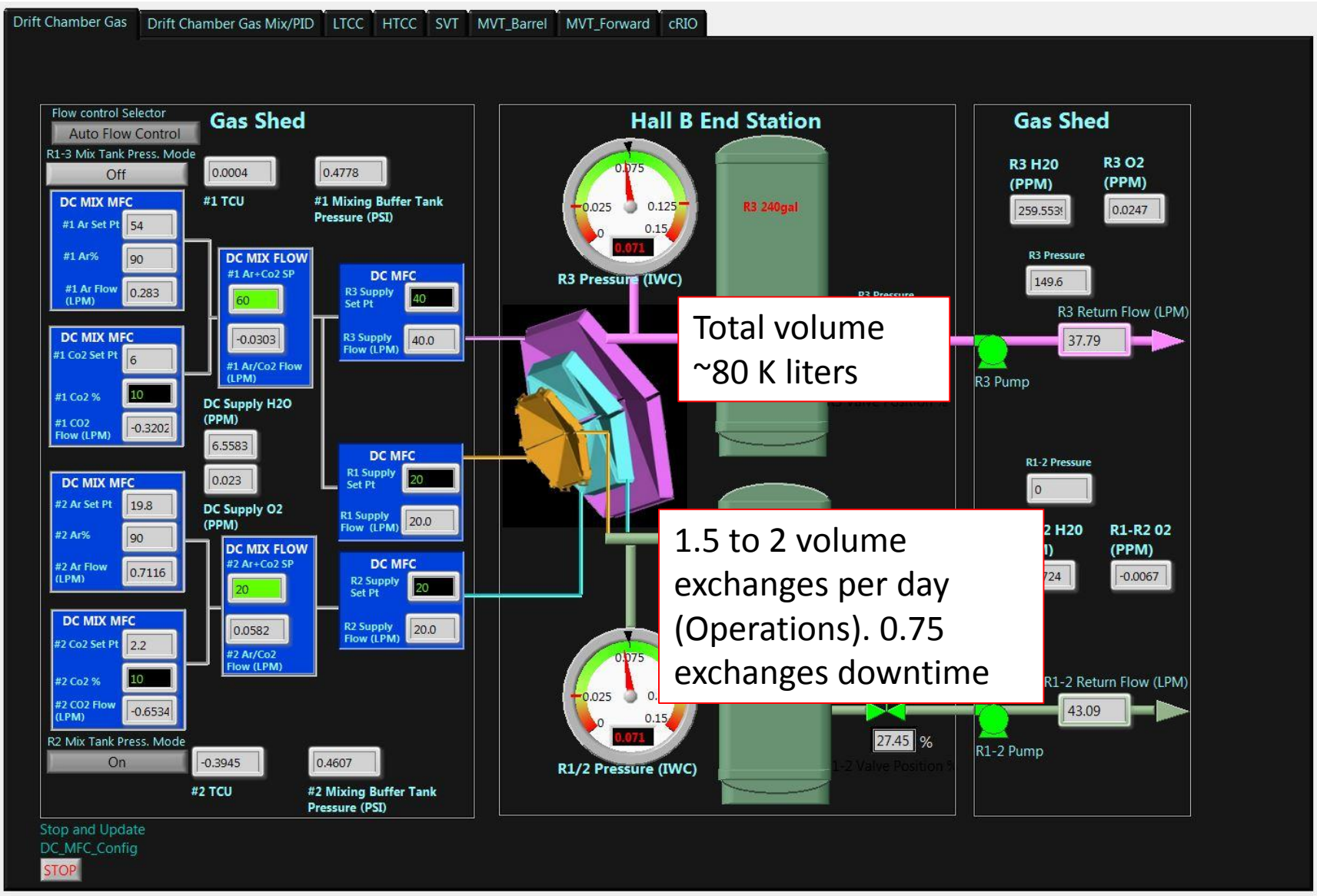
Mix #2 Flow

Reg. 2 MFC

Mix #2 CO_2 MFC

Mix #2 Buffer Pressure

DC Gas Controls: GUI



DC Gas Controls: R3 Gas Supply Controls

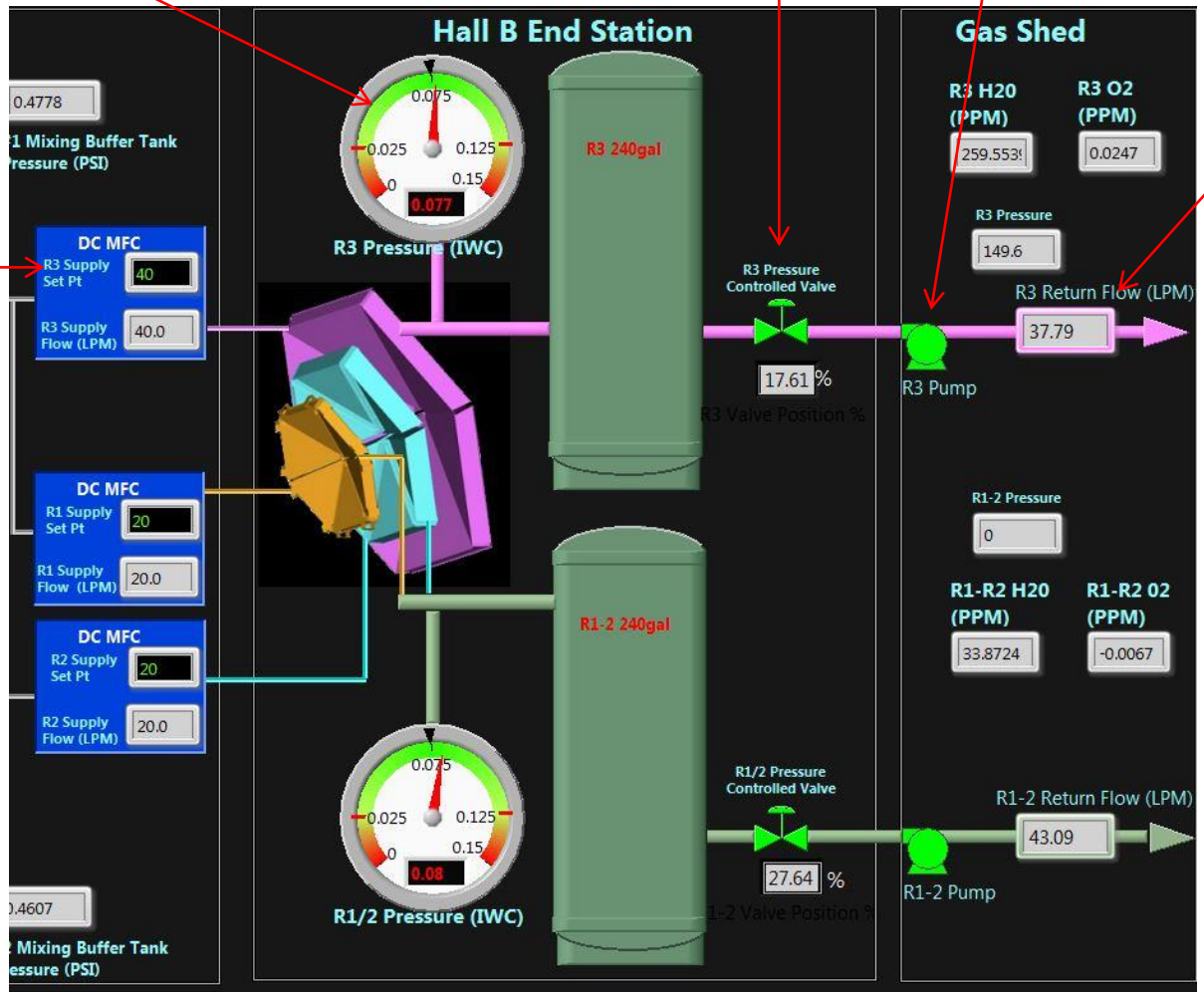
R3 Pressure gauge

R3 Pressure controlled valve.

Vacuum pump

Return flow transducer

R3 Supply set point



With the system running. Enter the gas supply set point on the desired mass flow controller.

DC pressure will be managed by a PID loop written in the code, which will continuously control the position of the corresponding pressure valve.

DC Gas System Fact Sheet

- DC total volume ~80K liters
- 1.5 – 2 volume exchanges per day
- R1 - 15 minutes at maximum flow rate (48 slm)
- R1 - 30 minutes standard flow (24 slm)
-
- R2 - 1.5 hours at maximum flow rate (90 slm)
- R2 – 2.25 hours at standard flow (60 slm)

- R3 – 3 hours at maximum flow rate (120 slm)
- R3 – 5 hours at standard flow (72 slm)

LTCC gas volume

- ~8500 liters per sector
- ~51000 liters total detector volume

HTCC gas volume 18 K liters

DC Gas Controls: Mixing Gas

Thermal Conductivity Unit (TCU)

CO_2 % control