LTCC
GAS SYSTEM
OPERATORS
MANUAL
V1.0

George Jacobs
26 Sept 2016

I Introduction

The LTCC Gas System supplies high purity perflourobutane, C4F10, gas to the detectors located in the Hall. The gas is stored, filtered, distilled, recovered, and a metered delivery is supplied to the detectors. The system also maintains a constant differential pressure between the atmosphere and the detectors exhaust by pumping gas out of the detectors.

Perflourobutane or C_4F_{10} gas is used in the detectors due to its inert chemical and desirable light transmission properties. This gas has a mass density 10 times greater than air. This is a specialty gas currently no longer in production. It is transported in liquid form in containers that hold 500 kg. This container is equivalent to 36,000 liters of gas @STP. Each of the 6 LTCC detectors holds approximately 7200 liters of this gas at about 1.5 inch water column (wc) pressure.

There are 3 basic modes of system operation; FILL, PURGE, and DISTILLATION RECOVERY.

FILL operation is used to fill the detectors with C4F10 gas when first installed and after system down times.

PURGE operation is used to recover the C4F10 gas prior to detector removal for maintenance.

DISTILLATION RECOVERY mode is the normal mode of operation.

The LTCC gas system manual valve positions determine which mode the system is setup for. It is possible to have different detectors in different modes. Some can be FILLING, while some are PURGING, while still others are in the DISTILLATION RECOVERY operating mode. The 3-way valve on the gas supply manifold determines what gas is supplied to each individual Mass Flow Controller, MFC. These 3-way valves have 3 positions; nitrogen, C_4F_{10}, and closed. The flow direction valves determine which physical gas connection on each detector is the physical inlet and outlet for each individual detector. The relative positions of these valves determine what mode of operation each individual sector is in.

A continuous flow of gas is supplied to each detector. This gas supply is controlled to each detector by individual Mass Flow Controllers. The pressure in the detector system is controlled by a PID loop which pumps gas out of the detectors as required to maintain a constant gas pressure in the pressure control buffer tank.

Detector Pressure Safety Systems

There are two levels of over-pressure and under-pressure protection for the detectors, passive and active.

The first level is passive. Oil filled bubblers are installed on the exhaust line. If pressure inside the detector exceeds 3.0"wc, gas will vent to atmosphere. If vacuum in the detector exceeds -3.0"wc, air is sucked into the system to break the vacuum. The passive system works well during static conditions, that is, conditions without gas flow.

The second level is active. Isolation solenoid valves afford the active level of protection. One valve isolates the detector from the gas supply to prevent an over-pressure condition. The other solenoid isolates the detector from the exhaust manifold to prevent an under-pressure condition. These solenoid valves also isolate the detectors in case of power failure. The active level automatically provides action to mitigate the pressure problem.

Detector Gas

Perflourobutane or C4F10 has the following operating characteristics;

- C_4F_{10} gas has thermodynamic properties similar to many low pressure refrigerants.
- It has a saturation pressure and temperature of about 12 psig @55^{o}F.
- When condensate collects in a MFT or MFC, the instrument fails, in the case of a MFC, it fails closed.
- Pumps with heated heads are used to minimize this problem by heating the gas above the saturation temperature for the pressure produced inside the pump during the compression cycle.

The entire system operates continuously. All modes of operation and system evolutions are manual in nature and require continuous monitoring and manual control. Changing from one mode of operation to another requires manual repositioning of the valves in the hall on the forward carriage and proper setup of the MFC for the gas supply, C4F10 or N2.

A) FILL MODE

Prior to FILL operation it is preferred that the detector be purged with N2 gas instead of air to minimize the presence of water vapor. Water vapor is a condensable gas. The DISTILLATION unit will collect all condensable gasses. Water vapor must be removed prior to the distillation process. Molecular sieve filters remove water and oil prior to distillation. The presence of humid air will decrease the life of the molecular sieve filters and increasing maintenance and cost of operations. During FILL operation, C4F10 gas flows to the detectors in the same manner as during the normal Distillation Recovery mode of operation. It is directed to the detector inlet at the physical lowest point of the detector. Because of the relative high density of the gas compared to air or nitrogen, it fills the detector much like water would. The C4F10 displaces the air or nitrogen which is removed at the detector outlet located at the physical top of the detector. The outlet gas is pumped into the vertical insulated tank outside the 96B GAS SHED. The Distillation unit is operated as needed to keep the buffer tank pressure below 25psig. The distillation process recovers the C4F10 gas and vents the non-condensable gasses to the atmosphere. Fill Mode is the same as the normal Distillation Recovery mode of operation, except that a higher C4F10 flow rate is used and the Distillation unit operates almost continuously.

B) PURGE MODE

For PURGE operation N2 gas is supplied by positioning the supply manifold 3-way valve to the N2 position. This supplies N2 gas to the MFC of that detector. The MFC must be setup with the correct gas correction factor for this gas before flowing gas. The flow reversal valve for the detector is reversed to flow nitrogen into the physical top of the detector in order to push the C4F10 gas out the bottom of the detector and toward the exhaust manifold. The outlet gas is pumped to the to the Return Buffer tank outside the 96B GAS SHED. The Distillation unit is operated as needed to keep the buffer tank pressure below 25 psig. This recovers the C4F10 gas and vents the non-condensable gases to the atmosphere. The distillation unit sits on a scale which displays the weight of C4F10 recovered. When this value stabilizes the PURGE has completed. If more than 1-2 detectors are in purge mode, several cycles of distillation unit operations will be required.

C) Distillation Recovery Mode

The Distillation Recovery Mode is the normal mode of operation. During the distillation recovery mode of operation, pure gas is supplied at a constant rate. Gas flows into the detectors and is then returned to the 96B gas shed return buffer tank , where it is stored until it can be recovered via the distillation unit. The distillation unit is operated as needed to maintain supply buffer tank pressure below 25 psig. The pressure control pumps are not rated for continuous duty at pressures >25psi. The pressure control system loses efficiency as the pumps load up. Pump lifetime decreases at these higher loads. When the supply buffer tanks reaches 20 psig, the distillation unit should be operated to recover the gas. Gas is pumped to the distillation unit and recovered until the supply buffer tank is at 20+ inches vacuum.

Caution must be used so as not to exceed the capacity of the distillation unit during recovery. It is important to note that it takes ~4 to 8 hours to cool the distillation unit to operating temperature. The unit must be prepared for operation before the pressure in the supply buffer tank reaches 25 psig. Several system parameters can be followed to properly estimate exactly when the distillation unit must be started up. The supply buffer tank has a constant volume, the rate at which it's pressure rises is proportional to the total flow rate of the system. Ambient temperature also has a significant effect on tank capacity. With normal C4F10 flow rates, 0.050 l/m per detector, the distillation unit will need to be operated for a ~3-4 day period every other week. A Monday or Tuesday startup followed by a Thursday or Friday shutdown.

II Controls Overview

The Cerenkov gas system consists of 4 separate subsystems;

- A gas delivery system,
- A pressure control system,
- A pressure protection system.
- A C4F10 distillation recovery system

Gas Supply

S1 gas flow-	MFC 1
S2 gas flow-	MFC 2
S3 gas flow-	MFC 3
S4 gas flow-	MFC 4
S5 gas flow-	MFC 5
S6 gas flow-	MFC 6
Supply tank weight	Scale analog output

Pressure Control

Pressure Control	cRIO PID loop
Pressure	MKS 223B differential pressure transducer

Pressure Protection

S1 differential pressure-	Omega DP25-E Controller #1
S1 supply valve-	Omega DP25-E Controller #1 Relay 1
S1 exhaust valve-	Omega DP25-E Controller #1 Relay 2
S2 differential pressure-	Omega DP25-E Controller #2
S2 supply valve-	Omega DP25-E Controller #2 Relay 1
S2 exhaust valve-	Omega DP25-E Controller #2 Relay 2
S3 differential pressure-	Omega DP25-E Controller #3
S3 supply valve-	Omega DP25-E Controller #3 Relay 1
S3 exhaust valve-	Omega DP25-E Controller #3 Relay 2
S4 differential pressure-	Omega DP25-E Controller #4
S4 supply valve-	Omega DP25-E Controller #4 Relay 1
S4 exhaust valve-	Omega DP25-E Controller #4 Relay 2
S5 differential pressure-	Omega DP25-E Controller #5
S5 supply valve-	Omega DP25-E Controller #5 Relay 1
S5 exhaust valve-	Omega DP25-E Controller #5 Relay 2
S6 differential pressure-	Omega DP25-E Controller #6
S6 supply valve-	Omega DP25-E Controller #6 Relay 1
S6 exhaust valve-	Omega DP25-E Controller #6 Relay 2

Distillation Unit

LN2 vent rate-	N2 vent flow MKS MFC
Distillation unit weight-	Scale analog out
Temperature-	Temp analog out
Return Tank pressure-	MKS absolute Baratron

System Components

MKS Mass Flow Controllers, MFCs, meter gas flow to the individual detectors. The MFCs are located on the valve panel installed on the forward carriage. The mass flow controllers are gas specific. This requires that the instrument be properly setup for each specific gas. The instrument setup must be run before changing the gas supplied to it. The respective characteristics of the gasses are very different. If one attempts to flow C4F10 gas through a MFC setup for N2, the actual flow will be a factor of 10 low. Conversely, if you flow N2 when you are setup for C4F10, the actual flow will be a factor of 10 higher than indicated. The later situation is of special concern because of the possibility for detector gas window damage.

Gas pressure inside the pressure control tank is controlled by a PID loop. Heated head diaphragm pumps in the gas shed provide the differential pressure required to return gas from the detectors to the return buffer tank outside the 96B gas shed.

Dwyer Magnahelic differential pressure transducers, DPTs, measure the differential pressure between the exhaust line on each detector and atmosphere. The 4-20ma output signal of the DPT is processed by an Omega DP25-E process controller. The Omega unit provides a digital display reading out directly in units of inches water column (wc). Each unit also provides an analog output signal to EPICS for the EPICS based alarm handler. The Omega has relays which control the isolation solenoid valves for the detector.

A normally closed (NC) solenoid valve is installed on the outlet side of each mass flow controller. This valve is energized when detector pressure is less than 2.5"wc. If detector pressure rises to greater than 2.5"wc, a relay opens to de-energize the solenoid and close the valve. This isolates the gas supply from the detector, preventing pressure inside the detector from increasing due to gas supply flow.

A normally closed (NC) solenoid valve is installed in the exhaust line just before the exhaust manifold. This valve is energized when detector pressure is greater than 1.00"wc. If detector pressure falls below 1.00"wc, a relay opens to de-energize the solenoid and close the valve. This isolates the gas exhaust from the detector, preventing pressure inside the detector from decreasing due to excessive gas removal.

The differential pressure between the pressure control tank and atmosphere is measured by an MKS 223B differential pressure capacitance manometer. The signal is used to control a pressure control valve located between the exhaust buffer tank in the Hall and the vacuum pumps in the gas shed. The PID loop output controls the pressure control valve to maintain a constant differential pressure between the buffer tank and the atmosphere.

III Operator Training

The Cerenkov gas system uses pressurized gas and cryogenic liquids. The Control system uses complex specialty controls, electronics, and instruments. There are personnel and equipment hazards associated with improper operation of this equipment. Because of this, only properly trained and certified persons can be permitted to operate this equipment.

The prospective operator must accomplish the following 3 steps

1) Operators must complete the proscribed training program
2) Operators must pass a final checkout with the SME
3) The Hall B Lead Engineer must certify the operator

IV System Operations

Normal Operating Parameters

Return buffer tank pressure, <25 psig
Return buffer tank temperature, >56^{o}F (for distillation unit operation only)
Hall supply header pressure, 3-5 psig
Supply tank weight after recovery, >900lbs
Detector differential pressure, 1.0-2.5 inches wc
Distillation unit temperature range, –10^{o}F to –35^{o}F
Distillation unit N2 mixing flow setpoint 1500cc/m
Distillation Unit liquid N2 flow setpoint 90-150 slm (adjust to temp)
Distillation unit flow setpoint, 4.5slm
Gas Flow to each detector, 0.050 slm
Pressure Control Tank Pressure, 1.00”wc

Gas Supply

Gas is supplied from a bulk shipping container or cylinder. Gas supply pressure is of special concern. The hall supply pressure regulator must be set to supply 3-5 psig. Pressure must remain below 10 psig to prevent MFC failure due to condensate formation. Normal supply pressure is controlled by a high accuracy low pressure gas regulator.

The operation of the gas supply is cyclic in nature, that is, the tank is filled with recovered gas from the distillation unit. This means the contents in the tank will decrease during normal operation. Normal usage is ~250-350lbs between distillation unit operations. The tank must have at least a minimum content of 400lbs after it is filled with the recovered gas. This means the total weight as indicated on the scale display must be >900lbs after recovery.

Charging the Supply Tank

The supply tank needs to be charged with fresh gas to make up for system losses. The supply tank fill level is cyclic due to the periodic fill of recovered gas from the distillation unit. The supply tank fill level is monitored by weight. The tank sits on a scale with a digital readout. An empty tank weighs ~520lbs. A tank filled to capacity weighs ~1620lbs. In order for a tank not to go empty during normal operations, it must weigh >900lbs after filling with recovered gas.

When the supply tank level fall below 900lbs after filling with recovered gas it must be filled from another storage tank. Gas is transferred from an outside container via a flexible nylon transfer hose to the manifold connection on the exterior gas shed wall. The outside tank is pressurized with low pressure (36psig) nitrogen from the N2 connection on the exterior gas shed wall. The weight of the supply container as indicated on the digital readout above the scale must be monitored continuously. The tank should never be filled to more than 1500lbs total weight as indicated on the digital scale readout to prevent overfilling. There still must be room in the tank to transfer recovered gas from the distillation unit. This process must be timed during the later stages of the distillation process such that there is at least a 15" vacuum in the buffer tank. The weight of the gas already recovered in the distillation unit must be taken into account to insure there will be a place to put it.

The Process must be monitored continuously to check for leaks and to insure the gas is not being lost to the atmosphere.

Procedures

1) Connect the ¼" nylon tube with check valve to the C_4F_{10} gas supply connection on the outside container, connect the other end to the N2 gas supply Valve at the manifold on the gas shed outer wall.

2) Connect the C_4F_{10} liquid supply connection on the outside container to CG115, at the manifold on the gas shed outer wall.

3) Check that the liquid supply valve on the supply bottle in the Gas Shed is shut .

4) Open the N2 gas supply valve and crack the fitting on the outside container to purge out any air.

5) Then pressurize the tank using the 30 psig N2 by opening the gas supply valve.

6) Open CG117, CG116, CG115, and CG79 to remove the air in the liquid transfer line using the vacuum in the buffer tank.

7) After several minutes crack open the liquid supply valve for 20 seconds and then close CG117 and CG79. Then fully open the liquid supply valve on the outside container.

8) Record the weight of the supply container inside the Gas Shed from the digital readout of the scale.

9) Open the liquid supply valve on the inside container/supply tank.

10) Monitor the transfer line for leaks and verify that liquid is in the line and flowing.

CAUTION- DO NOT PERMIT THE TANK TO GO DRY WHILE TRANSFERING LIQUID OR THE SUPPLY TANK WILL BECOME CONTAMINATED WITH NITROGEN USED TO PRESSURIZE THE TANK.

11) Fill the supply tank to no more that 1500lbs as read directly from the digital readout.

12) Shut the valves on the outside container.

13) Shut the liquid valve on the inside supply tank.

14) Open CG117 and CG79 to recover the gas in the transfer line using the vacuum in the buffer tank. After 30-45 minutes or when the line is void of liquid, shut CG117, CG116, CG115, and CG79.

15) Disconnect the transfer line and cap the connections on the outside tank.

16) Record the final weight on the inside tank and calculate the amount of gas transferred, then record this value in the proper computer file IAW previous transfer entries.

Filling a Detector with C4F10 Gas

Detectors are filled by flowing C4F10 gas into the detector low point while removing air, nitrogen, and other impurities by pumping gas out of the detector high point. Due to the large difference in densities of the gases, they stratify during fill and the heavy C4F10 gas displaces the lighter ones. The lighter gases are removed from the top corner of the detector and pumped into the 96B Gas Shed Outside Buffer tank. The distillation unit is operated in order to reclaim the C4F10 gas. Filling speed is limited by the following requirements; Buffer Tank pressure must be maintained <25psi and the Distillation unit must be recovered every 3-4 days of operation

ThecRIO PID pressure controller maintains a set pressure in the exhaust buffer tank. This setting in combination with the gas flow rate will determine the pressure in the detectors. A differential pressure between the detectors and the hall and the 96B gas shed exhaust buffer tank is required in order to have gas flow. The greater the flow, the greater the required differential pressure. As the gas density increases, the differential pressure between the detector and the purge buffer tank must also increase. In order to maintain a constant pressure in the detectors, the pressure setpoint for the hall pressure control tank must be adjusted accordingly. Failure to perform these adjustments properly will cause the safety solenoids to isolate the detector and the fill operation will be interrupted.

Procedure

1) Startup the Distillation unit IAW this manual and begin distilling the return buffer tank. Once the unit is operating normally, continue with the following steps.

2) Close or Check Closed the Supply and Exhaust manifold valves for the applicable sectors.
S1 - CG11 AND CG13
S2 - CG21 AND CG23
S3 - CG31 AND CG33
S4 - CG41 AND CG43
S5 - CG51 AND CG53
S6 - CG61 AND CG63

3) Position the flow reversal valve on the applicable sectors to the NORMAL position.
S1 - CG17
S2 - CG27
S3 - CG37
S4 - CG47
S5 - CG57
S6 - CG67

4) Position the supply manifold valves on the applicable sectors to the C4F10 position.
S1 - CG11
S2 - CG21
S3 - CG31
S4 - CG41
S5 - CG51
S6 - CG61

5) Set the applicable MFCs to initially flow gas at a rate less than 5 slm flow per detector.

6) Monitor system operating parameters.

7) Adjust combined fill flow such that the return buffer tank pressure is maintained <10psig such that the distillation unit can be emptied and then returned to service without the return buffer tank pressure exceeding 20psig.

8) Adjust the pressure control unit setpoint to maintain 1.5 to 2.0 inches wc pressure in the applicable detectors. This setpoint may require periodic adjust in order to maintain this pressure band.

9) Reduce gas flow to that sector once the detector is full

Refer to the LTCC Gas section of the Hall B Gas System Controls Operating Procedures to Perform these Tasks

Operating the Distillation Unit

Preliminary Discussion

The distillation unit is used to recycle the C_4F_{10} gas. Normal gas flow to each detector is 0.050 - 0.075 slm. This is a total of ~26,000 liters per month. If we did not recycle this gas, our gas usage would exceed 10 containers per year at a 2016 cost 750,000. Recycling C4F10 reduces the yearly gas bill.

The distillation unit must be frequently monitored to insure proper operation. If there is a problem with unit operation, the gas already recovered and the gas collected in the buffer tank could be lost.

Procedures

1) Turn on the Temperature Monitoring and Safety Heater Control Panel if de-energized.

2) Close or Check Closed the liquid removal Valve CG99.

3) Open CG91and CG93 and adjust the N2 purge gas flow to 1500cc/min using the N2 gas rotometer.

4) Open the LN2 supply valve CG92.

5) Open the LN2 cool down purge Valve CG100.

6) Adjust the LN2 vent flow rotometer to 6.0 to 8.0 scfm. Typical cool down times are 4-8 hours from ambient temperature.

Take special precautions while venting at high flow rates to prevent excessive icing or liquid discharge. Reduce flow as needed to maintain a safe cool down rate. The unit must be frequently monitored while venting at rates in excess of 4.0 SCFM. The operator should not leave the unit unattended. Venting at excessive rates can damage equipment and create a hazardous situation. Higher flow rates decrease cool down times but require more frequent monitoring.

7) When the temperature at the top of the liquefaction tank has fallen to -1^{o}F, Shut CG100. Then set the LN2 vent MFC to Auto.

8) Open or check open the filter inlets and outlets, CG229-CG236 and CG237-CG244, and close or check closed the bypass, CG94.

9) When the temperature has fallen to -5^{o}F, open CG90, CG01, and CG83 and adjust flow to a MAXIMUM of 4.5 SLM on the C4F10 MFC.

Monitor the molecular sieve banks and replace as needed. If moisture is present in the gas, it will freeze out and block gas flow through the unit. Recovery from this system failure requires a complete shut down of the unit, recovery of any liquid C4F10 and a complete restart of the unit after purging with N2 gas to remove any H2O.

10) If the ambient temperature is <50 F, energize the return tank heater when the pressure in the buffer tank has fallen to <15psig.

11). When the pressure in the return buffer tank has fallen to the point where a flow of 2 slm can no longer be attained, continue as follows; Start the return buffer tank purge pump, open CG85 and CG86, then close CG83.

12) When the pressure in the return buffer has fallen to 20" of vacuum, or when 450lbs of gas has collected in unit, shut CG92, CG85, and CG86 and turn off the pump.

13) Shut CG90, CG01, and CG93 to isolate the recovered gas.

14) Open the N2 purge flow rotometer to charge the unit to a pressure slightly higher than the pressure in the C4F10 container.

15) Shut or check shut CG79

16) Once the pressure in the distillation unit collection tank is greater than the supply tank pressure, open CG117, CG99, and the liquid supply valve on the container.

17) Monitor distillation unit weight and visually verify that only liquid is transferred to the bottle from the distillation unit.

18) When flow starts to change from liquid to gas, close CG99. CG117, and the liquid supply valve on the supply container.

19) Then shut CG117 and the liquid supply valve on the supply container record the supply tank weight.

20) While the unit is still cold, Vent the excess N2 pressure to atmosphere by opening CG93. When the pressure in the unit drop to ~1psig as limited by the check valve, shut CG93.

22) Vent the remainder of the gas in the unit to the return tank by opening CG99 and CG79. This will recover any gas left in the unit.

23) When the vacuum and weight of the unit has stabilized for several hours, shut CG99 and CG79.

24) Update the C4F10 usage spreadsheet

Refer to the LTCC Gas section of the Hall B Gas System Controls Operating Procedures to Perform these Tasks

Purging and C4F10 Recovery

Prerequisites
-Initial system configuration in normal operating mode.
-Distillation unit online IAW this manual.
-Forward carriage in downstream position permitting valve access.
-Detector protection system operating.

Procedures
1) Secure C4F10 flow to applicable detectors by setting the flow to 0.0 on the Mass Flow Controller

2) Change the gas setting to air for the applicable channels. This changes the gas correction factor to 1.0 for N2 service. (Note that the proper gas correction factor for C4F10 is 0.10)

3) Close the supply manifold valve and exhaust manifold valve for the applicable detectors. These are 3-way valves place them in the closed position.
S1 CG11 and CG13
S2 CG21 and CG23
S3 CG31 and CG33
S4 CG41 and CG43
S5 CG51 and CG53
S6 CG61 and CG63

4) Position the flow reversal valve on the applicable sectors to the PURGE position.
S1 CG12
S2 CG22
S3 CG32
S4 CG42
S5 CG52
S6 CG62

7) Position the supply manifold 3-way valve to the N2 position for the applicable detectors.
S1 CG11
S2 CG21
S3 CG31
S4 CG41
S5 CG51
S6 CG61

8) Open the N2 supply valve, CG06.

9) Adjust N2 purge gas flow to the applicable detectors in order to maintain <10psig in the buffer tank. Do not energize the Buffer tank heater while purging the detectors.

10) Operate the Distillation unit IAW this manual. It will be necessary to operate the unit continuously during purging operations. Do not exceed 450lbs of C4F10 in the collection tank.

Refer to the LTCC Gas section of the Hall B Gas System Controls Operating Procedures to Perform these Tasks

Troubleshooting and Problem Solving

As with any system a failure can occur. The purpose of this section is to minimize any downtime associated with the failure of equipment. This section will discuss past problems, indications, and solutions.

Low gas pressure in one or more of the detectors

The first step is to determine if gas is flowing into the detectors. This information is available from the LTCC Gas GUI. The OMEGA DP25-E units must be energized for gas to flow to the detectors. If the displays are blank there is a power failure to the units. A zero or near zero reading on the MKS Mass Flow Controllers readout indicates zero flow. A negative value which is abnormally beyond the normal zero offset amount indicates a failed MFC. The source of the failure could be due to a bad MKS MFC or C4F10 condensate. A high Hall C4F10 supply header pressure will cause the gas to condense in the lines and at the MFCs. Normal Hall supply header pressure is 2-3psig. A pressure of 10psig or greater will cause the gas to condense independent of the temperature in the hall. The gas will condense at lower pressures when temperatures are also lower.

If the Hall supply header pressure is zero and the MFC reads zero, that is why there is no flow to the detectors. This is a gas supply problem. Check the Supply buffer tank pressure. It may be empty.

If the Hall supply header pressure is high and the MFCs read abnormally negative there are two possibilities. The first is a failed power supply and the second is condensation. A Hall entry is required to check the power supply. A DMM is used at the distribution box to test for proper voltage in the case where the unit appears to be operating properly. A backup power supply is already installed. It can be energized by changing the position of the toggle switch on the power supply panel. A high C4F10 gas supply header pressure causes failure in the order of bottom to top at the manifold, S4, S5, S6, S1, S2, and S3.

These are the common causes which have been observed in system operations. There are other potential causes, such as MKS Multi-Gas Controller failure. A similar unit has failed in the DC Gas system. Physical damage to gas lines such as crushing, pinching, or breaking during movements of the forward carriage has also occurred.

High gas pressure in one or more of the detectors

There are three probable causes of this. First and least likely is due to excessive gas supply. This is only possible if both the control and the protection system fail simultaneously. Second, it could be caused by the transient described earlier in this manual. There is no real solution to this transient unless Hall temperature and pressure can be better controlled. All thermodynamic transients must run their course. And the third and most likely cause is that the pressure in the supply buffer tank is too high and the recirculation pumps are unable to remove gas from the recirculation buffer tank. The pressure in the detectors will then increase until the protection system takes over. The solution for this is to run the distillation unit on the supply buffer tank to remove contaminants and non-condensable gasses.

Inability of the control system to maintain 0.010 to 2.500"wc pressure in the detectors –

There are many possible causes for this. The following parameters must be checked: control valve position, pump suction pressure, pump discharge pressure, pressure control tank pressure, over and under pressure protection solenoid valve position, and gas supply pressure. Chances are that one of these will lead you to the source of the problem.

Examples;

Example 1) A high supply buffer pressure will cause a high pump discharge pressure which causes a high pump suction pressure which means the capacity of the pump is too small for the gas load at that discharge pressure.

Example 2) A high pump suction pressure with a normal pump discharge pressure indicates a bad pump or a clogged line between the pressure indication and the pump on either the suction side or discharge side of the pump.

Example 3) A fully opened control valve as indicated by the controller with a normal hall exhaust header pressure indicates a stuck closed control valve. If the valve were actually open fully the pressure in the header would be high.

Example 4) If the under pressure safety solenoids have tripped it indicates that the control system failed to shut the control valve or that the gas supply to the detectors has been interrupted.

Recovery of the Gas System Following a Power Failure

During a power failure the system fails to a safe condition. All components are designed or installed such that in the case of a component or power failure, the detectors will be protected from either an over or under pressure condition. All components turn off upon loss of power and the detectors are isolated from the gas system except for the over and under pressure protection bubblers.

Once power has been restored, check that all system components are operational. Then restore gas flow to the detectors using the controls GUI.

Refer to the LTCC Gas section of the Hall B Gas System Controls Operating Procedures to Perform these Tasks

Determining System Leak Rates and Localizing Sources

The Cerenkov gas system contains ~$80,000 of C4F10 gas. In the event of a large undetected leak, the entire contents of the system could be lost. It is vital that any increase in system leak rate is quickly determined and that mitigating actions are taken. Any increase in leakage can be determined by following system operating trends. By observing the time historytrends, one can detect increases in system leakage.

There are 2 types of leakage:
1) Gas leaking out of the system.
2) Gas, air, leaking into the system.

There are two classic scenarios which illustrate some obvious leakage problems.

Scenario 1

Indications
Buffer pressure is increasing faster than normal.
Pump suction pressure higher than normal.
Gas return flow rate increasing.

Possible Causes
A Pump Failure due to a leaking diaphragm
Air Leak in the sub-atmospheric portion of the system
Detector Window Failure
Protection Bubbler Failure

Scenario 2

Indications
Supply Tank usage rate increasing.
Buffer tank pressure is constant.

Possible Causes;
-Detector Window Failure
-Protection Bubbler Failure
-Physical Damage to the systems positive pressure gas piping
-Leaking connections between the supply tank and hall MFC's.

Corrective actions must be taken in order to mitigate the problem. First, the source of the leak must be localized.

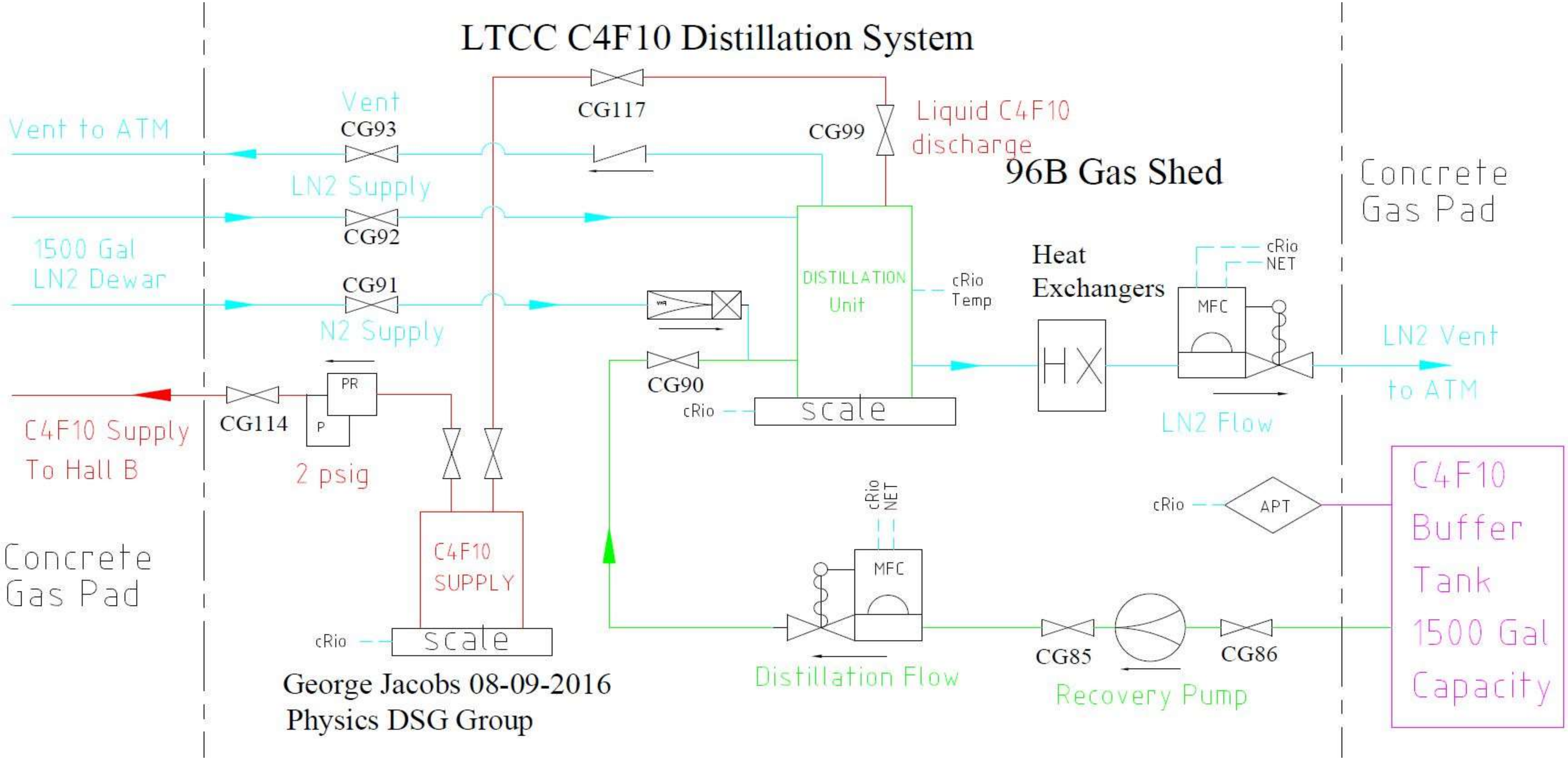
There are 3 most likely causes for leakage.
1) Detector window failure
2) Pump diaphragm failure
3) Protection bubbler failure

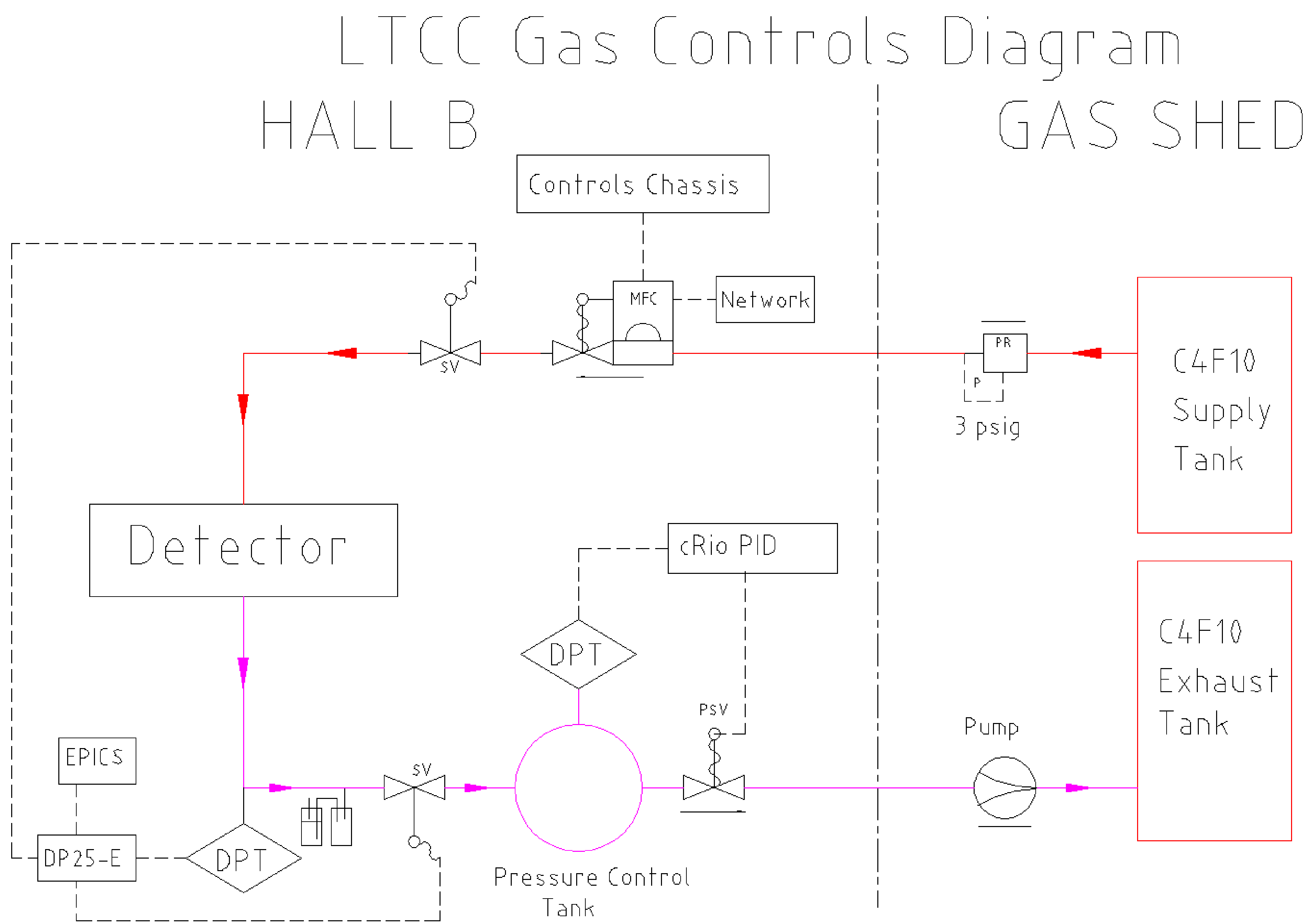
If the problem is caused by a pump diaphragm failure, the remedy is simple. Isolate and secure that pump, place one of the other 2 pumps on line. Then replace the diaphragm. If the problem is due to a detector window failure, The problem sector must be determined. To determine which detector has the failed window, each sector must be isolated from the gas system so a pressure drop test can be performed. Depending on leak severity, troubleshooting and repair may be postponed until after the run. The window should be repaired as soon as practical in order to conserve gas.

If the problem can be traced to a pressure protection bubbler, the failure mode must be determined. There are 2 possible causes for failure. It can have an incorrect oil level or it can be physically damaged. Of course, the physical damage could cause the oil to leak out or a large control system transient could push the oil out of a bubbler either into the trap or out to the surrounding area. If the incorrect oil level has been caused by a control system failure, the control system must be repaired such that the problem does not re-occur.

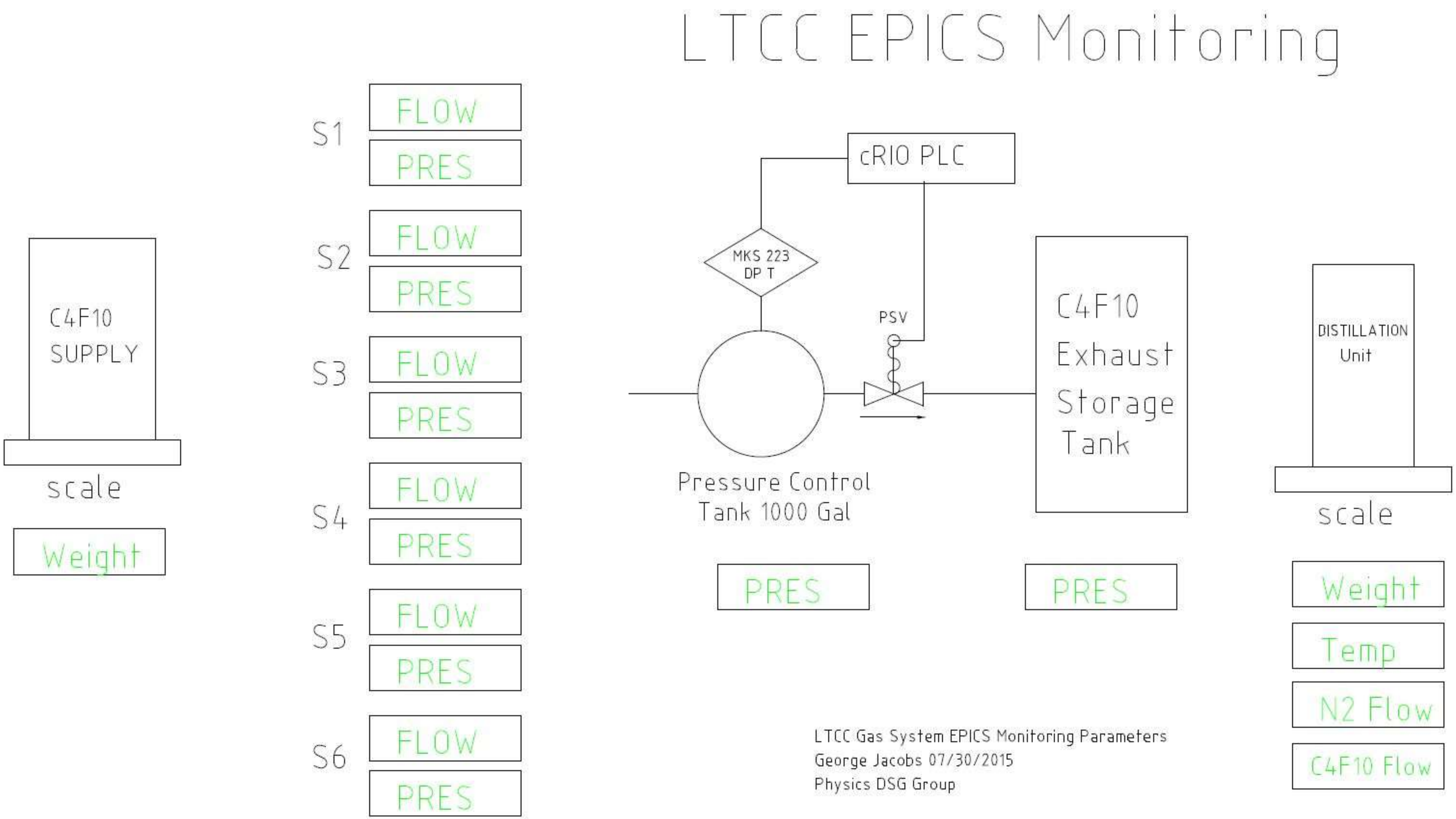
List of Appendices

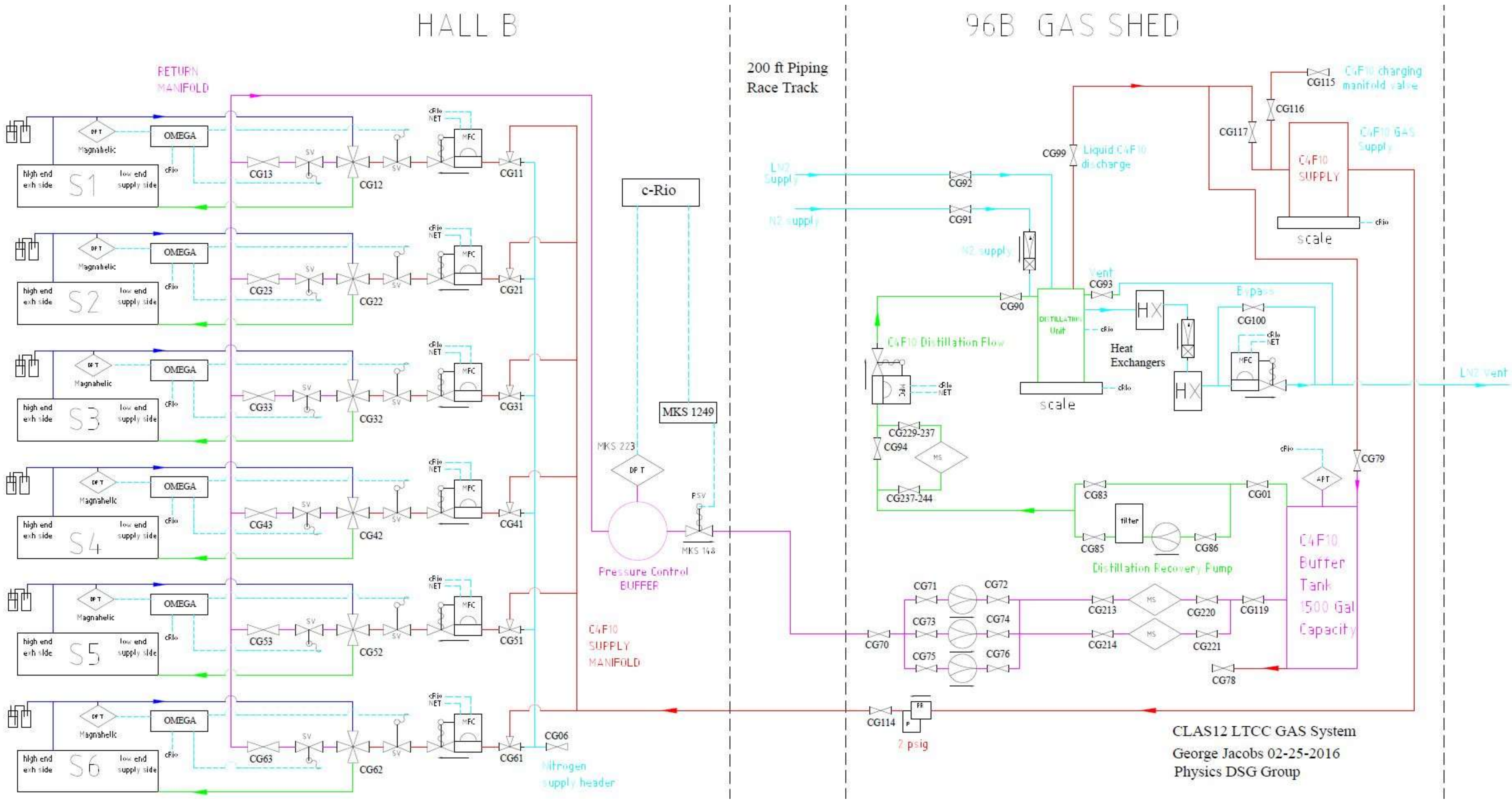
LTCC Gas System Manual Appedixes

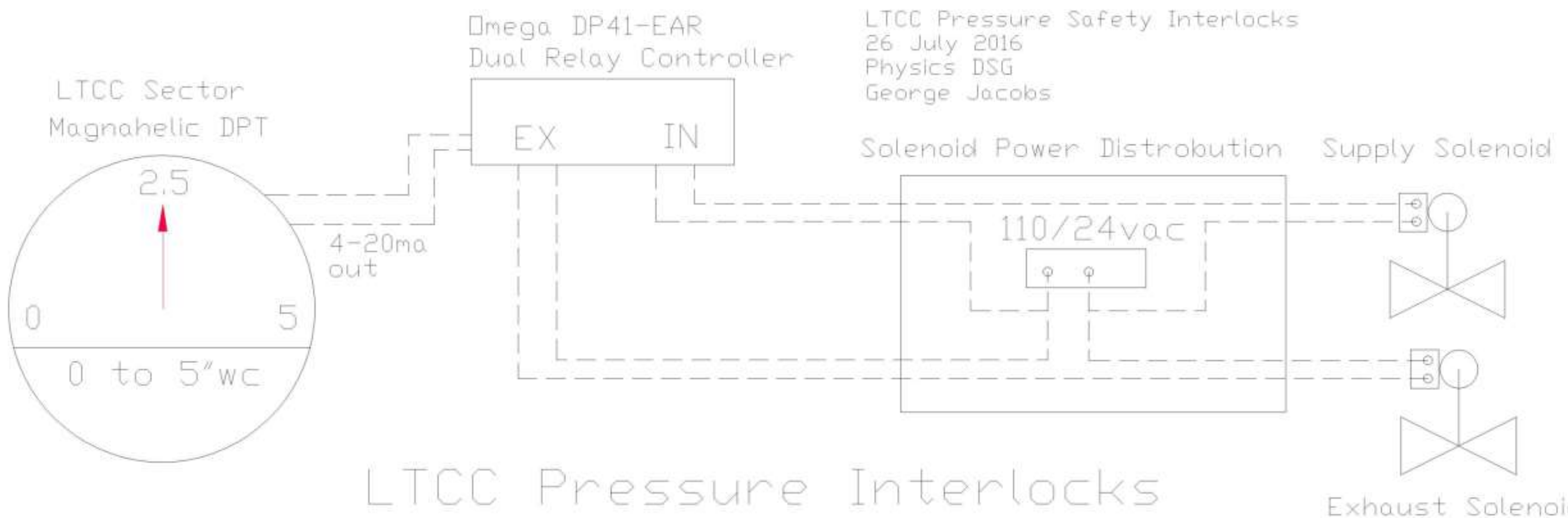

LTCC C4F10 Distillation System
Vent to ATM
Vent
CG93
CG117
CG99
Liquid C4F10
discharge
96B Gas Shed
Concrete
Gas Pad
LN2 Supply
CG92
1500 Gal
LN2 Dewar
CG91
DISTILLATION
Unit
cRio
Temp
Heat
Exchangers
cRio
NET
MFC
N2 Supply
HX
LN2 Vent
to ATM
PR
CG90
C4F10 Supply
To Hall B
CG114
P
cRio
scale
LN2 Flow
2 psig
C4F10
Buffer
Tank
1500 Gal
Capacity
cRio
APT
cRio
NET
Concrete
Gas Pad
C4F10
SUPPLY
MFC
cRio
scale
CG85
CG86
George Jacobs 08-09-2016
Physics DSG Group
Distillation Flow
Recovery Pump



CLAS Cerenkov Gas System Controls Diagram
Physics DSG Group
George Jacobs 03-28-2016


LTCC EPICS Monitoring
C4F10
SUPPLY
scale
Weight
S1
FLOW
PRES
S2
FLOW
PRES
S3
FLOW
PRES
S4
FLOW
PRES
S5
FLOW
PRES
S6
FLOW
PRES
cRIO PLC
MKS 223
DP T
PSV
Pressure Control
Tank 1000 Gal
PRES
C4F10
Exhaust
Storage
Tank
PRES
DISTILLATION
Unit
scale
Weight
Temp
N2 Flow
C4F10 Flow
LTCC Gas System EPICS Monitoring Parameters
George Jacobs 07/30/2015
Physics DSG Group


HALL B
96B GAS SHED
200 ft Piping
Race Track
RETURN
MANIFOLD
c-Rio
MKS 1249
MKS 223
Pressure Control
BUFFER
C4F10
SUPPLY
MANIFOLD
Nitrogen
supply header
OMEGA
Magnahelic
high end
exh side
low end
supply side
S1
S2
S3
S4
S5
S6
CG11
CG12
CG13
CG21
CG22
CG23
CG31
CG32
CG33
CG41
CG42
CG43
CG51
CG52
CG53
CG61
CG62
CG63
CG06
LN2
Supply
N2 supply
CG92
CG91
CG90
CG93
CG99
Liquid C4F10
discharge
Vent
Heat
Exchangers
scale
C4F10 Distillation Flow
CG229-237
CG94
CG237-244
CG83
CG85
CG86
filter
Distillation Recovery Pump
CG01
CG79
CG100
Bypass
LN2 Vent
CG115
C4F10 charging
manifold valve
CG116
CG117
C4F10 GAS
Supply
C4F10
SUPPLY
C4F10
Buffer
Tank
1500 Gal
Capacity
CG71
CG72
CG73
CG74
CG75
CG76
CG70
CG213
CG214
CG220
CG221
CG119
CG78
CG114
2 psig
CLAS12 LTCC GAS System
George Jacobs 02-25-2016
Physics DSG Group



Omega DP41-EAR
Dual Relay Controller
LTCC Pressure Safety Interlocks
26 July 2016
Physics DSG
George Jacobs
LTCC Sector
Magnahelic DPT
EX
IN
Solenoid Power Distrobution
Supply Solenoid
2.5
110/24vac
4-20ma
out
0
5
0 to 5"wc
LTCC Pressure Interlocks
Exhaust Solenoid